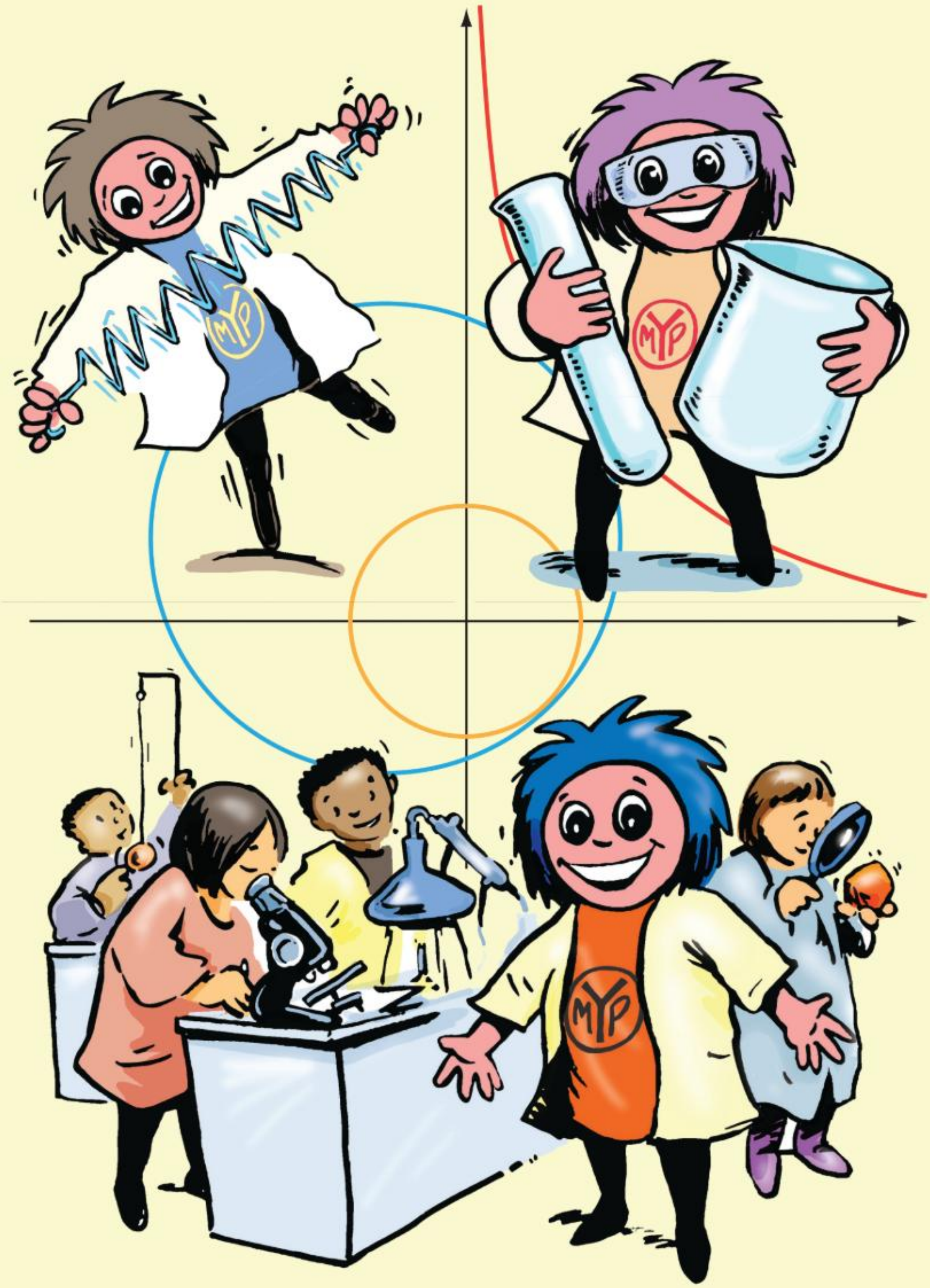
IA Handbook for MYP Sciences

Christopher Talbot, Cesar Reyes, David Fairley

FOR USE WITH THE I.B. PROGRAMME

2nd EDITION



MYP

IBID PRESS

INTERNAL ASSESSMENT HANDBOOK

FOR MYP SCIENCES

FOR USE WITH THE INTERNATIONAL BACCALAUREATE MYP PROGRAMME

COPY MASTERS

Authors: Christopher Talbot, Cesar Reyes, Dr. David Fairley

Series Editor: David Greig

Produced by: Science Teaching And Resources (S.T.A.R.)

Published by: IBID Press, Box 9, Camberwell, Victoria, Australia, 3124. URL: <www.ibid.com.au>

Library Catalogue: **Talbot C, Reyes C, Fairley D**

1. Internal Assessment Handbook for MYP Sciences (second edition)

2. IB Middle Years Programme

Series Title: MYP Science Resources

ISBN: 978-1-876659-09-7 EL

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Publishing Information

This Internal Assessment Handbook is part of a series of resources for IB Sciences produced by IBID Press.

More information about this series and other IB products may be obtained from:

IBID Press, PO Box 9, Camberwell, Victoria, Australia 3124

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David Greig has worked very closely with all three authors as Editor in developing volumes of Investigations for IBO Science subjects, for both the MYP and Diploma levels. He is the principal consultant of 'S.T.A.R.', a graduate of the University of Adelaide and a very experienced science teacher, editor and author.

The team would be pleased to receive comments and suggestions from MYP Science colleagues and can be contacted via the publisher.

Acknowledgements

It is a considerable pleasure to acknowledge the support and camaraderie of current and former colleagues at OFS: Sheela Thomas, Sara Hornseth-Bates, Leo Don, Don Brown, Lorne Schmidt, Christine Clement, Kishanda Vickneson, Jon Homewood, Alison Martin, Saengdao Philavane, Laurence van Koninckxloo, Deborah Rogozinski, Vicky McKnight, Debbie Marinelli, Jason Brough and Adele Querzoli.

We would especially like to thank our former colleague Chris Coates (Head of Science at Tanglin Trust School, Singapore) for his editing and review of early drafts of the material, as well as professional discussions regarding interpretation of the assessment criteria. The material has benefited greatly from his advice and input.

All digital photography is by Cesar Reyes, except *Figures 210 and 211* which were taken by David Talbot.

Any mistakes and omissions remain the responsibility of the authors. Feedback and comments relating to this publication may be sent to the Publisher (rory@ibid.com.au). The authors welcome constructive feedback from both students and teachers on the current contents and suggestions for additional inclusions in future editions.

Foreword

This MYP Handbook has been written specifically to support the teaching of the current Middle Years Science Programme (© International Baccalaureate Organisation 2014). It has been written by three experienced and practicing MYP Science Teachers with close reference to the assessment criteria and the objectives of the MYP Science Programme. All of this material has been developed over a number of years and then successfully trialled in the classroom with MYP science students.

The publication is aimed to help you as an MYP Science student plan, carry out and 'write up' your assessed investigations, complete assignments in which you reflect on the impacts of science and other MYP assessment tasks (both formative and summative). It contains a wide variety of information and advice that will help you at all stages during the final two years of the MYP Science Programme.

Formative assessment is part of your daily learning in the class and helps your teacher find out what you and the other students already know in order to plan the next stage of learning. Summative assessment occurs at the end of the teaching and learning process and provides you and other students with opportunities to demonstrate what you have learned. The MYP Handbook will help you with formative and summative MYP assessment tasks.

The material was written with close reference to the Middle Years Programme Sciences Guide published in May 2014. Some material is reproduced from the Guide with the kind permission of the IBO.

The Handbook is organised around the four MYP Sciences assessment criteria. These are:

Criterion A: Knowing and Understanding

Criterion B: Inquiring and Designing

Criterion C: Processing and Evaluating

Criterion D: Reflecting on the Impacts of Science.

In-text exercises have been included so you can test your knowledge of skills before you are involved in formative or summative MYP assessment tasks. Answers are provided at the end of the Handbook.

In the Appendices there is a complete model 'write-up' showing you how an MYP investigation should be presented. It is annotated with comments related to the assessment criteria. Other appendices contain useful information about data-logging and a glossary of terms related to practical investigations.

This publication is designed to provide a smooth transition to the requirements of the Group 4 Subjects by gently introducing IB Diploma topics such as errors and significant figures.

The authors

Singapore

March 2015

Aims of the MYP Science Programme

The aims of all MYP subjects state what a teacher may expect to teach and what a student may expect to experience and learn. These aims suggest how the student may be changed by the learning experience.

The aims of MYP Sciences are to encourage and enable students to:

- understand and appreciate science and its implications
- consider science as a human endeavour with benefits and limitations
- cultivate analytical, inquiring and flexible minds that pose questions, solve problems, construct explanations and judge arguments
- develop skills to design and perform investigations, evaluate evidence and reach conclusions
- build an awareness of the need to effectively collaborate and communicate
- apply language skills and knowledge in a variety of real-life contexts
- develop sensitivity towards the living and non-living environments
- reflect on learning experiences and make informed choices.

Alby

The character on the front cover is the mascot for the MYP Science Handbook. His name is Alby and he is named after Albert Einstein. How many times do Alby and his friends appear in the MYP Science Guide? Why did the authors and editor choose Albert Einstein? You probably think it is because Einstein is considered by many scientists to be one of the greatest scientists of all time. He developed many new areas of theoretical Physics, notably relativity and quantum theory, for which he was awarded the Nobel Prize in Physics in 1921.

However, we chose him because he embodies many of the characteristics of the MYP Learner Profile. For example, when Einstein was five, his father showed him a pocket compass. Einstein realised that there must be something in the space, previously thought to be empty, that was moving the needle and later said that this experience made 'a deep and lasting impression'. He also taught himself Mathematics, Science and Philosophy. Einstein was clearly an enquirer, a thinker and knowledgeable from a young age.

Einstein was also clearly open-minded and principled. He was born a German Jew, but attended a Catholic school and lived in Switzerland and Italy. Later he moved to the United States of America and became an American citizen. He was also active in politics.

HEALTH AND SAFETY SYMBOLS

Laboratories can be hazardous places. Often scientists, Science teachers and students handle equipment and materials which can be dangerous to their health and safety. Throughout these Volumes of Investigations you will see a number of symbols and warnings which will represent particular hazards. For each of these we will briefly describe the hazard and indicate what precautions you should take to avoid damage and/or what responses are appropriate in the event of an accident. In all cases, of course, you should seek advice and assistance from the teacher or laboratory technician.

A biohazard is any organism or body fluid which could possibly cause illness or disease in your body. This particularly includes micro-organisms.

A flammable substance is one which will readily burn in air. It may be a solid, liquid or gas. If you are using such a substance it is vital that there are no sparks or naked flames which could ignite it. It is vital that you know what to do in the event of fire. This may include the use of fire extinguishers and evacuation procedures.

A radioactive substance is one which emits particles or 'radiation'. This radiation is known to cause damage to cells and may also be cancer causing. If you are using radioactive substances it is vital that you wear protective clothing, use metal tongs and listen carefully to instructions given by your teacher or laboratory technician.

Sharp instruments are often used in Science, particularly in Biology, to cut sections through plant or animal tissue. These instruments, which include scalpels and razor blades, are very sharp and will also cut through your tissues. When using these instruments it is essential that you always cut away from your body and preferably onto a cutting board. It is also important to be very careful when carrying these instruments and also ensure they are placed on the workbench in a safe place.

When certain chemicals are mixed together they can become explosive. An explosion is caused by rapid expansion of gas in a confined space and can be very dangerous. Sometimes it is important to ensure that the space is not confined and sometimes it is important to conduct these reactions behind a protective screen.

It is often necessary to protect your hands from heat, chemicals or other hazards and gloves will be made available for these situations. The type of glove needed will depend on the particular hazard and your teacher will provide further advice. In some cases you will be advised to dispose of the gloves after use and in other cases to wash and dry them carefully.

Your eyes are the most vulnerable and easily damaged external part of your body. This is why they must be protected if you are using solids and liquids which could get into them. Whenever you are heating things or using corrosive liquids, and in other cases as instructed by a teacher, you should wear safety goggles. You should also do this, if possible, even if you wear spectacles to correct your vision. In the event that something gets in your eye you should immediately make use of the eyewash facility in the laboratory as instructed and notify your teacher.

Some chemicals, which are used in a laboratory, are corrosive. This means that they can react with and 'eat away' materials like the bench, your books, clothing and skin. It is essential that you handle these materials, which are usually liquids, with care. Always tip from the container with the label uppermost, never add water to concentrated acid and never have your face anywhere near the container. It is usually advisable to wear both safety goggles and gloves. If protective aprons are available you should also wear one.

As a general rule, 12 or 24 volt electrical appliances are unlikely to cause serious injury. However, ‘mains’ voltage (110V or 240V or higher) can cause serious injury or death. The appliances you use should be regularly tested and certified safe. If you notice sparks or smell insulation burning, turn the power off immediately and notify staff. Be particularly careful not to allow water to get into any appliance as it may cause a short circuit.

Some chemicals are poisonous and should not be inhaled or ingested. It will be necessary to use a fume cupboard when using poisonous gases or volatile liquids. They could make you very ill and you may require medical assistance. It is vital that you listen to instructions, follow them carefully and notify your teacher immediately if there is accidental exposure to poisonous or toxic substances.

Lasers are very intense beams of light. They are capable of causing burns to the skin and permanent damage to the eyes. It is essential that these are only ever used under the supervision of a teacher and in a situation where people can not see the beam directly or when it is reflected from a shiny surface. Sunglasses or welding masks do not provide sufficient protection and special ‘laser glasses’ must be used where there is a risk.

UV light is harmful to skin and especially eyes. Do not expose these areas directly to a UV light source. If it is not avoidable, sunscreen should be applied to the skin and special goggles should be worn.

There are other dangers or hazards as well, for example carrying heavy or hot objects. This may also include chemicals which are not poisonous but which may smell unpleasant or irritate the skin. Whenever you see this icon more information will be provided in the adjacent text about the specific danger.

In Science, particularly in Biology, there are situations when ethics and ethical issues need to be considered in experimental work. This is particularly the case when human volunteers are being used, not just for experimental work but also when they are being surveyed to collect personal information. In these cases, a consent form should be used to explain the nature of their involvement and to get their approval. Ethics will also be an issue whenever animals are used in experimentation or when they are collected in the field. They should not be exposed to conditions that are outside their natural range of tolerance and wild animals must be released back where they were sampled with minimal disturbance.

The environment and environmental issues become important when hazardous substances are used or produced during an experiment. Their disposal must result in minimal impact on the environment. In field work the protocol that is used must reflect practices that minimise the impact of the investigation on the site.

IMPORTANT NOTE

Although every care has been taken in preparing and trialling these investigations, absolutely no responsibility or liability whatsoever can be accepted for any damage or accident which may occur for whatever reason during the conduct of any of these activities. The *Safety Warnings* and *Icons* are advisory only and are not intended to be exhaustive or exclusive. It is a strict condition of sale that safety in the laboratory is the responsibility of the staff and students doing the laboratory work and not the author, editor or publisher of this work.

On the following pages is a copy of the relevant Assessment Criteria (*©IBO 2014 and used with permission*). These may be copied for use as you wish within your school.

A. KNOWING AND UNDERSTANDING: *YOU...*		
	Level	
[ ] **Explain** scientific knowledge. [ ] Apply scientific knowledge and understanding to **solve problems** set in **familiar and unfamiliar situations**. [ ] **Analyse** and **evaluate** information to make **scientifically supported judgments**.	**7**	**8**
[ ] **Describe** scientific knowledge. [ ] Apply scientific knowledge and understanding to **solve problems** set in **familiar situations** and **suggest solutions** to problems set in **unfamiliar situations**. [ ] **Analyse** information to make **scientifically supported judgements**.	**5**	**6**
[ ] **Outline** scientific knowledge. [ ] **Apply** scientific knowledge and understanding to **solve problems** set in **familiar situations**. [ ] **Interpret** information to make **scientifically supported judgments**.	**3**	**4**
[ ] **State** scientific knowledge. [ ] Apply scientific knowledge and understanding to **suggest solutions** to problems set in **familiar situations.** [ ] **Interpret** information to make **judgments**.	**1**	**2**
[ ] The student does not reach a standard identified by any of the descriptors above.	**0**	

B. INQUIRING AND DESIGNING: *YOU...*			
Research question and hypothesis	**Variables and Design**	**Level**	
[ ] **Explain** a problem or question to be tested by a scientific investigation. [ ] **Formulate and explain** a testable hypothesis **using correct scientific reasoning**.	[ ] **Explain** how to manipulate the variables, and **explain** how **sufficient, relevant data** will be collected. [ ] Design a **logical, complete and safe method** in which you **select appropriate materials and equipment**.	**7**	**8**
[ ] **Describe** a problem or question to be tested by a scientific investigation. [ ] **Formulate and explain** a testable hypothesis using scientific reasoning.	[ ] **Describe** how to manipulate the variables, and **describe** how **sufficient, relevant data** will be collected. [ ] Design a **complete and safe method** in which you **select appropriate materials and equipment**.	**5**	**6**
[ ] **Outline** a problem or question to be tested by a scientific investigation. [ ] **Formulate** a testable hypothesis **using scientific reasoning**.	[ ] **Outline** how to manipulate the variables, and **outline** how **relevant data** will be collected. [ ] Design a **safe method** in which you **select materials and equipment**.	**3**	**4**
[ ] **State** a problem or question to be tested by a scientific investigation. [ ] **Outline** a testable hypothesis.	[ ] **Outline** the variables. [ ] **Design** a method, **with limited success**.	**1**	**2**
[ ] The student does not reach a standard identified by any of the descriptors above.		**0**	

C. PROCESSING AND EVALUATING: *YOU...*

Present and interpret data and explain results	Evaluate hypothesis and method and explain improvements	Level	
[ ] **Correctly collect, organize, transform and present** data in numerical and/or visual forms. [ ] **Accurately interpret** data and **explain** results using **correct scientific reasoning**.	[ ] **Evaluate** the validity of your hypothesis based on the outcome of your scientific investigation. [ ] **Evaluate** the validity of your method based on the outcome of your scientific investigation. [ ] **Explain** improvements or extensions to the method that would benefit the scientific investigation.	**7**	**8**
[ ] **Correctly collect, organize and present** data in numerical and/or visual forms. [ ] **Accurately interpret** data and **explain** results **using scientific reasoning**.	[ ] **Discuss** the validity of your hypothesis based on the outcome of your scientific investigation. [ ] **Discuss** the validity of your method based on the outcome of your scientific investigation. [ ] **Describe** improvements or extensions to the method that would benefit the scientific investigation.	**5**	**6**
[ ] **Correctly collect and present** data in numerical and/or visual forms. [ ] **Accurately interpret** data and **explain** results.	[ ] **Outline** the validity of your hypothesis based on the outcome of your scientific investigation. [ ] **Outline** the validity of your method based on the outcome of your scientific investigation. [ ] **Outline** improvements or extensions to the method that would benefit the scientific investigation.	**3**	**4**
[ ] **Collect and present** data in numerical and/or visual forms. [ ] **Accurately interpret** data.	[ ] **State** the validity of your hypothesis based on the outcome of your scientific investigation. [ ] **State** the validity of your method based on the outcome of your scientific investigation. [ ] **State** improvements or extensions to your method.	**1**	**2**
[ ] The student does not reach a standard identified by any of the descriptors above.		**0**	

D. REFLECTING ON THE IMPACTS OF SCIENCE: *YOU…*

Application and implications of science	Communication modes and documenting sources	Level	
[ ] **Explain** the ways in which science is applied and used to understand and address a specific problem or issue. [ ] **Discuss and evaluate** the implications of using science and its application to solve a specific problem or issue, interacting with a factor.	[ ] **Consistently apply** scientific language to communicate understanding **clearly and precisely**. [ ] Document sources **completely**.	**7**	**8**
[ ] **Describe** the ways in which science is applied and used to understand and address a specific problem or issue. [ ] **Discuss** the implications of using science and its application to solve a specific problem or issue, interacting with a factor.	[ ] **Usually apply** scientific language to communicate understanding clearly and precisely. [ ] **Usually** document sources correctly.	**5**	**6**
[ ] **Summarize** the ways in which science is applied and used to understand and address a specific problem or issue. [ ] **Describe** the implications of using science and its application to solve a specific problem or issue, interacting with a factor.	[ ] **Sometimes apply** scientific language to communicate understanding. [ ] **Sometimes** document sources correctly.	**3**	**4**
[ ] **Outline** the ways in which science is used to understand and address a specific problem or issue. [ ] **Outline** the implications of using science to solve a specific problem or issue, interacting with a factor.	[ ] **Apply** scientific language to communicate understanding but does so **with limited success**. [ ] Document sources, **with limited success**.	**1**	**2**
[ ] The student does not reach a standard identified by any of the descriptors above.		**0**	

INTERNAL ASSESSMENT HANDBOOK FOR MYP SCIENCES

TABLE OF CONTENTS


MYP

OBJECTIVES

Students should be able to:

1. explain scientific knowledge
2. apply scientific knowledge and understanding to solve problems set in familiar and unfamiliar situations
3. analyse and evaluate information to make scientifically supported judgments.

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Level	Descriptor
0	The student does not reach a standard identified by any of the descriptors below.
1-2	The student is able to: i. **state** scientific knowledge ii. apply scientific knowledge and understanding to **suggest solutions** to problems set in **familiar situations** iii. **interpret** information to make **judgments.**
3-4	The student is able to: i. **outline** scientific knowledge ii. apply scientific knowledge and understanding to **solve problems** set in **familiar situations** iii. **interpret** information to make **scientifically supported judgments.** .
5-6	The student is able to: i. **describe** scientific knowledge ii. apply scientific knowledge and understanding to **solve problems** set in **familiar situations** and **suggest solutions** to problems set in **unfamiliar situations** iii. **analyse** information to make **scientifically supported judgments.**
7-8	The student is able to: i. **explain** scientific knowledge ii. apply scientific knowledge and understanding to **solve problems** set in **familiar and unfamiliar situations** iii. **analyse** and **evaluate** information to make **scientifically supported judgments**. *©IBO 2014*

Introduction

Students develop scientific knowledge (facts, ideas, concepts, processes, laws, principles, models and theories) and apply it to solve problems and express scientifically supported judgements.

Tests or exams must be assessed using this objective. To reach the highest level students must make scientifically supported judgments about the validity and/or quality of the information presented to them. Assessment tasks could include questions dealing with "scientific claims" presented in media articles, or the results and conclusions from experiments carried out by others, or any question that challenges students to analyse and examine the information and allows them to outline arguments about its validity and/or quality using their knowledge and understanding of science.

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SECTION 1.1 USING SCIENTIFIC KNOWLEDGE

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 state scientific knowledge

3-4 outline scientific knowledge

5-6 describe scientific knowledge

7-8 explain scientific knowledge.

Disclaimer: The classification of different questions into the four bands of Criterion A is difficult and often depends on the nature and scope of your school's MYP Science curriculum. The examples provided are the author's interpretation of Criterion A for one particular school's MYP Science curriculum.

Key terms

State: give a specific name, value or other brief answer without explanation or calculation.

Suggest: propose a solution, hypothesis or other possible answer.

Interpret: use knowledge and understanding to recognize trends and draw conclusions from given information.

Outline: give a brief account.

Solve: obtain the answer(s) using appropriate methods.

Describe: give a detailed account or image of a situation, event, pattern or process.

Unfamiliar situation: refers to a problem or situation in which the context or the application is modified so that it is considered unfamiliar for the student.

Analyse: to identify parts and relationships and to interpret information to reach a conclusion.

Explain: give a detailed account, including reasons or causes.

Evaluate: to assess the implications and limitations; to make judgments about the value of ideas, works, solutions and methods in relation to selected criteria.

1.1.1 STATE SCIENTIFIC KNOWLEDGE (LEVEL 1-2)

Examples

Stating scientific laws, for example, Newton's first law of motion (Physics), Mendel's first law of genetics (Biology) and the law of conservation of mass (Chemistry) or identifying concepts, for example, osmosis and negative feedback (Biology), conservation of charge and laws of magnets (Physics) and writing word equations (Chemistry).

Level 1 – 2 tasks may also involve the labelling of diagrams, for example, the features of plant cells or a cross section of a root (*Figure 101*) and testing simple recall of definitions of mathematical formulas or scientific terms, for example, chemical element and acid (Chemistry), momentum and work (Physics) and homeostasis and hormone (Biology).

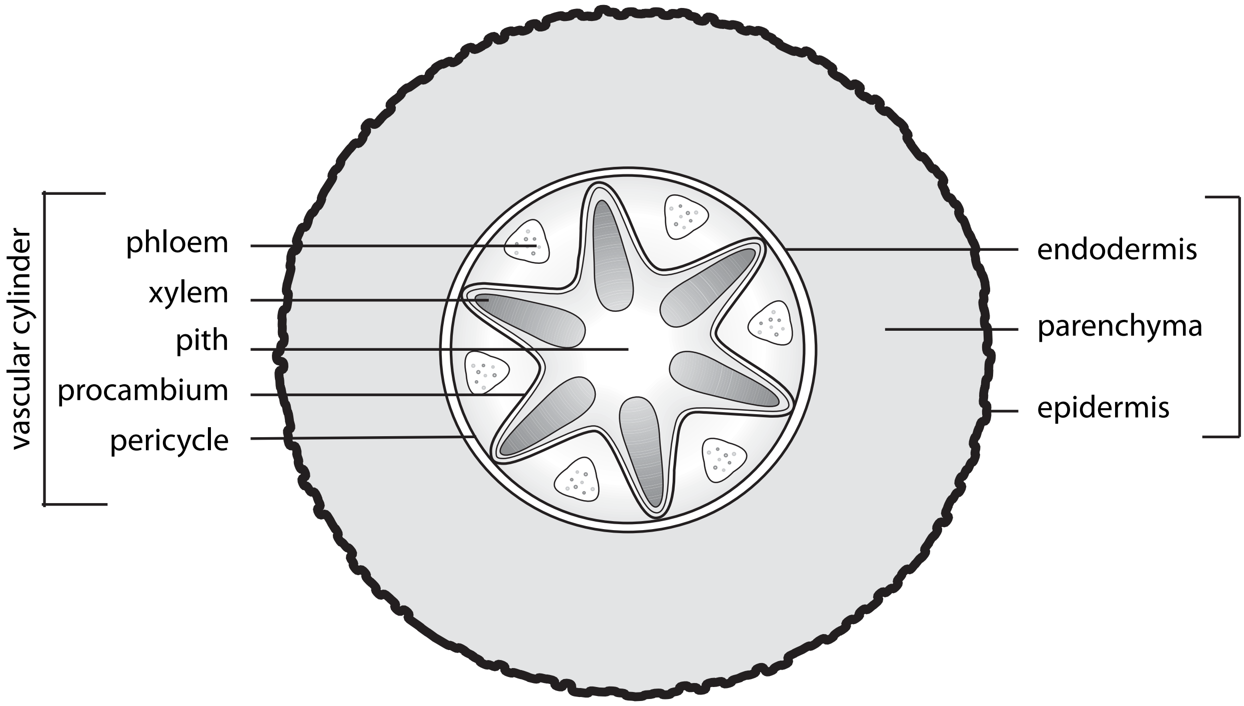

Figure 101 Labelled cross section of a plant root

1.1.2 OUTLINE SCIENTIFIC KNOWLEDGE (LEVEL 3-4)

PHYSICS

Convection is the transfer of heat (thermal energy) through a liquid or gas by the movement of particles in the fluid.

The liquid or gas in contact with the heat becomes hotter, expands (due to more vigorous translations and vibrations of the particles), becomes less dense and rises. (*Density is the mass per unit volume*). Its place is then taken up by cooler liquid or gas. This circulation of liquid or gas is termed a convection current.

CHEMISTRY

Balancing an equation involves adjusting the number of atoms so that they are equal on both sides of the equation.

The principle of a balanced chemical equation is derived from the Law of Conservation of Mass: the total mass of the reactants equals the total mass of the products. This is observed because atoms are not created or destroyed during a chemical reaction.

BIOLOGY

Bile is needed for digestion of simple fats and oils in the small intestine (ileum).

Bile is an emulsifying agent – it disperses large globules of oil or fat into a large number of smaller droplets, which collectively have a larger surface area than a single large droplet. This increased surface area allows lipase to digest the oil or fat at a much faster rate.

1.1.3 DESCRIBE SCIENTIFIC KNOWLEDGE (LEVEL 5-6)

Level 5-6 Questions

1. Describe in terms of particles, how sweating cools the body by evaporation.

2. Translocation is the movement of sugars and amino acids from regions of production to regions of storage or utilization via the phloem. Describe why this process is necessary for plant growth.

3. Describe how electricity is produced in nuclear power plants using nuclear fission.

4. During a car journey the temperature of the air in the tyres increased by 20°C. Describe, in terms of particles, why the pressure of the air in the tyres increases when this happens.

5. Describe, in terms of particles and collisions, the effect that increasing the concentration of a reactant has on the rate of a chemical reaction.

Level 5-6 Answers

1. Water molecules in the sweat absorb energy/heat from the skin to overcome forces of attraction between the molecules and change state from liquid to gas, thereby cooling the skin.

2. Sucrose is formed in the leaves from glucose produced by photosynthesis but is used and stored in other areas, such as the stem and roots, so must be carried to these locations.

3. - nucleus of nuclear fuel / uranium / plutonium is split (known as fission)

   - fission / splitting of nucleus releases heat energy

   - used to boil water to produce steam which turns a turbine

   - turbine turns a generator, producing electricity.

4. When the temperature increases the air molecules in the tyres gain kinetic energy/move faster and therefore the force of the air molecules against the walls of the tyre (per unit area) is greater.

5. Increasing the concentration of a reactant **increases the rate of reaction** because there are more particles **in the same volume**, and hence more (successful/effective) collisions occur **in the same period of time.**

1.1.4 EXPLAIN SCIENTIFIC KNOWLEDGE (LEVEL 7-8)

CHEMISTRY

Your MYP Science course may include a study of the structure and bonding present in diamond and graphite: two familiar allotropes of carbon.

A Level 7-8 question may introduce carbon-60, C_{60}, a new form of pure carbon that is a simple molecular substance consisting of 60 carbon atoms bonded in a soccer ball-shaped molecule. You may be asked to compare and contrast the structure of C_{60} with diamond and graphite and predict the likely physical properties of carbon-60 in the solid state.

BIOLOGY

Your MYP Science course may include a unit on classical genetics. It is likely to include monohybrid inheritance with traits that show simple recessive and dominant characteristics. A Level 7-8 question may introduce co-dominance or incomplete dominance, for example, the inheritance of sickle cell trait or multiple alleles, the inheritance of the human ABO blood group. You will be given some background information on the genetics before being asked to use a Punnett square to predict phenotype ratios {*Figure 102(a) and (b)*}.

PHYSICS

Phenotypes	Possible genotypes
O	ii
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
AB	I^AI^B

Punnett square		I^Ai		Genotype parent
Genotype parent	Gametes	I^A	i	Gametes
I^Bi	I^B	I^AI^B *type AB*	I^B i *type B*	genotype offspring phenotype offspring
	i	I^Ai *type A*	ii *type O*	genotype offspring phenotype offpring

Figure 102 (a) Blood groups and (b) Blood group test cross

Your MYP Science course may introduce you to the concept of ionising or nuclear radiation. It may also include knowledge about the three forms of radiation: alpha, beta and gamma.

A Level 7-8 question may give you the atomic symbols for alpha particles (helium nuclei) and beta particles (high speed electrons released when a neutron converts into a proton) and expect you to write balanced nuclear equations. A balanced nuclear equation is where the sums of the subscripts (atomic number or particle charge) on both sides of the equation are equal and the sums of the superscripts (mass number) on both sides of the equation are equal.

Level 7-8 Question

When a person develops Type II diabetes, the cells in the liver that are targeted by the hormone insulin become insensitive to insulin. Explain the effect this would have on the blood glucose content of the blood of a person affected with this disease.

Level 7-8 Answer

Insulin stimulates the liver to remove excess glucose from the blood and store it as glycogen. If cells are insensitive to insulin they will not respond/will not store glucose. Glucose will remain in the blood/there will be increased blood glucose levels.

SECTION 1.2 APPLYING SCIENTIFIC KNOWLEDGE

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 apply scientific knowledge and understanding to **suggest solutions** to problems set in **familiar situations**

3-4 apply scientific knowledge and understanding to **solve problems** set in **familiar situations**

5-6 apply scientific knowledge and understanding to **solve problems** set in **familiar situations** and **suggest solutions** to problems set in **unfamiliar situations**

7-8 apply scientific knowledge and understanding to **solve problems** set in **familiar and unfamiliar situations.**

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1.2.1 APPLY KNOWLEDGE IN FAMILIAR SITUATIONS (LEVEL 1-2)

PHYSICS

Numbers and units are substituted into a simple equation (which was given), for example, Ohm's Law, which gives the final answer (without the need for rearranging).

CHEMISTRY

Production of a word equation or naming a salt produced by a process of neutralisation.

BIOLOGY

The flow of water is correctly predicted between two plant cells with different cytoplasm concentrations.

It is assumed that students are familiar with the concept of osmosis: the flow of water across a semi-permeable membrane from a region with a low concentration of dissolved solute to a region with a high concentration of dissolved solute.

1.2.2 APPLY KNOWLEDGE AND SOLVE PROBLEMS IN FAMILIAR SITUATIONS (LEVEL 3-4)

CHEMISTRY

The deduction of formulas (from simple ions and oxyanions (or valencies)) and construction of balanced equations from chemical formulas.

BIOLOGY

Carry out genetic crosses and predict phenotypic ratios using a Punnett square.

PHYSICS

Calculate the effective resistance of electrical circuits. Selecting the appropriate formula (in series or in parallel circuit) and rearranging as necessary.

Questions

Figure 103 shows some equipment which can be used to investigate the effect that different light intensities have on the rate of photosynthesis of a pond plant called *Elodea*.

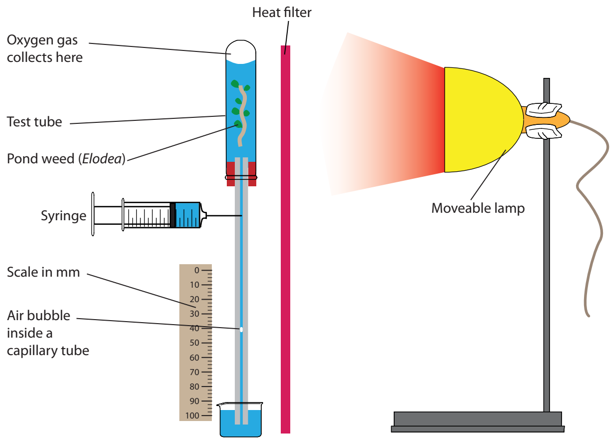

Figure 103 Apparatus used to study photosynthesis

Bubbles of oxygen gas are produced by the plant as it carries out photosynthesis. These oxygen bubbles rise to the top of the test tube, where the build up of pressure forces water to move down the capillary tube pushing the bubble of air along with it.

Experiment A

The lamp was placed at several different distances from the plant. The intensity of light received by the plant was recorded at each distance (*Figure 103*).

The lamp was switched on for four minutes at each distance, and the movement of the air bubble in the capillary tube was measured (in mm) and recorded. Measurements of the light intensity at each distance were also taken and recorded.

The syringe was used so the bubble could be returned to the start position (back to zero on the scale) after each four minute recording session.

Experiment B

The entire experiment was repeated as for Experiment A, but with the addition of 0.1 g of sodium hydrogencarbonate ($NaHCO_3$) to the water in the test tube to provide an excess of dissolved carbon dioxide (*Figure 104*).

Light intensity (in arbitrary units)	Distance moved by the bubble in a four minute period/ mm Experiment A	Distance moved by the bubble in a four minute period/ mm Experiment B
0.5	0	0
1.0	6	6
2.0	18	26
3.0	25	46
4.0	42	Result missing
5.0	54	86
6.0	58	96
7.0	58	100
8.0	58	100

Figure 104 Student results

Level 3-4 Questions

(a) Outline the reason for the heat filter.

(b) Each time the lamp was moved to a new position, an interval of five minutes was allowed before starting to time the movement of the air bubble. Outline a reason for this five minute waiting time between recordings.

(c) In Experiment A, outline a reason why the movement of the air bubble was the same for light intensity 6.0 and light intensity 7.0.

(d) Outline a reason why the air bubble did not move at light intensity 0.5 units.

(e) Outline why the results for the first experiment (Experiment A) are different from the results of Experiment B at light intensity 5.0 units.

(f) In the second experiment (Experiment B) outline a reason why the movement of the air bubble was the same for light intensity 7.0 and light intensity 8.0.

(g) Outline a suitable control experiment for this investigation.

Level 3-4 Answers

(a) A heat filter is required to absorb the heat associated with sunlight falling onto the apparatus. Such an arrangement prevents, or at least reduces, changes in the amount of heat falling on the apparatus. The result of such an arrangement is that the heating effect is a constant and not a variable.

(b) This is to allow the plant to adapt to the new level of light intensity so that the rate of photosynthesis can equilibrate (reach a stable state). This approach facilitates the recording of more accurate readings.

(c) The rate of photosynthesis at 6.0 and 7.0 units of light intensity remains constant and therefore light intensity and temperature changes have no effect on the production of oxygen. The light intensity has reached saturation point and other factors, in particular the amount of carbon dioxide, becomes a limiting factor.

(d) The light intensity is too low and light becomes the limiting factor that prevents the rate of photosynthesis from rising.

(e) In Experiment B, sodium hydrogencarbonate was added to the water which released dissolved carbon dioxide (a limiting factor) and resulted in an increase in the rate of photosynthesis relative to Experiment A.

(f) Temperature was now the limiting factor. An increase in the rate of photosynthesis could only be achieved by a rise in temperature and hence a higher enzyme activity.

(g) Identical experiments are set up, but the apparatus is placed in a dark room.

Level 3-4 Questions

Students are familiar with deducing formulas of ionic compounds from tables of common positive ions and negative ions. They are also familiar with the concept of a reactivity series involving metals and have carried out displacement reactions with metal powders and their compounds and heated a range of metal carbonates.

1. Using the list of ions below, write the formulas for the chloride, carbonate and sulfate of singaporium (symbol Sg - see page 14). Explain your reasoning.

   chloride; Cl^-; carbonate, CO_3^{2-} and sulfate, SO_4^{2-}. (3 marks) [Level 3/4]

2. Outline what is observed when a sample of singaporium carbonate is heated in the laboratory.

   (2 marks) [Level 3/4]

3. A student wrote that when solid singaporium hydroxide is dissolved in water, the temperature of the solution increases because heat energy is released. Hence singaporium hydroxide forms a compound. Outline the correct explanation to the student. (2 marks) [Level 3/4]

Level 3-4 Answers

1. SgCl [$Sg^+ + Cl^-$] Sg_2CO_3 [$2Sg^+ + CO_3^{2-}$] and Sg_2SO_4 [$2Sg^+ + SO_4^{2-}$]

   Ionic compounds are electrically neutral: the charge due to the positive ions is neutralised by the charge due to the negative ions.

2. Singaporium carbonate is a white powder which does not undergo decomposition when strongly heated. Singaporium is a reactive metal and hence forms thermally stable compounds.

3. Singaporium hydroxide and water undergo a physical change – no new substance is formed. Singaporium hydroxide dissolves in water to form a solution – hydrated singaporium and hydroxide ions are released.

1.2.3 APPLY KNOWLEDGE AND SUGGEST SOLUTIONS IN UNFAMILIAR SITUATIONS (LEVEL 5-6)

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **interpret** information to make **judgments**

3-4 **interpret** information to make **scientifically supported judgments**

5-6 **analyse** information to make **scientifically supported judgments**

7-8 **analyse** and **evaluate** information to make **scientifically supported judgments**.

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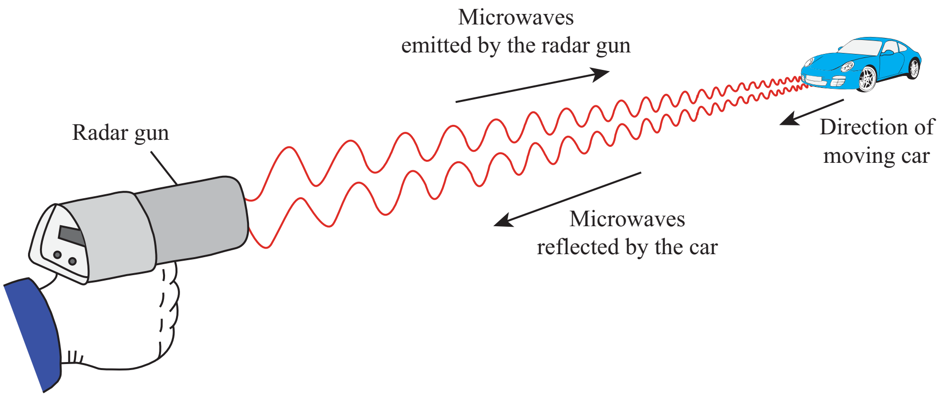
Level 5-6 Questions

1. In order to jump over the bar, a high jumper must raise her mass by 1.50 m. The high jumper has a mass of 70 kg. The gravitational field strength is 10 N kg^{-1}.

   a) The high jumper just makes it over the bar. Calculate the gain in gravitational potential energy of the high jumper.

   b) The high jumper's kinetic energy, E_K, is given by the formula: $E_K = ½ \times m \times v^2$. Calculate the minimum speed the high jumper must reach for take-off, in order to make it over the bar.

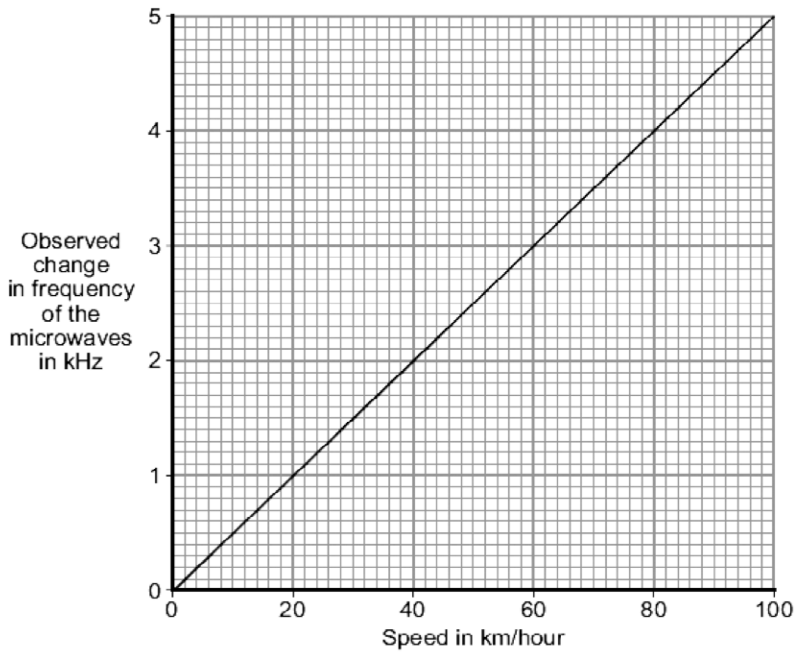
2. A police officer uses a radar gun to check the speed of motor cars travelling on a busy city road. The radar gun emits a beam of microwaves that are reflected by the moving cars.



The reflected microwaves have a different frequency from the microwaves emitted by the radar gun. The change in frequency can be used to determine the speed of the car. If the frequency increases, then the car is moving towards the police officer. The graph shows the relationship between the speed of the car and the observed change in frequency of the microwaves.

a) A car is travelling in an area where the speed limit is 70 km/h. The frequency of the microwaves emitted by the radar gun is 12 000 000 kHz. The frequency of the microwaves reflected by the car is 12 000 004 kHz. Is the car exceeding the speed limit? Use information from the data given and the graph to explain your answer.

b) The police officer determines the speed of a different car. The frequency of the microwaves emitted by the radar gun is 12000000 kHz. The frequency of the microwaves reflected by the car is 11 000 998 kHz. What is the speed and direction of the car? Show clearly how you work out your answer.



Level 5-6 Answers

1. a) $E_p = mgh$

$= 70 \times 10 \times 1.5$

$= 1050$ J

b) Set $E_p = E_K$

$1050 = ½ \times m \times v^2$

$1050 \times 2 \div 70 = v^2$

$v^2 = 30$

$v = \sqrt{30}$

$= 5.48$ m/s (3sf)

2. a) Frequency difference = 4 kHz. Interpolation from the graph shows that the car is travelling at 80 km/h towards the police officer, and hence is exceeding the speed limit.

b) Frequency difference = 2 kHz. Interpolation from the graph shows that the car is travelling at 40 km/h. Since the frequency has decreased the car is travelling away from the police officer.

1.2.4 APPLY KNOWLEDGE AND SOLVE PROBLEMS IN UNFAMILIAR SITUATIONS (LEVEL 7-8)

Level 7-8 Questions

Students are familiar with the Periodic Table and familiar with the concept of radioactivity, but are unfamiliar with mass spectrometry. They are familiar with the concept of isotopes and relative atomic masses.

1. Evaluate the claim that a new element *singaporium* has been discovered. Based on your knowledge of the Periodic Table, how likely is it to be a new stable element? See also Page 14.

2. What additional evidence might be required to support the claim? Find out about a mass spectrometer, outline its operation and how it can be used to establish or disprove this claim. You also have access to a Geiger-Müller tube ('radiation counter').

Level 7-8 Answers

1. The Periodic Table reveals that any new Group 1 metal would have an atomic number greater than 92 (uranium). All elements beyond uranium are very unstable and highly radioactive.

2. A Geiger-Müller tube could be placed near a sample of singaporium. A very high radioactive count would suggest that it could be a new radioactive member of Group 1. A low radioactive count would suggest that it is an existing member of Group 1. The count would be due to the background rate.

   Its identity could be suggested by determining its melting and boiling point and comparing with the values quoted in a data book or text book. Further confirmation could be achieved by analyzing a sample of *singaporium* with a mass spectrometer. The instrument will identify the number of isotopes, their relative masses, their abundances and can be used to calculate the relative atomic mass. This value can then be compared with the relative atomic masses of the elements in Group 1.

   A mass spectrometer vaporizes the sample of singaporium to produce gaseous atoms. These are then converted into unipositive ions by electron bombardment. The ions are then accelerated and enter a powerful magnetic field where they experience deflection according to their mass. The lighter ions undergo more deflection. The numbers of ions are counted at the end of the mass spectrometer. A bar chart is produced showing the number of isotopes and their percentage abundances.

SECTION 1.3 USING INFORMATION TO MAKE JUDGEMENTS

1.3.1 INTERPRET INFORMATION AND MAKE JUDGMENTS (LEVEL 1-2)

Examples

- stating the trend apparent in a data table or graph
- selecting an appropriate item of equipment from a list to carry out a stated laboratory procedure
- identifying anomalous data point(s) in a table or on a graph
- comparing two or more graphs or data sets, e.g. two or more solubility curves to identify which compound is more soluble at a given temperature
- identifying the correct atom model for an element from a list, given its chemical symbol and nucleon number
- identifying, from a list, the correct diagram showing the diffusion of carbon dioxide and oxygen between an alveolus and a capillary
- identifying distance-time graphs representing objects at rest, travelling at constant speed or accelerating

Level 1-2 Questions

CHEMISTRY

Students will be familiar with the reactions of the elements in Group 1 (alkali metals). They would have seen the reactions, both in the laboratory and on video clips. They would have tested for hydrogen in the laboratory using magnesium and dilute acid. They are familiar with the idea of valency (combining power).

A new metallic element named singaporium is claimed to have recently been discovered. It is high up the reactivity series. When added to water it reacts rapidly, releasing an explosive gas. It forms an ion represented by the formula Sg^+.

(a) Define the term valency. (1 mark) [Level 1/2]

(b) (i) State the name of the gas released by the reaction of singaporium with water. State its chemical formula. (2 marks) [Level 1/2]

(ii) State the name of a test to prove the presence of the gas. (1 mark) [Level 1/2]

(c) Write a word equation from the symbol equation below describing the reaction between singaporium and water.(2 marks) [Level 1/2]

$2Sg\ (s) + 2H_2O\ (l) \rightarrow 2SgOH\ (aq) + H_2\ (g)$

(d) State which group of the Periodic Table singaporium should be classified into. (1 mark) [Level 1/2]

(e) State how a sample of singaporium should be stored. (1 mark) [Level 1/2]

(f) State the expected pH range of water after singaporium has reacted completely with the water. (2 marks) [Level 1/2]

Level 1-2 Answers

(a) The number of chemical bonds formed; the combining power (or the number of electrons gained, lost or shared).

(b) (i) Hydrogen, H_2

(ii) Mix the gas with air inside a sealed test tube. Apply a lighted splint - it will burn with a 'squeaky pop'.

(c) singaporium + water → singaporium hydroxide + hydrogen

(d) Group 1.

(e) Under oil.

(f) pH greater than 7 but less than 14 (provided the concentration was less than 1 mol/dm^3).

1.3.2 INTERPRET INFORMATION AND MAKE SCIENTIFICALLY SUPPORTED JUDGMENTS (LEVEL 3-4)

Examples

- outlining the reason for the trend apparent in a data table or graph
- selecting an appropriate item of equipment from a list to carry out a stated laboratory procedure and outlining why it is the most appropriate
- identifying anomalous data point(s) in a table or on a graph and outlining why it is anomalous
- comparing two or more graphs or data sets, e.g. two or more solubility curves to identify which compound is more soluble at a given temperature and outlining the reason why
- drawing an atom model for an element given its chemical symbol and nucleon number
- drawing a diagram to represent oxygen and carbon dioxide diffusion in an alveolus and outlining a scientific reason for the direction(s) of diffusion
- sketching distance-time graphs to represent objects at rest, travelling at constant speed and accelerating and outlining the scientific reason for the shape of each graph.

Level 3-4 Questions

The table below gives the composition of six particles that are either atoms or ions.

Particle	Number of protons	Number of neutrons	Number of electrons
A	33	40	33
B	19	20	18
C	34	45	36
D	33	42	33
E	13	14	13
F	24	28	21

a) Identify the particles that are **atoms** and outline the reason for your choice.

b) Identify the particle that is a **negative** ion and outline the reason why it has a negative charge.

Level 3-4 Answers

a) A, D and E because the number of protons = the number of electrons/electrically neutral

b) C because it has two more electrons than protons

1.3.3 ANALYSE INFORMATION AND MAKE SCIENTIFICALLY SUPPORTED JUDGMENTS (LEVEL 5-6)

Examples

- describing and accounting for the trend apparent in a data table or graph
- selecting an appropriate item of equipment from a list to carry out a stated laboratory procedure and describing why it is the most appropriate
- identifying anomalous data point(s) in a table or on a graph and describing why it is anomalous
- comparing two or more graphs or data sets, e.g. two or more solubility curves to identify which compound is more soluble at a given temperature and describing the reason why
- drawing an atom model for an element given its chemical symbol and nucleon number, and fully describing the reasons for the arrangement of the particles
- using a distance-time graph to determine average velocity by calculating the gradient, or using a speed-time graph to determine acceleration by gradient, or distance travelled by determining the area under the graph
- using a plot of gas volume against time to describe and account for the changes in the rate of a chemical reaction

Level 5-6 Question

When a person receives an electric shock, their body becomes part of an electrical circuit. The current passes through the body from the point of contact with the live wire to the ground. The muscles then go into fibrillation, a period of rapid, irregular contraction. The resistances of some parts of the body are given in the table below.

Part of body	Condition	Resistance (ohms)
from ear to ear	skin not included	100
from head to foot	skin not included	500
skin	wet	1000
skin	dry	100 000

The minimum current required to cause fibrillation is 100 mA. What is the minimum voltage across the **length** of the body needed to cause fibrillation? Support your answer with a scientific explanation and calculation.

Level 5-6 Answer

Since $V=IR$ (Ohm's Law) the voltage will be a minimum when the resistance is a minimum.

Minimum resistance = head to foot + wet skin = 500 + 1000 = 1500 Ω

$V_{min} = I \times R = 0.1 \times 1500 = 150$ V

1.3.4 ANALYSE AND EVALUATE INFORMATION AND MAKE SCIENTIFICALLY SUPPORTED JUDGMENTS (LEVEL 7-8)

This may take the form of evaluating an investigation

Six different paintbrushes were scientifically tested to find out which paint brush retained the most paint. The apparatus is shown in *Figure 105*.

Discuss whether or not the claim of manufacturer A (that their brush holds much more paint) is valid by evaluating the design of the experiment (including the control of variables) and the results.

MATERIALS

Lever, Electronic balance (see *Figure 105*)

METHOD

1. 202 grams of paint were placed in a small flat trough.
2. The trough was placed on an electronic balance that weighed to the nearest gram.
3. Each paint brush was attached to a lever.
4. The paint brush was lowered into the paint and then lifted out.
5. The mass of paint left in the trough was then recorded.

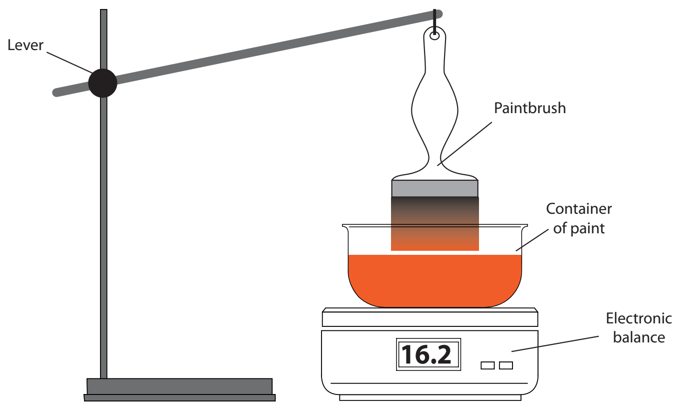


Figure 105 The experimental set-up

RESULTS

Brand of paint brush	Mass of paint left in trough/ g	Mass of paint absorbed/ g
A	165	37
B	180	22
C	184	18
D	187	15
E	190	12

CONCLUSION

Brush A has the greatest ability to absorb paint.

EVALUATION

There are a number of variables that may affect the results and it is not made explicit that they are controlled:

- The size of the brushes? Were they all the same?
- The type of material used to make the brushes? Were they all the same?
- The time the paint brush was immersed in the paint? Were they immersed in the paint for the same time?
- The immersion depth? Were they immersed to the same depth?
- The temperature of the paint? Was the temperature monitored with a thermometer?
- The type and brand of paint. Was the paint the same - oil-based or water-based - with the same viscosity (thickness)?
- The colour of paint? Was the same colour used?
- The method was not reproduced. Replicate and average results are not given.
- The experiment is not a 'fair test' and hence the results are not reliable and therefore invalid.

This may take the form of evaluating scientific claims in media articles

Criterion A may involve analyzing the arguments and data presented in a media article on a scientific issue.

This type of activity may also be used to provide a stimulus prior to writing a Criterion D report on the topic.

Read the article called, 'Climate Change Menace or Myth'.

<http://www.mng.org.uk/gh/threat/threat9.htm> and

<http://www.newscientist.com/article/mg18524861.400>.

It is from *New Scientist* which was published on the 12th February 2005 to coincide with the starting date for the Kyoto Protocol.

Use the article to answer the questions that follow.

The questions are not banded against Criterion A, but are designed to prepare you for a Criterion D report about Global Warming.

NB: The answers can all be found in the main body of the text and in the first graph, not in the interest boxes.

Exercises

1. What is the Kyoto Protocol? [2]
2. Which gases in the atmosphere contribute the most to global warming? [1]
3. What would be the temperature of our planet without these gases? [1]
4. How do these gases warm our planet's surface? [2]
5. What is the main way that human activity has pumped carbon dioxide into our atmosphere since the industrial revolution began? [2]
6. Look at the graph of carbon dioxide levels measured on Mauna Loa since 1958;

   i) what was the concentration of carbon dioxide in the air in 1958? [2]

   ii) and what is the current measured level? [1]

   iii) what percentage increase is this in the last 46 years? [2]

   iv) Pre-industrial carbon dioxide levels were 280 ppm. When did the major increases in carbon dioxide levels in our atmosphere start? Why? [2]
7. What type of energy does carbon dioxide absorb? [1]
8. What do you think the word, '*anthropogenic*' means? [1]
9. 19 of the 20 warmest years on our planet in the last 150 years have occurred since 1980. There is one issue which may be used to dismiss this data. What is it and why can it be used by global warming sceptics? [2]
10. Why has this evidence used by the sceptics of global warming been dismissed by climate scientists? [2]
11. Global warming sceptics have two main arguments they can make against claims for enhanced global warming. What are they? [2]
12. What causes natural fluctuations in the planet's surface temperatures? [2]
13. Explain what the phrase, '*negative feedback*' means. [2]
14. List the three main expected positive feedbacks that will occur as our planet warms in the next 50 years, making it even warmer than expected. [3]
15. List the negative feedbacks that may help reduce our planet's temperature. [2]
16. Richard Lindzen of MIT is a sceptic in a special category. What is it? [1]
17. What does Michael Crichton have in common with many global warming sceptics? [1]
18. Do you think Michael Crichton's book, '*State of Fear*' is based on scientific fact? Explain. [2]
19. What do you think the term, '*paradigm*' means? [1]

Question 1

Factories handling foods such as grain, flour, powdered milk or sugar must be careful to guard against explosions. A table of the explosion characteristics of some common dusts in the food industry is shown below.

Product	Explosive?	MIE (mJ)	MIT – cloud (°C)	MEC (g/m³)
Corn	Yes	45-100	390-400	73
Wheat	Yes	50-100	370-380	67
Oats	Yes	>500	420-430	30
Barley	Yes	50-100	360-370	73
Soybeans	Yes	50-100	600-620	80
Starch (rice)	Yes	>30	460-470	60
Starch (wheat)	Yes	10-30	470-480	30
Sugar	Yes	<10	470-480	30

a) MIE - Minimum ignition energy in millijoules when an electrical spark is used for ignition.

b) MIT - Minimum ignition temperature in degrees Celsius when a hot surface is used for ignition.

c) MEC - Minimum explosive concentration of dust in grams per cubic metre.

Explain, using your understanding of reaction rates, why there is a risk of dust explosions in food factories. Then evaluate the data in the table to select the food product which has the highest risk of explosion. Fully explain your choice.

Answer 1

Dust particles have a large surface area and will therefore undergo a large number of collisions with oxygen molecules in a short amount of time leading to an explosion/explosive combustion.

Sugar would appear to have the highest risk of explosion as it has the minimum ignition energy and its dust has one of the lowest explosive concentrations (although barley has the lowest minimum ignition temperature for a cloud of dust).

Question 2

The Trophic State Index (TSI) is a number used to represent the quality of the water in a lake. The higher the Trophic State Index, the higher the level of eutrophication in the lake. A TSI of 0-59 indicates good water quality, 60-69 indicates fair water quality and 70-100 indicates poor water quality.

The table below gives data relating to the Trophic State Index for a typical lake.

Trophic State Index (TSI)	Total nitrogen/mg per litre (mg/L)	Chlorophyll/micrograms per litre (μg/L)	Secchi depth*/metres (m)
0	0.06	0.3	12.0
10	0.10	0.6	10.0
20	0.16	1.3	9.0
30	0.27	2.5	8.0
40	0.45	5.0	4.0
50	0.70	10	2.0
60	1.2	20	1.0
70	2.0	40	0.5
80	3.4	80	0.25
90	5.6	160	0.15
100	9.3	320	0.05

** The Secchi depth indicates how clear the water is. The larger the Secchi depth, the clearer the water.*

Use your knowledge of eutrophication to explain why the nitrogen level in a lake can vary and why this affects the level of chlorophyll and the Secchi depth of the lake.

Answer 2

Fertilizer run-off increases the levels of nitrogen in the lake, leading to runaway growth of plants and algae, hence chlorophyll levels in the lake increase and the clarity of the water (as indicated by the Secchi depth) decreases.

SECTION 1.4 SAMPLE TEST QUESTIONS

A Criterion A test is likely to contain a variety of questions from all four bands. Below is part of a test on human reproduction that includes questions from all four bands.

Questions

A woman with blocked oviducts cannot have a baby in the normal way, but can have a 'test tube' baby. A doctor, using a fine tube through the body wall, extracts several ova from the ovary, puts them in a dish and mixes them with sperm. The ova are then kept for a few days before they are put back into the woman's uterus via the cervix.

(a) Outline what normally occurs in the oviduct. (Level 3/4; 2 marks)

(b) Evaluate the doctor's procedure for obtaining ova from the woman and compare it to doing so through the vagina or uterus. (Level 7/8; 2 marks)

(c) Outline why the sperm must be mixed with the ova before they are put back into the woman. (Level 3/4; 1 mark)

(d) Evaluate the reason for the keeping the ova for a few days outside the body before they are introduced into the woman. (Level 7/8; 2 marks)

(e) Name the hormone responsible for sperm production. State the name of the organ responsible for sperm production. (Level 1/2; 2 marks)

Freshly ejaculated sperm were compared with sperm that had been frozen (in liquid nitrogen), stored and then thawed. The percentage of ova penetrated by sperm at different times after ejaculation or thawing is shown below in *Figure 107* below.

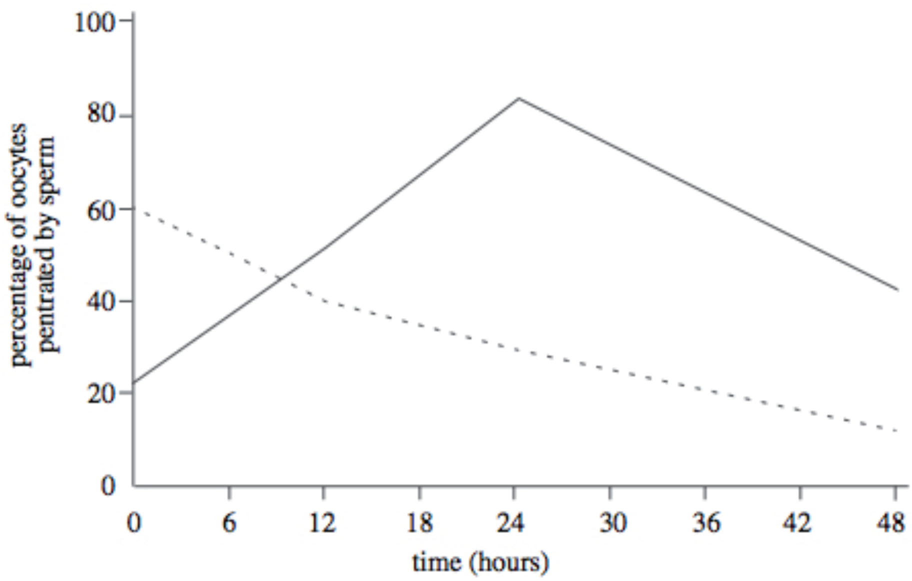


Figure 107 The percentage of ova penetrated by sperm

(f) Describe the ability of the two types of sperm to penetrate ova. (Approximate percentages should be quoted). (Level 5/6; 3 marks)

Answers

(a) A sperm can fertilise an ovum, giving rise to a zygote.

(b) There is no connection between the ovaries and the oviducts. Therefore, obtaining ova directly from the ovaries is a surer method of collection.

(c) Sperms must be mixed with the ovum for fertilization to take place.

(d) The fertilized ovum will divide into several cells. The collection of cells has a greater chance of survival and implantation than a single ovum.

(e) Testosterone; testes/testis.

(f) Fresh spermatozoa display a better ability to penetrate ova within 24 hours, increasing from 18% to 80%. However, beyond 24 hours, the ability of fresh sperm to penetrate ova decreases from 80% to 40%, but remains higher than the frozen and thawed sperm. In summary, the frozen and thawed sperm showed poorer ability to penetrate, reducing in an almost linear fashion from 56% to 10%.

OBJECTIVES

Students should be able to:

1. explain a problem or question to be tested by a scientific investigation
2. formulate and explain a testable hypothesis using correct scientific reasoning
3. explain how to manipulate the variables, and explain how sufficient, relevant data will be collected
4. design a logical, complete and safe method in which he or she selects appropriate materials and equipment.

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Level	Descriptor
0	The student **does not** reach a standard described by any of the descriptors below.
1-2	The student is able to: i. **state** a problem or question to be tested by a scientific investigation ii. **outline** a testable hypothesis iii. **outline** the variables iv. **design** a method, with **limited success**.
3-4	The student is able to: i. **outline** a problem or question to be tested by a scientific investigation ii. **formulate** a testable hypothesis using **scientific reasoning** iii. **outline** how to manipulate the variables, and **outline** how relevant data will be collected iv. design a **safe method** in which he or she **selects materials and equipment.**
5-6	The student is able to: i. **describe** a problem or question to be tested by a scientific investigation ii. **formulate and explain** a testable hypothesis using scientific reasoning iii. **describe** how to manipulate the variables, and describe how **sufficient, relevant data** will be collected iv. design a **complete and safe method** in which he or she selects **appropriate materials and equipment.**
7-8	The student is able to: i. **explain** a problem or question to be tested by a scientific investigation ii. **formulate and explain** a testable hypothesis using **correct scientific reasoning** iii. **explain** how to manipulate the variables, and explain how **sufficient, relevant data** will be collected iv. **design a logical, complete and safe method** in which he or she selects appropriate materials and equipment. *© IBO 2014*

SECTION 2.1 OUTLINING A PROBLEM OR RESEARCH QUESTION

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **state** a problem or question to be tested by a scientific investigation

3-4 **outline** a problem or question to be tested by a scientific investigation

5-6 **describe** a problem or question to be tested by a scientific investigation

7-8 **explain** a problem or question to be tested by a scientific investigation

Introduction

Intellectual and practical skills are developed through designing, analysing and performing scientific investigations. Although the scientific method involves a wide variety of approaches, the MYP emphasizes experimental work and scientific inquiry.

When students design a scientific investigation they should develop a method that will allow them to collect sufficient data so that the problem or question can be answered. To enable students to design scientific investigations independently, teachers must provide an open-ended problem to investigate. An open-ended problem is one that has several independent variables appropriate for the investigation and has sufficient scope to identify both independent and controlled variables. In order to achieve the highest level for the strand in which students are asked to design a logical, complete and safe method, the student would include only the relevant information, correctly sequenced.

Key terms

Explain: give a detailed account including reasons or causes.

Formulate: express precisely and systematically the relevant concept(s) or argument(s).

Select: choose from a list or group.

Design: produce a plan, simulation or model.

Investigate: observe, study or make a detailed and systematic examination, in order to establish facts and reach new conclusions.

2.1.1 STARTING AN MYP SCIENCE INVESTIGATION

Focused Problem or Research Question

The focused problem or research question outlines what you are planning to find out by performing an investigation. In most of your MYP Science investigations you will investigate the relationship between two different variables – also known as the independent and dependent variables. The research question will be generally to test a hypothesis.

An MYP Science investigation should have a clear, focused problem or research question before the hypothesis. Focused problems or research questions should begin, 'To discover ...' or 'To investigate ...', 'To find …' or 'To establish ...'. The focused problem or research question of the Investigation is clearly defined when the independent and dependent variables are also clearly identified and the cause and effect principle is correctly stated.

Independent variable: the variable that you as the experimenter directly change.

Dependent variable: the variable that is affected by the change in the independent variable.

Cause and effect: the dependent variable changes as a response to the change in the independent variable. The change in the independent variable is the 'cause' and the change in the dependent variable is the 'effect'.

Figure 201 (below) includes examples of clear focused problems or research questions for Chemistry, Biology and Physics MYP investigations. Note that, in each example, it is easy to identify the independent and dependent variables and the cause and effect relationship.

Subject	Focused problem or research question
Chemistry	To determine how the concentration of hydrochloric acid affects the rate of reaction between magnesium ribbon and hydrochloric acid (as measured by the time for a piece of magnesium ribbon to completely react with excess acid).
Biology	To find the optimum temperature for the activity of human salivary amylase (as measured by the time for excess starch solution to turn from blue to brown with iodine).
Physics	To determine how the surface area of a silicon-based solar cell affects the potential difference that is produced when white light from a table lamp is absorbed (*Figure 202*).

Figure 201 Examples of clear focused problems or research questions

In the first example, the statement implies that the concentration of hydrochloric acid (HCl) will be changed. The effect of the change in concentration of hydrochloric acid on the rate of reaction will be measured. Hence, the independent variable is the concentration of the hydrochloric acid, while the dependent variable is the time for the reaction to finish. The 'cause' is the change in the concentration of hydrochloric acid and its 'effect' on the time of reaction will be investigated.

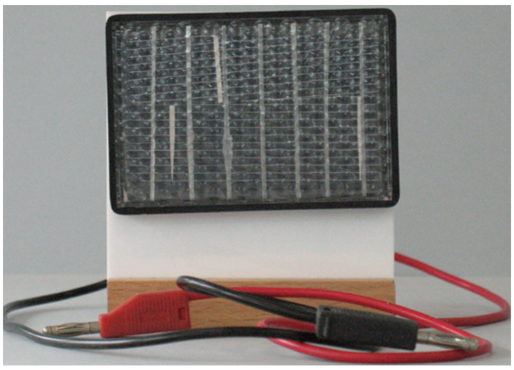


Figure 202 A silicon-based solar cell

Note that both the independent and dependent variables are measurable. The concentration of hydrochloric acid has units of mole per cubic decimetre (mol/dm^3), while the rate of reaction can be measured as the reciprocal of the time it takes (s^{-1}) to completely react a given mass of magnesium strip in hydrochloric acid (the shorter the time, the faster the rate of reaction).

Examples of some focused problems or research questions are given below:

CHEMISTRY

An example of a poorly focused problem or research question

To investigate rusting.

Comments*: Are you investigating which substances rust? Are you trying to establish the chemical nature of rusting? Are you trying to find out which substances in the air are involved in rust formation?*

An example of a clearly focused problem or research question

To investigate the effect of the concentration of dissolved sodium chloride on the rate of rusting of iron nails, as measured by their increase in mass.

BIOLOGY

An example of a poorly focused problem or research question

To investigate photosynthesis.

Comments*: Are you trying to establish what the reactants or products are? Are you trying to find out where in a plant or leaf photosynthesis is taking place? Are you trying to establish the relationship between the rate of photosynthesis and variables such as light intensity or carbon dioxide?*

An example of a clearly focused problem or research question

To determine how the rate of photosynthesis in *Elodea* (as measured by bubble movement in a potometer) is affected by the concentration of dissolved carbon dioxide.

PHYSICS

An example of a poorly focused problem or research question

To investigate refraction.

Comments*: Are you going to investigate the refraction of light waves, sound waves or water waves? Are you trying to establish the relationship between the angle of incidence and the angle of refraction for light waves? Are you going to find out the values of critical angles for different media?*

An example of a clearly focused problem or research question

To determine how the angle of refraction changes with the angle of incidence for white light at an air/perspex boundary.

GENERALLY

All clearly focused problems or research questions identify measurable variables and have an explicit cause and effect.

You should not start with a focused problem or research question that begins 'Investigation to prove....'. It suggests that the investigation you planned and carried out was a demonstration of an experiment you were already familiar with. The results of investigations are said to validate or invalidate a hypothesis. You do not prove a hypothesis.

EXERCISE 2.1

What possible focused problems or research questions might there be for an investigation entitled 'Resistance of a wire'?

EXERCISE 2.2

Formulate a focused problem or research question for the following investigations.

1. Angelica investigated the reaction between potato strips and aqueous hydrogen peroxide. She used different lengths of cylindrically shaped potato strips. The total mass of the strips was the same throughout. She placed the strips into a conical flask which contains 5% by volume of hydrogen peroxide. The gas produced by the reaction in one minute was collected and measured using a gas syringe. She repeated the process four times, with 1%, 10% and 15% by volume of hydrogen peroxide. Potato is a source of the enzyme catalase.

2. Cyril is conducting an investigation involving rubber bands. He hung a 10 g mass from a rubber band and he measured the change in the length of a rubber band using a ruler. He repeated the process four times, hanging a different mass each time.

3. Rachel investigated the reaction between magnesium strips and hydrochloric acid (HCl). She noticed that magnesium reacts with hydrochloric acid to form a soluble product. She poured 10 cm^3 of 2 mol/dm^3 hydrochloric acid into a boiling tube. Using a water bath, she warmed the boiling tube with acid to 30 °C. She then dropped a 2 cm length of cleaned magnesium strip into the test tube. Using a stopwatch, she measured the time it took the magnesium strip to completely react. She repeated the process four times, heating up the acid to a different temperature each time.

4. A freshly cut *Elodea* plant that is immersed in water produces bubbles due to oxygen production by photosynthesis. During an investigation involving an *Elodea* plant, Gian used a 50 W lamp as a light source. He placed the lamp 10 cm from the plant and he counted the number of bubbles the plant produced in 2 minutes. He then reduced the intensity of light which the plant received by moving the lamp 20 cm away from the plant. He again counted the number of bubbles produced after two minutes. Gian repeated the experiment three times more, moving the lamp to a different distance each time.

2.1.2 THE USE OF SCIENTIFIC MODELS

After a clearly focused problem or research question has been established, the next step in an MYP investigation is the generation of a hypothesis. It is also necessary for you to discuss the underlying scientific model or scientific theory that your hypothesis will be based upon. A scientific model is *not* the same as a scale model of a house or other object. A scientific model is simply a description of an idea that allows us to create explanations of how we think part of the physical world works. A model may be qualitative and/or quantitative.

Figure 203 shows a scale model of a human kidney – this is *not* a 'scientific' model.

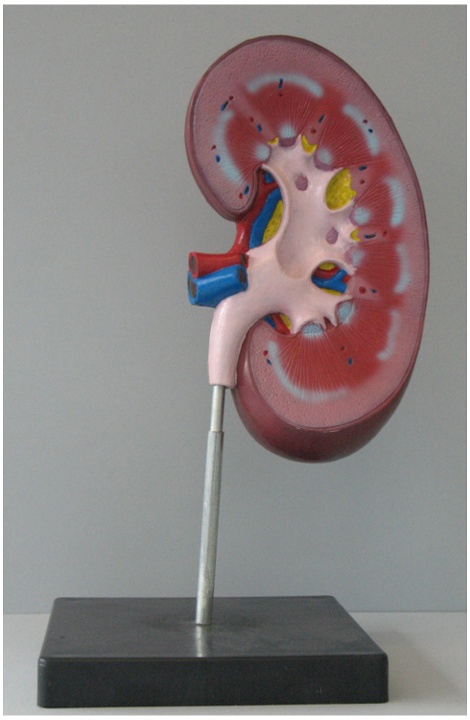


Figure 203 A model of a human kidney

A simple qualitative model from Chemistry is the nuclear model (*Figure 204*) of the atom. It describes atoms as consisting of negative electrons (organised into shells) that orbit the nucleus, which contains positively charged protons. The shells can each hold a maximum number of electrons: first shell (2), second shell (8) and third shell (8 or 18). The atom is stable due to the electrostatic attractive forces operating between the protons in the nucleus and the electrons.

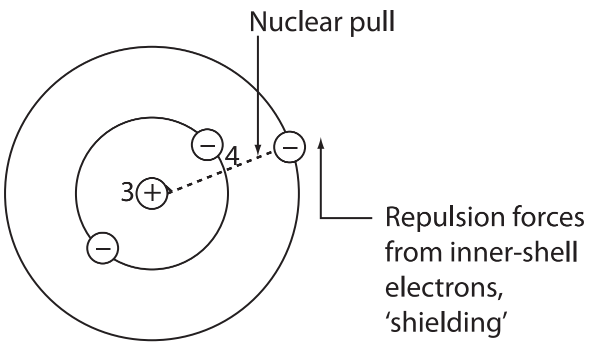


Figure 204 A simple nuclear model of lithium

The model of the atom can be used to explain ionic and covalent bonding. Ionic bonds are formed between oppositely charged positive and negative ions. Positive ions are formed when a metal atom loses electrons. For example, the sodium atom, Na (2,8,1) loses its outer electron to form a sodium ion, Na^+ (2,8). Negative ions are formed when a non-metal atom gains electrons.

For example, the chlorine atom (2, 8, 7), gains an outer electron to form a chloride ion, Cl^- (2, 8, 8). Both ions have stable electron arrangements with full outer shells of electrons.

Non-metal atoms can also gain full outer shells by sharing one or more pairs of outer electrons. Hydrogen, methane, ammonia, oxygen, nitrogen and water molecules are examples of covalently bonded molecules where all the atoms gain a full outer shell. The number of bonds formed is equal to eight minus the number of electrons in the outer shell. For example, carbon can form 8 – 4 = 4 bonds; oxygen can form 8 – 6 = 2 bonds. This very basic and simple model of the atom allows chemists to explain the chemical formulas of a wide range of compounds, as well as make predictions about which atoms will or will not undergo chemical combination when brought into contact with each other.

The simple nuclear model can also be used to account for the trends in reactivities of the elements in Groups 1 and 17. In Group 1 reactivity increases down the group because the outer electron that is lost is located progressively further from the nucleus and hence smaller amounts of energy are required to remove it during a chemical reaction. The increasing charge on the nucleus is counteracted by the presence of extra electron shells which shield the outer electrons from the attraction of the nucleus.

However, in Group 17, the opposite trend in reactivity is observed: the elements become more reactive as you move up the group. Group 17 atoms gain an electron during a chemical reaction. As you move up Group 17 the captured electron enters an outer shell which is located progressively closer to the nucleus. There are fewer electron shells and hence the shielding becomes smaller.

It is important to understand that a scientific model is not the picture of protons and neutrons surrounded by electrons that is found in chemistry textbooks, nor is it a physical structure that can be seen or directly observed. The scientific model is simply the idea that particles such as protons, neutrons and electrons exist and behave in certain ways.

Protons, neutrons, and electrons, in this sense, are not necessarily real in the way that objects that we can see are. Rather, they are ideas that chemists have developed to help explain what we see and to make predictions about what may yet be seen.

Later experiments have shown the nuclear model to be incorrect and the idea of electrons as particles has been replaced (at the IB Diploma Physics level) with the idea that electrons behave as particles and waves (known as the quantum mechanical model). This illustrates two points: firstly, that models change with time, usually becoming more complicated, and secondly, that simplified models can be useful.

Collision Theory

For a chemical reaction to happen, the particles of the reacting chemicals must collide with each other. In addition, the colliding particles must collide with enough combined kinetic energy, known as activation energy.

At higher temperatures, the faster moving particles have more kinetic energy, which means they are moving at higher speeds. The particles will collide more often and collide with more kinetic energy. Both these factors increase the number of effective collisions per unit time, which results in a higher rate of reaction.

More concentrated solutions contain more particles in the same volume, making them more likely to collide per unit time. The increase in the number of collisions with enough kinetic energy increases the rate of reaction. A similar effect occurs when reacting gases are put into a smaller volume (at a constant temperature).

If a solid is a reactant then an increase in surface area results in a greater number of collisions on the surface of the reactant per unit time.

BIOLOGY

Models are also used in Biology to illustrate (in a simplified way) how biological systems work. *Figure 205* shows a simple model of the human respiratory system. When the teacher pulls down on the rubber sheet (representing the diaphragm) air enters through the tube (representing the trachea) and inflates the balloons (representing the lungs). Note that the model is a simplification – it ignores the action of the ribs and the intercostal muscles in the ventilation process.

Figure 205 A model of human lungs

PHYSICS

One very important model that is relevant in Chemistry, Biology and Physics is the kinetic theory model. The kinetic theory is a model that tries to explain the properties of solids, liquids and gases by using the movement of particles. In its simplest form, it suggests that all substances are composed of particles (atoms, ions or molecules) that are constantly moving. In solids, the particles vibrate around fixed positions and the bonds or intermolecular forces behave like springs (*Figure 206*), but in liquids and gases the particles are free to move.

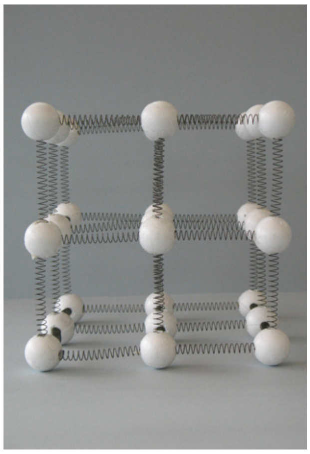


Figure 206 A ball and spring model of a solid

CHEMISTRY

Kinetic theory describes a gas as a collection of particles which move about in straight lines between collisions (*Figure 207*). The gas particles are assumed to have no attraction for each other. The average kinetic energy of the gas particles increases with temperature. These two statements are important assumptions about the kinetic model.

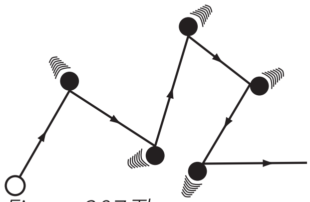


Figure 207 The movement of a gas particle

You should use simple observations to ask questions. An observation combined with scientific knowledge (model) can lead to a hypothesis, a prediction and finally, an MYP Science investigation (*Figure 208*).

A hypothesis is a statement that proposes a possible explanation for some phenomenon or event. A useful hypothesis is a testable statement that may include a prediction. A hypothesis can be qualitative (descriptive) or quantitative (numerical). In MYP Science investigations, hypotheses are usually generated to explain and quantify the relationship between two variables: the dependent and independent variables.

Ideally, the scientific method should be a *cyclic* process. If the evaluation shows that the data does not support the hypothesis then a new hypothesis (based upon the same or different model) should be generated and a new investigation performed. If the evaluation shows that the data supports the hypothesis then a new investigation could be planned with an extended or improved method designed to generate more accurate and precise data.

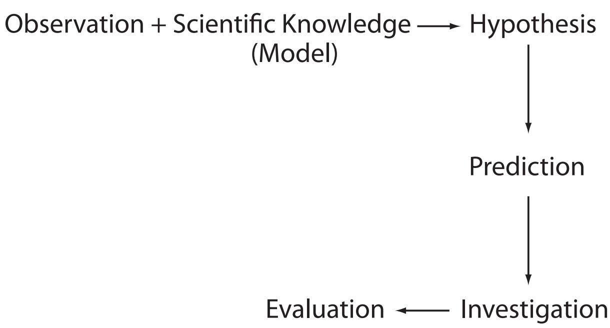


Figure 208 The Scientific Method

2.1.3 EXAMPLES OF OBSERVATIONS, MODELS AND HYPOTHESES

CHEMISTRY

Observation

Iron objects become covered in rust if left outside for several months.

Model

Chemical reactions involve the formation of chemical bonds between the atoms of substances. Chemical reactions involve the rearrangement of combinations of atoms in substances.

Hypotheses

- Rusting involves a chemical reaction between water and iron (false)
- Rusting involves a chemical reaction between water, oxygen and iron (true)
- Rusting involves a chemical reaction between carbon dioxide and iron (false)

BIOLOGY

Observation

Plants do not grow in the presence of salt.

Model

Osmosis involves the movement of water across a semi-permeable membrane from a region where there is a low concentration of solute to a region where there is a high concentration of solute. The process occurs because of the concentration gradient and is driven by an increase in disorder. The membrane is assumed to be impermeable towards solute.

Hypotheses

- Plants are losing water via osmosis and becoming dehydrated (true)
- Plants are unable to take up water in the presence of salt (false)
- Plants are unable to respire in the presence of salt (false)

EARTH AND SPACE

Observation

Global average temperature is related to the atmospheric concentration of carbon dioxide (and other greenhouse gases).

Model

Chemical bonds vibrate when they absorb infra-red radiation of specific frequencies. This radiation is re-emitted when the vibration "relaxes".

Hypotheses

Average global temperatures are connected with atmospheric carbon dioxide concentration (true)

Average global temperatures have increased since the Industrial Revolution (true)

The increase in average global temperature during the last 100 years can be accounted for by natural variation alone (false).

PHYSICS

Observation

The current flowing through a wire (at a constant temperature) increases when the potential difference is increased.

Model

A metal consists of a lattice of cations (positive ions). These are assumed to be immobile and in fixed positions. The valence or outer electrons are assumed to be mobile and, in the absence of voltage, move randomly between the cations (*Figure 209*). When a potential difference or voltage is applied then an orderly flow of electrons occurs, with electrons flowing from the negative electrode to the positive electrode. A larger potential difference means that more energy is delivered to each electron.

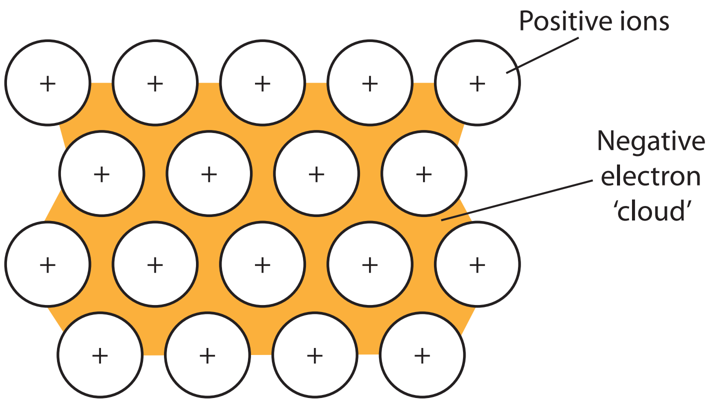


Figure 209 A simple model of metallic bonding

Hypothesis

The rate at which electrons flow through the wire increases when the potential difference is increased.

Each of these observations has more than one hypothesis. However, only one of these hypotheses can be correct. A hypothesis must be testable, which means it can be clearly validated or invalidated by experiments. A hypothesis must be made into a prediction and then tested by carrying out an investigation.

A testable hypothesis suitable for an MYP Science investigation should meet the following criteria:

- It should be quantitative and suggest a mathematical relationship (if possible)
- It should make scientific sense - it should not break any scientific laws
- It should be consistent with the available scientific information and data
- It should be simple
- It must be capable of being tested by an investigation using techniques, instruments and chemicals which are available in your school's Science laboratory
- It must be capable of being either accepted/supported or rejected/not supported when tested.
- It need not be 'correct'. If it is not, it can be rejected at the end of the MYP investigation report and a new hypothesis put in its place.

A hypothesis may come to mind if you ask yourself the following questions about observations:

WHAT?

WHY?

WHERE?

WHEN?

HOW?

Hypotheses or problems to investigate may be generated when you question a piece of scientific information, or simply observe phenomena. For example, you may read statements advertising products, for example, products that claim to prevent rust (*Figure 210*) or remove rust (*Figure 211*).

Figure 210 Anti-rust coat

Figure 211 Rust remover

There are several possible investigations involving these products. An obvious investigation would be the effect of different anti-rust coatings or rust removing agents on rust.

The best type of hypotheses for an MYP Science investigation are those that make a quantitative prediction and are justified by scientific knowledge.

Examples of quantitative and justified testable hypotheses

CHEMISTRY

Example: Electrolysis of aqueous copper(II) sulfate by carbon electrodes

Hypothesis

It is predicted that there will be a directly proportional relationship between the time and mass of copper deposited during the electrolysis of aqueous copper(II) sulfate by carbon (graphite) electrodes (at constant temperature and voltage). This implies that when the length of time of electrolysis is doubled, the mass of copper deposited also doubles.

Explanation

Electric current, *I*, is defined as the flow of charges per unit time (C/s), that is;

$$\text{current (A)} = \frac{\text{charge (C)}}{\text{time (s)}}$$

The current in the electrolyte (copper(II) sulfate solution) is due to the flow of positive ions to the negative electrode and of negative ions to the positive electrode.

The reaction occurring at the negative electrode is the reduction of copper(II) ions to form copper atoms:

$Cu^{2+}\ (aq) + 2e^{-} \rightarrow Cu\ (s)$

Since the voltage is constant, this implies that the current is also constant. If the time is doubled, then the number of charges that has flowed through the circuit is also doubled. If the time is doubled then the number of electrons supplied on the surface of the cathode (negative electrode) for reduction will double. Hence, the mass of copper deposited will be doubled.

BIOLOGY

Example: Photosynthesis by Elodea

Hypothesis

It is predicted that the rate of photosynthesis in *Elodea* (as measured by bubble production of oxygen-enriched air) will double if the concentration of dissolved carbon dioxide is doubled (provided temperature and light intensity are not limiting factors).

Explanation

Photosynthesis is a reaction where the overall result is the formation of glucose and oxygen from carbon dioxide and water. The reaction occurs inside chloroplasts (where chlorophyll is present) in the presence of sunlight.

$6CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

The reaction shows that for every six molecules of carbon dioxide reacting with water, six oxygen molecules are produced. Carbon dioxide is a reactant for photosynthesis and hence a doubling in the amount of carbon dioxide should result in the formation of double the amount of oxygen (in the same period of time).

PHYSICS

Example: The extension of a spring

Hypothesis

It is predicted that there will be a directly proportional relationship between the size of the force applied to the spring and its extension, that is, the increase in length.

In other words, if the load is doubled, the extension will be doubled; if the load is halved; the extension will be halved.

Explanation

This behaviour is expected to be observed (at least over relatively small loads) since, according to kinetic theory, once the force is removed the spring is expected to return to its original length due to the action of the attractive forces operating between adjacent metal atoms in the spring.

EARTH AND SPACE

Example: Crater impacts

Hypothesis

It is predicted that there will be an exponential relationship between the diameter of an impact crater and the height from which the impactor falls.

Explanation

This behaviour is expected because the size of the impact crater is dependent on the kinetic energy of the impactor, which in turn varies with the square of the impactor velocity.

EXERCISE 2.3

Formulate a testable hypothesis regarding the dissolving of sodium chloride in water at different temperatures. Your hypothesis should be supported by the particle or kinetic theory.

SECTION 2.2 FORMULATING A TESTABLE HYPOTHESIS

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **outline** a testable hypothesis

3-4 **formulate** a testable hypothesis using **scientific reasoning**

5-6 **formulate and explain** a testable hypothesis using **scientific reasoning**

7-8 **formulate and explain** a testable hypothesis using **correct scientific reasoning**

2.2.1 MAKING PREDICTIONS

An MYP Science investigation will include a prediction. Often you will predict that there is a relationship between two variables.

- An **independent** variable is a variable that is changed by you.
- A **dependent** variable is measured for every change in the independent variable.
- All other variables are **controlled** variables. This is to ensure that your investigation is a fair test.

It is very important that all the controlled variables are identified and controlled. An uncontrolled variable may affect the data collected.

Some examples of predictions

CHEMISTRY

Example: The greater the mass of magnesium burnt, the greater the mass of magnesium oxide formed (provided oxygen is not a limiting reagent).

- The mass of magnesium is the independent variable; the mass of magnesium oxide is the dependent variable.
- Length of combustion time, combustion temperature, composition of air and surface area of the magnesium are the controlled variables.

BIOLOGY

Example: The longer potatoes are boiled the less vitamin C they will contain.

- Length of boiling time is the independent variable; the concentration of vitamin C is the dependent variable.
- Variety of potato, volume and mass of potato, dimensions of potato and method of extraction of vitamin C are the controlled variables.

PHYSICS

Example: The time period of a simple pendulum is not affected by the amplitude of the swing.

- The amplitude of the swing is the independent variable; the period is the dependent variable.
- The length of the pendulum and the mass and shape of the pendulum bob are the controlled variables.

When you are designing an MYP investigation you must make sure that other MYP students could obtain the same results (within experimental error) as you. In other words, your results must be **reliable**. You must incorporate repeat measurements into your plan.

You need to make sure that you have controlled as many variables as you can, to ensure your investigation produces reliable data. The results from your investigation should allow you to decide whether your hypothesis is supported or not supported.

2.2.2 RELATIONSHIPS BETWEEN INDEPENDENT AND DEPENDENT VARIABLES

The two variables may be linked together in one of three ways:

- The independent variable may cause a change in the dependent variable. This is known as a causal link and is an example of 'cause and effect'. This is the type of relationship that is investigated or assumed to be investigated during an MYP Science investigation.

For example, increasing the velocity of a car increases its braking distance.

- It could be because a third variable has caused changes in the two variables you have been investigating. There is an association between the two variables.

For example, the rate of growth of a crop can be affected by soil acidity (pH). The amount of fertiliser used on the crop will affect both the rate of growth and the soil acidity (pH). The information from links due to association is less clear than those from 'cause and effect' relationships.

- The apparent relationship between two variables may just be due to chance.

For example, the ozone layer has undergone depletion and acid rain has damaged forests and lakes.

EXERCISE 2.4

Copy the following table and fill in the gaps

Research question	Independent variable	Dependent variable
1. How do different types of exercise affect my pulse rate?	Type of exercise	Pulse rate
2. In this experiment, I will investigate the effect of the type of surface on the height the ball bounces.		Height of bounce
3.	Mass of fertiliser	Height of grass
4.	Intensity of light	Number of oxygen bubbles produced / min
5. In this investigation, I will find the relationship between the amount of acid and the amount of hydrogen gas (*Is this a good statement of the focused problem or research question? Why or why not?*)		

2.2.3 OBSERVATIONS

When you are recording data during an MYP investigation it is important that you record relevant data. You can judge this by having a clear idea of the research question of the investigation. Knowing what you are looking for is the first step in recording relevant observations.

Record the values of all manipulated variables, both independent and controlled. This is important because if it is not recorded another student cannot repeat the investigation.

For example:

CHEMISTRY

You are using different sized lumps of marble with 2 mol dm^{-3} nitric acid, and then timing how long it takes to fill up a gas syringe with carbon dioxide.

- The dimensions of the marble blocks and the time taken to fill the gas syringe need to be recorded.
- The temperature should also be recorded since temperature affects the rate of reaction. If temperature changes during the experiment, then it will affect the results.

BIOLOGY

You are trying to establish whether a sample of cress seedlings with no light will grow or not.

- The heights of the seedlings will be measured every day for a week.
- The temperature, amount of water, and amount of fertiliser (if added) would also need to be recorded since these variables will also affect growth.

PHYSICS

You are trying to establish whether heat loss from a glass beaker of hot water will decrease as the thickness of the insulating material increases.

- The temperature of the water will be recorded every minute for thirty minutes.
- The type of material used, the thickness of the material and the surrounding air temperature all need to be recorded since they will affect heat loss.

SECTION 2.3 MANAGING VARIABLES AND COLLECTING DATA

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **outline** the variables

3-4 design a **safe method** in which he or she **selects materials and equipment.**

5-6 **describe** how to manipulate the variables, and describe how **sufficient, relevant data** will be collected

7-8 **explain** how to manipulate the variables, and explain how **sufficient, relevant data** will be collected.

2.3.1 VARIABLES

There are four types of variables:

- A **categoric** variable is a variable that is described using words. For example, the colour of hair is a categoric variable, such as red, blond or black hair.
- A **discrete** variable is a variable described in whole numbers. For example, the number of flowers on a leaf or the number of beetles in a quadrat.
- An **ordered** variable is a variable where the data can be placed into order. For example, small, medium and large lumps of calcium carbonate.
- A **continuous** variable is a variable that can be measured and represented by a number. For example, the height of trees.

When designing your MYP investigation you should always plan to measure continuous data whenever possible.

For example, if you were growing seedlings in volumes of water with different salt concentrations then it would be best to measure the heights of all the seedlings. This is more scientific than recording the number that are 'tall' or 'short'.

Proximate and ultimate variables

A proximate dependent variable is the variable that is directly measured in an experiment, e.g. in a calorimetry experiment this would be a temperature change. The ultimate dependent variable in this case would be an enthalpy change, which requires processing of the proximate variable in order to determine it (by using the specific heat capacity of water to calculate the heat released and dividing this by the number of moles of fuel burnt). In short, the proximate variable is determined directly by experimental measurement, the ultimate variable is obtained by processing the proximate variable in some way. Another example would be an electrical investigation where we wish to determine the resistance of a particular material - the voltage and current would be proximate variables and the resistance (calculated using Ohm's Law) would be the ultimate variable. In an investigation of reaction rate a student would first measure reaction time in seconds (proximate) before taking the reciprocal to obtain a value proportional to rate, in seconds^{-1} (ultimate). It is important that your method indicates clearly what data processing will be performed with your raw data (see **Chapter 3: Criterion C: Processing and Evaluating**).

EXERCISE 2.5

Classify the following variables:

- Internal body temperatures of people
- Lengths of tree snakes (compared with each other)
- Eye colour in domestic cats
- Number of toes on the left foot of people

2.3.2 DESIGNING AN INVESTIGATION

METHOD

Fair Testing

When conducting a scientific investigation, it is possible that there are other variables, aside from the selected independent variable, which could affect the dependent variables. If this is the case, then it is important that these other variables must not change.

A fair test is one in which there is one independent variable that affects the dependent variable. All other variables are controlled and kept constant.

Consider an investigation studying the variables that affect the rate of reaction between marble chips (calcium carbonate) and dilute hydrochloric acid. Possible independent variables include: concentration of acid, temperature of acid and surface area of the calcium carbonate. Three investigations are possible, each involving the changing of one of these variables and making the other two controlled (*Figure 212*).

Independent variable	Controlled variables
Concentration of acid	Temperature of hydrochloric acid and surface area of calcium carbonate
Temperature of acid	Surface area of calcium carbonate and concentration of hydrochloric acid
Surface area of calcium carbonate	Temperature of hydrochloric acid and concentration of hydrochloric acid

Figure 212 Possible investigations into the reaction between calcium carbonate and hydrochloric acid

If the MYP Science investigation is a Biology investigation, perhaps involving fieldwork, then additional issues should be considered. Plants and animals live in complex environments whose variables are complex and difficult to control. You should aim to ensure that the controlled variables change in the same way, except for the variable you are investigating. For example, if you are studying a small section of woodland then you must take measurements to see whether all parts are receiving the same rainfall and sunlight.

If you are investigating two variables in a large population of animals or plants then you will need to carry out a survey of the population. A random sample of the population needs to be studied.

Controls are used in MYP Chemistry and Biology investigations to allow comparison of observations in the presence and absence of the independent variable (i.e. the variable being changed).

EXERCISE 2.6

An MYP Science student proposes the following hypothesis: leaves in the light need carbon dioxide to synthesize starch. Outline the test and the control. Explain the need for a control in the investigation.

For example, you might be studying the effect of a phosphate fertiliser on the growth of plants. A control group should be included. For example, ten plants may receive the fertiliser and the other group of ten plants will be a control and not be treated with fertiliser.

The three test tubes shown below in *Figure 213* summarise a simple investigation to determine whether air and water are required for rusting. Test tubes A and B are the controls since they exclude water and air, which are both hypothesized to be necessary for rusting.

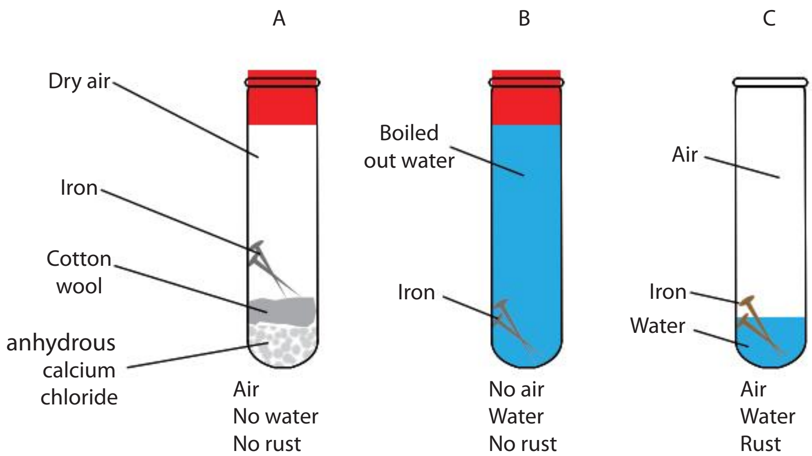


Figure 213 Factors affecting the rusting of iron

2.3.3 CHOOSING VALUES OF A VARIABLE

A trial run may be very useful before you perform your MYP Science investigation. A trial run is performed to establish the upper and lower limits (the range) of your independent variable. An absolute minimum of five trials should be performed.

Do you have the correct conditions?

CHEMISTRY

For example: An investigation into the reaction between magnesium and hydrochloric acid produces gas too quickly to measure at 30 second intervals in a 100 cm^3 gas syringe.

This could be improved by one or more of the following:

- lower the temperature of the acid
- lower the concentration of the acid
- use a gas syringe with a larger volume

BIOLOGY

For example: An investigation into photosynthesis that produces insufficient amounts of oxygen-enriched air.

This could be improved by one or more of the following:

- light of high enough intensity
- sufficient pondweed (*Elodea*)
- sufficient dissolved carbon dioxide
- raising or lowering the temperature
- using water with a lower concentration of chlorine

PHYSICS

For example: An investigation into the evaporation of volatile liquids resulted in a mass loss too small to accurately measure.

This could be achieved by one or more of the following:

- use larger amounts of the liquid
- raise the temperature of the surroundings
- increase the surface area of the evaporating liquid
- use an electronic balance with a greater sensitivity, i.e. more decimal places

Have you chosen a sensible range?

CHEMISTRY

For example: Burning alcohols investigation (*Figure 214*)

There is sufficient alcohol for a reasonable burn length, but only small amounts of alcohol are combusted. Type of alcohol or, preferably, number of carbon atoms is the independent variable.

- You might need to move the spirit burner closer to the calorimeter.

BIOLOGY

For example: Photosynthesis investigation

There is sufficient oxygen to measure, but the results are all very similar. Light intensity is the independent variable.

- You may not have chosen a wide enough range of light intensities. You might need to move the lamp further away from and closer to the photosynthesising plant.

Figure 214 Apparatus required for burning alcohols

PHYSICS

For example: Strength of an electromagnet (operated using a small battery and a variable resistor)

The electromagnet picks up a small mass of iron filings, but the results are all very similar. Electric current is the independent variable.

- You may not have chosen a wide enough range of electric currents. You might need to replace the battery and variable resistor with a power pack.

Have you got enough readings that are close together?

If the results are very different from each other you might not see a pattern because you have large gaps between readings over the important part of the range. This is especially important for investigations that aim to find the optimum pH or temperature for enzyme activity.

2.3.4 ACCURACY AND PRECISION

Accuracy

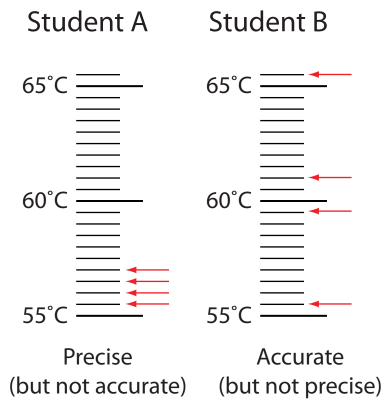


Figure 215 Accuracy and precision

Accurate results are very close to the true values. Your investigation should provide data that is accurate enough to validate or invalidate your hypothesis. However, it is not always possible to know what the true values are.

How do I obtain accurate data?

- Repeat the investigation and average the results obtained.

Try repeating the measurements with a different measuring instrument and see if you obtain the same readings. For example, if you are measuring temperature changes then use another thermometer of the same type.

- Use high quality instruments that measure accurately.

For example, use a burette which measure volumes more accurately than a measuring cylinder. A mercury thermometer is more accurate than an alcohol thermometer.

- Use the instruments properly and carefully.

For example, you should read to the bottom of the meniscus (curved liquid surface) when measuring volumes of liquids.

Precision

If your repeated results are closely grouped together then the results are said to be precise. Your MYP investigation must provide data with sufficient precision. If there are large differences within sets of repeat readings then you will not be able to draw a valid conclusion.

How do I get precise data?

- You have to repeat your tests.
- You have to repeat your tests in exactly the same way.

For example, you might be assessing the rate of reaction between sodium thiosulfate and dilute acid in a flask by observing a cross on a piece of paper. The same or identical cross and conical flask must be used. The same person must record the observation.

However, note that results may be precise but inaccurate. For example, consider a digital balance, it is very precise and measures masses to 4 decimal places. However, when there is no mass on the pan, the balance gives a reading of 0.0050 g. This means that every mass is inaccurate by a factor of 0.0050 g, for example, a mass of 50.055 g is actually 50.05 g.

The difference between accurate and precise results is illustrated in *Figure 215*. A spirit burner with ethanol is used to heat 100 cm^3 of water at room temperature for 5 minutes. Two MYP Science students repeated this experiment, four times each. Their results are marked on the thermometer scales in *Figure 215*.

Precise results are grouped together closely. Accurate results will have a mean or average close to the true value (60°C).

Method

The method for your investigation should be written in a distinctive style. It is meant to be factual, functional and objective (impersonal). Since the investigation has not been completed, the method should be written in the future tense. However, you will not be penalised if you write a formal method in the past tense after carrying out your planned method.

Many MYP students number the steps of their method. This is not necessary, but may be helpful so you do not miss out any steps when you come to perform the investigation.

However, the guiding principle when you write your method for your MYP Science investigation is that another MYP Science student could perform the investigation and obtain results within experimental error. It is very important that you emphasise which part of the method is the test and which, if relevant, is the control.

If something you did not expect happened, you may have to describe it and explain why it occurred. You may then have to repeat that part of the investigation. Any changes that you make to your planned method while implementing it should be included, highlighted and justified. The method must indicate which steps will be repeated and how many times.

Do not hide your mistakes or problems. The IBO strongly encourages academic honesty.

Examples

CHEMISTRY

Some of the copper(II) sulfate crystals from the third crystallisation experiment were spilt.

BIOLOGY

Two of the thirty germinating pea seeds grew fungus and died.

PHYSICS

The resistance wire became hot and melted, breaking the circuit.

A list of materials and equipment should also be included at the beginning of the method. A poor (left column) and a good list (right hand column) of material and equipment are shown in *Figure 216*.

Materials or equipment	Materials or equipment
Amylase	*Beta*-amylase from barley grains
Magnesium	Cleaned magnesium ribbon (1 cm diameter)
Gas syringe	Gas syringe (250 cm^3)
Flask	Conical flask (250 cm^3)
Thermometer	Mercury thermometer (0 - 100 °C) ± 0.5 °C
Spatula	Plastic spatula
Methanoic acid	1.00 mol dm^{-3} methanoic acid, HCOOH(aq)
Clock	Manually operated electronic stop watch (± 1 s)
Data logger	pH data logger sensor (manufacturer: Vernier Logger Pro 3.1: ± 0.02 pH units)
Voltmeter	Analogue voltmeter 0 – 6V (±4%)
Wire	Constantan (copper/zinc) wire; diameter 1.62 mm

Figure 216 Poor (left) and good (right) lists of material and equipment for MYP Science Investigations

Many pieces of glassware and other apparatus in the laboratory will have the manufacturer's error printed on them. This information should be recorded in the method of your plan.

A method should be more than just a 'recipe' that another student can follow. You should try to give scientific reasons for anything you plan to do. *Figure 217* shows three measuring cylinders. If, for example, the measuring cylinder on the far right was going to be used then it should be described as a glass measuring cylinder, capacity 100.0 mL ± 0.8 mL. This means that a measurement of 100 mL will lie within the range 100.8 mL and 99.2 mL. The plus-or-minus 0.8 mL is the error or random uncertainty. It is an example of a random error.

For example, if during an investigation into osmosis you are surface drying potato chips that have been placed in a solution, explain why you are doing this e.g. to remove surface solution which could vary and make the chips appear heavier.

If you are investigating a chemical or biochemical reaction, then make it quite clear what the end point of the reaction is. For example, if investigating the enzyme rennin then the end point could be the time taken for the milk to coagulate so that it will not run when the tube is placed horizontally. Or, alternatively, when catalase reacts with hydrogen peroxide, measure the time taken for an amount such as 10 cm^3 of oxygen to be produced.

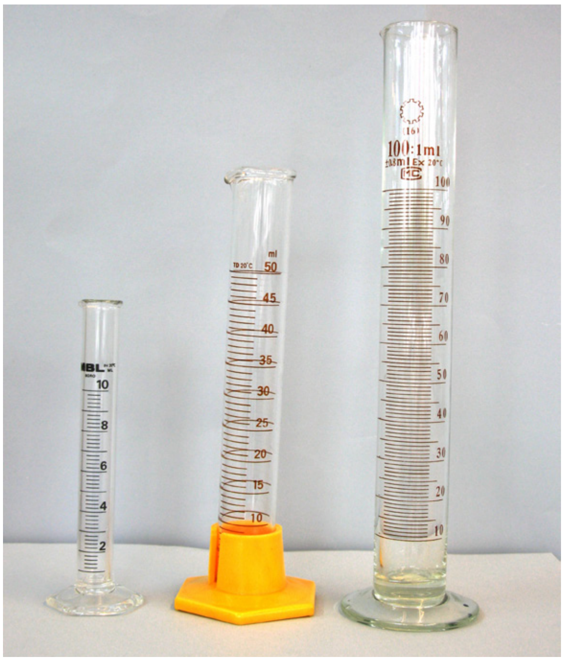


Figure 217 Three measuring cylinders

Write down the range and number of readings you are going to take. You should aim for at least 5 different measurements of a variable for an investigation. Also give reasons why you have chosen this range. For example, for an enzyme investigation you may obtain data between 20 and 70 ^{0}C but not between 0 and 100 ^{0}C. This is because enzymes are expected to be denatured at the extremes of the second range and be inactive. The first range is expected to include the optimum temperature of the enzyme.

Always make it clear that you are going to repeat your results at least three times and obtain an average (mean) of each measurement. You must explain why this is necessary, for example, to give an indication as to how reliable the results are - if the readings are close to each other then the data is reliable. *Figure 218* shows an example of the outline of a plan of a method from a relatively simple investigation into the solubility of sodium chloride. A detailed description of the chemicals and apparatus has not been included, but note how the outline of the method relates to the requirements of Criterion B: Inquiring and Designing. Include a cross-section diagram with labels and dimensions.

Identifying all the relevant variables and explaining how to manipulate them.	In this investigation, the independent variable is the temperature of water. I will use a Bunsen burner to raise the temperature of the water and ice to lower the temperature of the water. The dependent variable is the time it takes to dissolve powdered sodium chloride. I will use 3.00 g of sodium chloride so that I will not have to wait a long time for it to dissolve. The electronic balance will be used to measure out 3.00 g. To make my experiment a fair test, I will use the same volume of water, same mass of sodium chloride powder and the same size and shape container as this can affect the rate of heat lost to the environment. I will monitor the temperature with a thermometer. I will stir five times after the sodium chloride has been added.
Include precise values	The temperature of the water will be varied from 40 °C to 90 °C at intervals of 10°C. The volume of the water used will be kept at 100 cm^3.
Rationale for the method is provided	I will use sodium chloride powder instead of crystals so that the time it will take to dissolve is shorter. If time is measured, it is good practice to have at least three trials.

Figure 218 An outline for a plan into an investigation of the solubility of sodium chloride

Two examples of parts of detailed methods are given, one for a Biology investigation involving enzymes and one for a Physics investigation involving resistance. Note the detail and precision in the method.

BIOLOGY

For example: From an investigation into the activity of salivary amylase

5 cm^3 of the 2% (by volume) salivary amylase solution will be added to a labelled test tube containing 5 cm^3 of 2% (by volume) starch solution. The tube containing this reaction mixture will be placed in a water bath thermostatted at 37 °C. An electronic stop clock will be immediately started.

Figure 219 A spotting tile

After 4 minutes, 1.0 cm^3 of the reaction mixture will be placed onto a ceramic spotting tile (*Figure 219*). Three drops of dilute iodine solution will be added to this sample and any colour change noted. Immediately after sampling, the reaction mixture will be returned to the water bath. The procedure described will be repeated at three minute intervals and the investigation will be continued for a total of fifteen minutes.

PHYSICS

For example: From an investigation into how the resistance of a nichrome wire varies with length

A potential difference of 6.0 volts will be applied to a 70 cm length of 0.28 mm diameter nichrome wire. This voltage will be measured with a 0 – 15 V D.C. analogue voltmeter. The current will be measured with a 0 – 3 A analogue ammeter but a more sensitive ammeter may be needed once I start performing some trial runs. The resistance can then be calculated from the ammeter and voltmeter readings. Values of resistance will be calculated by dividing voltage readings (in volts) by current readings (in amps).

The potential difference will be maintained at 6.0 volts, but the procedure above will be repeated and the nichrome wire shortened by 5.0 cm each time until it is only 10.0 cm long. The wire will be measured with a steel rule whose smallest divisions are 0.5 mm. I will view the wire and rule from directly above a flat table. The experiment described will then be repeated three times and average values calculated for each length. *Figure 220* shows part of the circuit the student intends to construct.

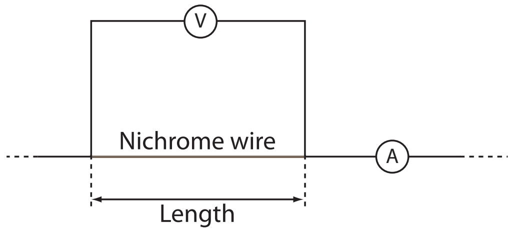


Figure 220 A possible circuit for investigating the resistance of a wire

However, since electrical resistance varies with temperature I plan to use a large beaker of cold water to keep the temperature of the nichrome wire constant and compensate for the heating effect of an electrical current. The resistance of a wire also varies with diameter and so, to ensure that I have the same diameter, I will use lengths of nichrome wire taken from the same reel.

I will use a micrometer screw gauge (with an accuracy of 0.01 mm) to check the diameter of each piece before using it. I will use a thermometer to monitor the temperature of the water bath to ensure that it does not change during the investigation. *Figure 221* shows an improved circuit.

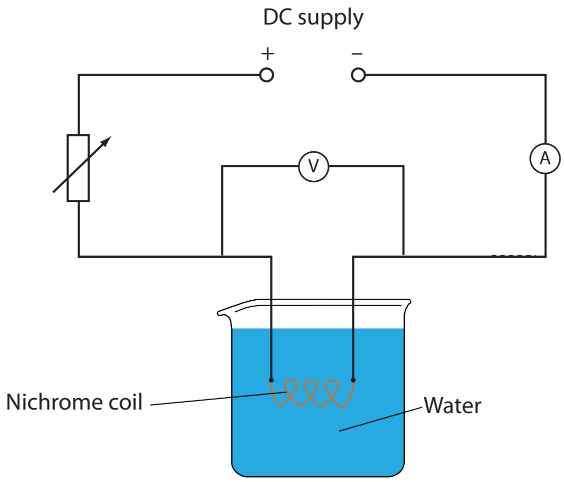


Figure 221 A more suitable circuit for investigating the resistance of a wire

2.3.5 DRAWINGS OF APPARATUS

A drawing of apparatus is also necessary for many MYP Science Investigations. It is very important that relevant information not included in the diagram is included in the method.

Examples

CHEMISTRY

The aspirin was dried for 4 hours in an oven maintained at 60 degrees Celsius.

BIOLOGY

The plant (*Tradescantia*) used in the experiment had first been de-starched by keeping it in a dark cupboard for 48 hours.

Drawing Apparatus

- Draw diagrams in cross section, not as three-dimensional pictures.
- Start at the top of your page and work downwards, so that you are less likely to run out of space.
- Make drawings sufficiently large so the detail can be seen.
- Do not draw Bunsen burners (use an arrow labelled 'heat'), the bench, gas taps or clamps.
- A water bath should be shown if used.
- Label important points on the diagram or unusual items.
- If you name the glassware, then use the correct names.
- Include relevant measurements or dimensions that would allow another student to set up the same apparatus in an identical way.

You may have to design and build an electrical or electronic circuit as part of an MYP Physics investigation. Circuit diagrams show the connections as clearly as possible with all wires drawn neatly as straight lines. The actual layout of the components is usually quite different from the circuit diagram and this can be confusing for the beginner. You should concentrate on the connections, not the actual positions of components.

Criterion B: Inquiring and Designing also requires you to suggest in your plan and method how you will process and analyse the raw data you are collecting.

For example, if you were investigating the stretching of a spring then you would plot a line graph of extension (y axis) against load (x axis). The extension is the increase in length compared to the unstretched spring. The spring constant is obtained from the reciprocal of the slope or gradient of the straight line. If the "load" force is being plotted then it is correct to plot load on the x-axis and extension on the y-axis.

However, Hooke's Law is usually given in the form $F = kx$ (or more correctly $F = -kx$) where x is the extension and also the x-axis variable. The force is no longer the "load" force, but rather the "elastic restoring force" in the spring (which equals the load by Newton's third law of motion and is dependent on the extension). The reason for doing this is that the gradient of the graph then directly gives the force constant of the spring in Newtons per metre. If extension is plotted vs load the force constant is then the reciprocal of the gradient.

If you were measuring times for magnesium to completely react with the same volume of different concentrations of hydrochloric acid then you would want to calculate the reciprocal of times (1/time or $time^{-1}$) as a measure of the rate of the reaction. A line graph of rate versus concentration could then be drawn.

If you were investigating the effect of sucrose solution on the mass and length of potato cylinders then you would probably want to calculate the increases and decreases and plot them on the same graph: length or mass on the y axis and concentration of sucrose on the x axis.

SECTION 2.4 DESIGNING SCIENTIFIC INVESTIGATIONS

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **design** a method, with **limited success**.

3-4 design a **safe method** in which he or she **selects materials and equipment**.

5-6 design a **complete and safe method** in which he or she selects **appropriate materials and equipment.**

7-8 **design a logical, complete and safe method** in which he or she **selects appropriate materials and equipment**.

2.4.1 COMMON EXPERIMENTAL TECHNIQUES

Your MYP Science teacher will use some of your investigations to assess your ability to use apparatus and equipment. Adopting these practices will also help reduce random errors and prevent systematic errors. Your MYP Science teacher may have a tick list covering key points. Some simple examples of what they might be looking for are outlined below.

Measuring temperature

Below are some simple but essential rules to help maximise the accuracy of temperatures recorded with a liquid-in-glass mercury or alcohol thermometer (*Figure 222*):

- Ensure that the thermometer covers the temperature range you require.
- Ensure that the thread of liquid has no gaps in it; it must be unbroken.
- Carefully stir the liquid or solution before recording the temperature.
- Hold the bulb of the thermometer in the 'body' of the liquid or solution, away from the sides and bottom of the container.
- Place your eye level with the top of the alcohol meniscus to minimise parallax errors. The use of a magnifying glass will help you improve the precision of your measurement.
- Do not use thermometers to stir liquids or solutions as you may break the bulb.
- To maximise the precision of your reading you will need to estimate the marks on the scale.
- The bulb of the thermometer must be fully immersed in the liquid throughout the time it takes you to record the temperature. Do not lift the thermometer out and up to your eye to read the scale, as the thermometer will cool. The thermometer should be immersed in the liquid for 30 seconds to allow the mercury or alcohol inside the thermometer to reach the temperature of the liquid.

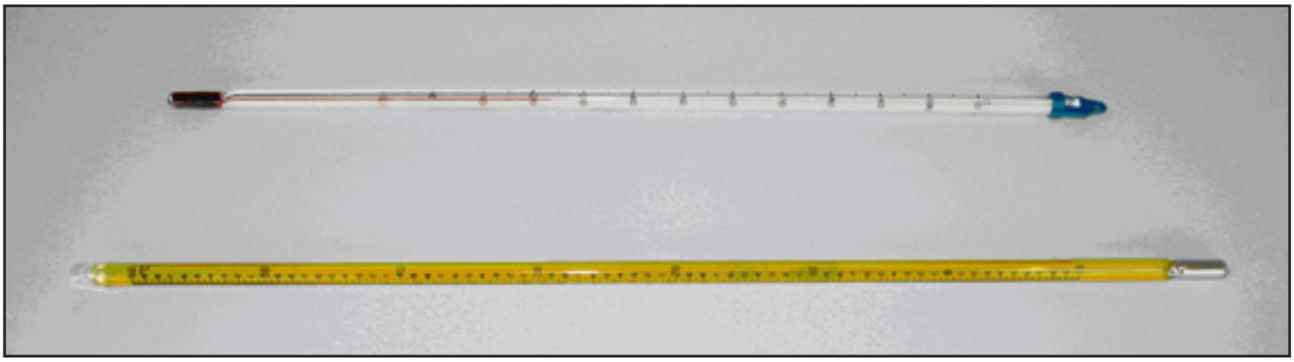


Figure 222 Alcohol (top) and mercury thermometers (bottom)

Measuring time

Timing is usually carried out with an electronic stopwatch (*Figure 223*) (typically one that measures times to within 0.01 seconds). The accuracy of a short time is often determined by the speed at which the stopwatch is turned on and off by the operator.

The precision of the measurement can therefore be improved by getting familiar with the controls, and also by anticipating the beginning and end of the timing. The random errors present in such measurements can be minimised by repeating the experiments. Average or mean times can then be calculated.

You should remember that every human recorded measurement of time has a systematic error due to the short length of time needed by a person seeing an event and then moving the muscles in the hand to start or stop the stopwatch. This length of time is known as the reaction time and for a typical adult is in the order of 0.3 seconds. Hence, you could round up times to the nearest second, for example, 89.92 s could be expressed as 90 s. Alternatively, the time could be expressed as 89.9 ± 0.3 s.

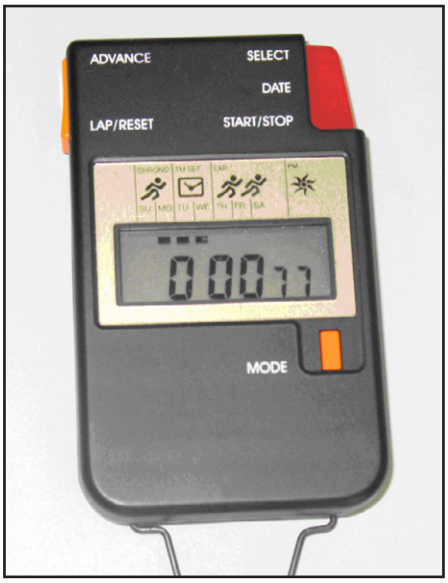


Figure 223 Electronic stopwatch

Measuring length

The unit used to measure length will be determined by the scale of the object being measured. For small measurements, a ruler (*Figure 224*) will be frequently used. However, since the ends of the ruler are often damaged you will get a more accurate result when you measure, for example, from the 10 cm line and subtract 10 cm from your measurement. This avoids introducing a small systematic error.

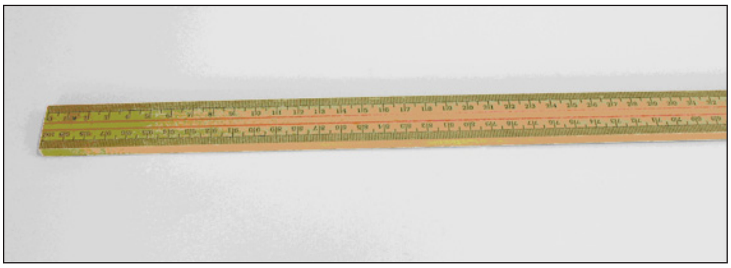


Figure 224 A wooden ruler

Measurements to within 0.5 mm can be made with an ordinary ruler and longer measurements can be made with a metre ruler. Longer distances can be measured using a long tape measure. Accuracy becomes critical in measuring small distances, since even small errors can make a significant difference. In measuring any length, you must look straight down at right angles to the ruler and the object to avoid any parallax error (see *Figure 225*).

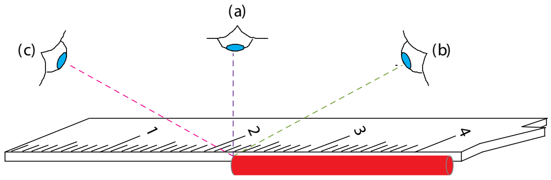


Figure 225 Illustration of parallax error with a ruler

Measuring mass

The mass of a substance or an object is usually measured by an electronic balance (*Figure 226*) that gives a direct digital reading to a particular degree of precision. Before using the balance it should be 'tared' to read zero. Failure to calibrate the balance in this way may result in a systematic error.

You then need to take into account the mass of the container holding the object or substance being weighed. The mass of the container should be determined before the object itself is weighed. The first mass (the container) can then be subtracted from the second (the container and the object) to find the true mass of the object. This approach to weighing is known as 'weighing by difference'.

It is not good practice to place chemicals or biological specimens, especially if they are wet, onto the pan of the balance and weigh them directly. In addition, no attempt should be made to weigh hot samples since the resulting convection currents will cause the pan, and hence the mass reading, to fluctuate (go up and down). The object to be weighed must be placed in the centre of the pan on the balance.

Figure 226 An electronic balance

Measuring gas volumes

A gas syringe (*Figure 227*) is a piece of laboratory glassware frequently used to collect a volume of gas from a flask where a chemical reaction is occurring. The gas syringe will have an airtight seal of ground glass around the top and sides, and will move more freely than a normal syringe. Most gas syringes can measure up to 100 cm^3 of gas with a precision of 1 decimal place.

When using a gas syringe it is important to keep it dry. Gases could dissolve in water, resulting in inaccurate measurements. The gas syringe works due to the fact that equal amounts of gases occupy a fixed volume under conditions of equal pressure. Therefore the amount of a gas formed can simply be measured by measuring the volume it occupies under standard pressure conditions. The inner part of the syringe and the outer tube should move freely, otherwise the friction could prevent the inner part being pushed back by the pressure of the collected gas.

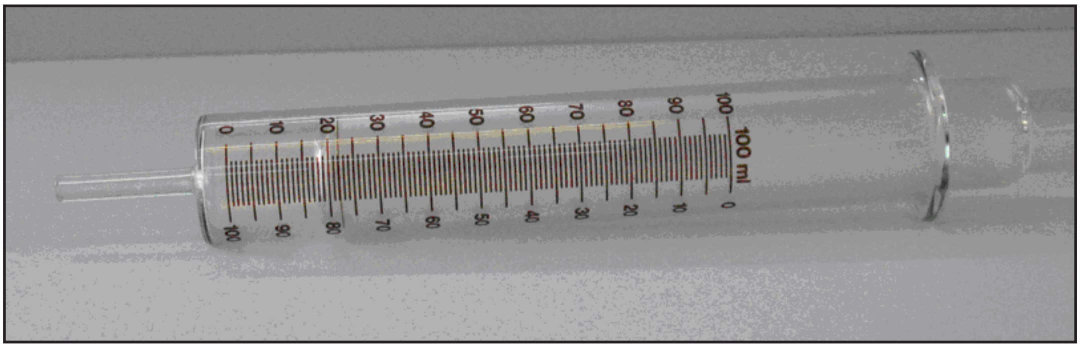


Figure 227 Gas syringe

Using a pH meter (glass electrode type)

Take care to rinse the electrode thoroughly by rinsing it with distilled water from a wash bottle every time you change solutions. Do not leave the electrode out of water or the solution for longer than you need. Do not let the electrode dry out: salt deposits will form interfering with the electrode response.

Do not touch the electrode or move about near to it whilst a reading is taken. If you are using a magnetic stirrer then switch it off when you take the readings. The electrode needs time to reach equilibrium in solution, so do not rush to record the measurement, but wait patiently until the meter reading becomes steady.

Measuring volumes of solutions and liquids

Pipettes, burettes and measuring cylinders are all used for measuring volumes of liquids or solutions. A pipette filler should always be used when filling graduated pipettes. Solutions and liquids, even distilled water, should never be extracted, using one of these pieces of apparatus, by mouth.

Before using a graduated pipette, look carefully to see how the scale is orientated. Some pipettes read from zero to full volume, whereas others start at full volume and read to zero. A volumetric pipette is used in the same manner as a graduated pipette except it has a single calibration mark and can only deliver a fixed volume.

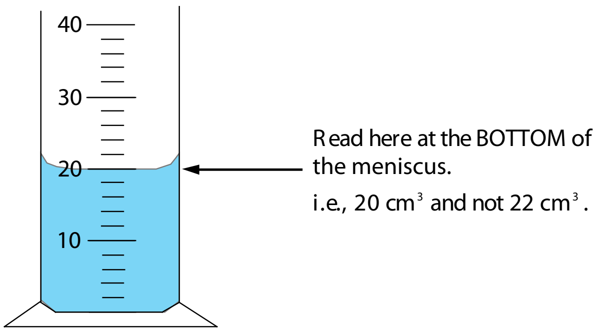


Figure 228 Illustration of the correct use of reading the volume of a liquid in a measuring cylinder

When reading the volume of water or an aqueous solution in a measuring cylinder or graduated pipette, you should look directly at the bottom of the meniscus (curved surface) and read the volume from this point (*Figure 228*). If a graduated pipette is being used to prepare a number of serial dilutions, from a stock solution, then it is important to use a clean pipette at each stage, to avoid any carry-over of liquids or solutions. These pieces of apparatus will come in a variety of sizes; ensure you choose the most appropriate size. For example, if you are to measure 5 cm^3 of solution then use a 10 cm^3 measuring cylinder, as opposed to a 25 cm^3 (or larger) measuring cylinder. This will improve the precision and accuracy of your volume measurement.

2.4.2 AVOIDING 'ACCIDENTS'

There will be a set of safety rules in your school laboratory. You will probably be required to write down the safety rules or paste a copy of them in your book or folder.

There may also be specific safety equipment (*Figures 229* and *230*) in your laboratory, for example, a fire blanket and an eye wash bottle. Never use these unless told to do so by your MYP Science teacher.

Make sure you know and apply these rules when you are performing practical work. If you do not follow the rules, then sooner or later an accident will occur. You and perhaps other students will be hurt and may need medical treatment.

If you do not follow all of the safety rules your MYP Science teacher will award low marks for this Criterion. More importantly, your teacher may also stop you from working on your investigation and ask you to leave the laboratory.

There are some safety rules that apply to all laboratories:

- Always use the lab coat, disposable gloves (*Figure 231*) (used for biohazards and harmful chemicals) or safety glasses (*Figure 232*) - if they are provided.
- Never touch chemicals with your skin.
- Never taste or eat anything in the laboratory.
- Never inhale (breathe in) chemicals.
- Never point a test tube with heated chemicals at anyone.

Most accidents in school laboratories are caused by students failing to follow one or more of the safety rules. It is the job of every MYP Science student to follow the safety rules in their laboratory.

Most of the accidents that occur in school science laboratories do not kill students or disable them. However, they must be dealt with correctly and quickly. The first thing to do, even if you or another student is not hurt, is to inform your MYP Science Teacher. They will have access to information about the required first aid. Many schools have a safety manual that tells Science teachers and Laboratory Technicians how to deal with spillages, accidental swallowing of chemicals and burns from specific chemicals etc.

Even the simplest breakage of laboratory glassware should be reported. A hot broken test tube with chemicals is a hazard that needs to be dealt with by your MYP Science teacher or technician. The mercury from a broken thermometer releases very harmful mercury vapour which must be dealt with by your MYP Science teacher or technician. They will add powdered sulfur to the mercury to prevent it evaporating. Under no circumstances are students to touch liquid mercury.

Figure 229 An eye wash bottle

Figure 230 A fire blanket

Figure 231 Disposable safety gloves

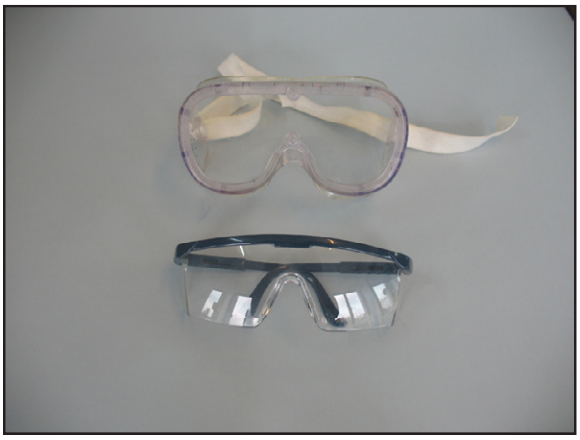


Figure 232 Safety glasses and goggles

2.4.3 DISPOSING OF CHEMICALS

During MYP investigations you will come across chemicals which need to be disposed of or 'recycled' by a particular method in the laboratory. The proper method will be printed on the MYP investigation sheet and told to you by your MYP Science teacher. For example, you may have excess marble chips from a rates of reaction investigation. Your MYP Science teacher may come round with a sieve and ask you to empty your flasks into the sieve while it is held over a sink. The majority of chemicals you will use can be disposed of easily by dilution with lots of water and disposal down the laboratory sink. Do not put insoluble solids down the sink, even if they are powders. Dilute acids and alkalis can be separately disposed of down the sink with running water.

The best way of dealing with the issue of safety in the laboratory is to make it a habit. By becoming used to working safely in the school laboratory, you will reach a stage when it is second nature. Doing so will free your attention for the other more difficult demands of the assessment, for example, recording accurate data.

During an MYP Science investigation involving chemicals ask yourself the following questions related to your working area

- Does it look organised?
- Do all the bottles have stoppers on them?
- Are any stoppers placed down on the bench?
- Is the Bunsen burner placed far enough away from chemicals or papers?
- Is the Bunsen flame adjusted appropriately for the task?
- Is the Bunsen burner hose likely to knock any chemicals or apparatus over?
- Are all liquids away from any electrical sockets?
- Have you labelled any samples of chemicals?
- Are there any spills of chemicals?
- Do you have a cloth or tissues to mop up spills?
- Are there any books or papers which may get wet if a solution or liquid is spilled?
- Is the floor in your area free from school bags?
- Are all your tubes and flasks labelled?

Hopefully, you are able to answer 'yes' to all of the questions, which are relevant to your laboratory. In addition to your physical surroundings, the other issue in working safely is your mental attitude. To work safely you need an attitude of confident respect. In other words, you need to be aware of potential dangers in different investigations. However, you should not be extreme in your attitude. Do not be fearful, but do not be complacent or arrogant either. Safety issues are important for all practical work. Consider them during the planning of your practical work and when you are carrying out your practical work. Continue following the safety rules while you are clearing and tidying up after practical work.

2.4.4 HANDLING CHEMICALS

You should regard all the chemicals you handle during an MYP Chemistry or Biology investigation to be hazardous. The most commonly used dangerous chemicals in Science are acids, halogens in solution and alkalis. All of these are corrosive and will damage skin and eyes. If you have an accident or spill an acid, halogen or alkali, then wash the chemical off with lots of running water and ask another MYP Science student to immediately report the accident to your MYP Science teacher.

Another group of dangerous chemicals are oxidising agents, such as potassium dichromate(VI), $K_2Cr_2O_7$, and potassium manganate(VII), $KMnO_4$. These substances may produce large amounts of heat as they react with other substances. They can create a fire risk. Your MYP Science teacher will warn if there are any potential hazards with chemicals made available for your investigation or for chemicals that you have requested for a planned investigation.

You must make careful note of any safety instructions your teacher gives you. Look for the safety symbols which may indicate you need to wear gloves and goggles. You must also read any practical instructions, noting any warnings given. You must also look at the labels on the reagent bottles. There are international symbols for chemical hazards and these are shown in *Figure 233*. More information can be found in the front section of this MYP Sciences Handbook. In the USA, due to concerns that the skull and bones symbol is associated with pirates and might encourage children to play with toxic materials, the '*Mr Yuk*' symbol (*Figure 234*) is also used to denote poison. Make sure you get information about chemicals before you start to use them. If you are using solutions, it is much easier to use the correct solution if you already have a mental image of Benedict's solution as the 'blue solution' and iodine solution as the 'brown solution'. Where possible use colours to distinguish between chemicals. If the chemicals are colourless or the same colour then make sure you label or mark them carefully.

These chemicals destroy living tissue, including the eyes and skin.

These substances may explode if ignited in air or exposed to heat. A sudden shock or friction may also start an explosion.

These are substances that may easily catch fire in a laboratory under normal conditions.

Figure 233 A selection of chemical hazard symbols

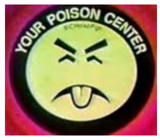


Figure 234 'Mr Yuk'

You must also ensure that all your glassware is cleaned with detergent to the best of your ability and that chemical residues are not left behind in glassware (*Figure 235*).

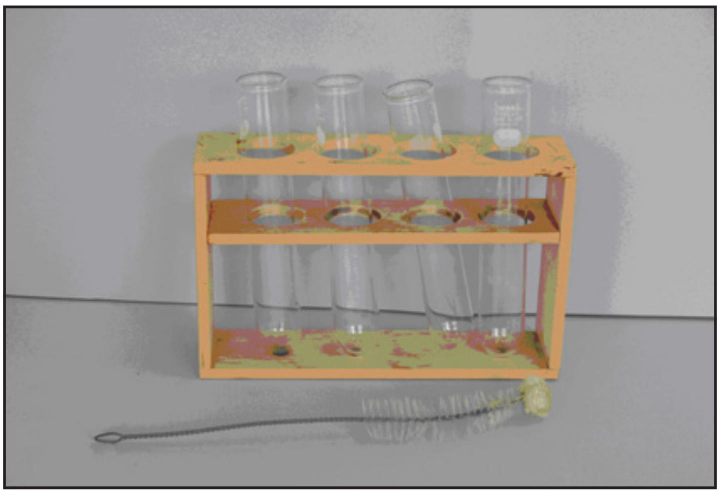
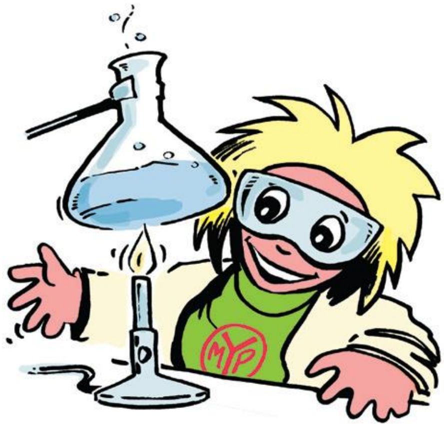


Figure 235 Test tubes in test tube holder with a brush

2.4.5 LABORATORY TECHNIQUES FOR CHEMISTRY

Observing gases

Many gases made in the laboratory are corrosive, e.g. hydrogen chloride, or poisonous, e.g. nitrogen dioxide and chlorine, or unpleasant, e.g. ammonia. When observing the odours (smells) of gases, the aim is not to breathe in (inhale) too much. Do not put your nose near the test tube or beaker, or you may end up with damaged nostrils or lungs. Put the test tube in front of your chest, and with your other hand, waft the gas towards your nose.



Heating liquids in a test tube

The test tube should be held with suitable test tube holders. To avoid liquids spurting out of the test tube, heat near the top of the liquid and heat gently by removing from the flame as soon as boiling begins, then heating and removing to maintain gentle boiling. Always point the mouth of the test tube away from yourself and others.

Heating a solution to dryness

When heating in an evaporating basin, heat as for liquids, until there is a only a thin layer of solution left, then heat more gently by removing the burner more often. As the solution starts to look 'sticky' or crystals form, remove from the heat even more.

Titrations

Here is a checklist for an MYP Chemistry investigation for a titration:

- Safety glasses worn at all times during the practical
- Careful handling of acid and alkali
- Burette filled at suitable height
- Apparatus not near the edge of your bench
- Beaker of acid labelled correctly
- Excess chemicals washed down the sink with running water
- Chemical spills reported and dealt with appropriately

However, it is not a good idea to guess what is on your teacher's checklist. It is much better to rely upon your own ability to carry out the investigation safely.

2.4.6 LABORATORY TECHNIQUES FOR BIOLOGY

Living organisms that you may work with during an MYP Science investigation include bacteria, yeast, vertebrates (for example, mice) invertebrates (for example, woodlice, earthworms, centipedes and millipedes) and plants. You might be studying these organisms in their natural habitat as part of some field work. Whenever you are working 'in the field' you must remember to cause as little change or disturbance as possible.

You may also work with fresh biological material in the laboratory. However, work with human blood, human saliva and cheek cells is not encouraged due to the risk of infection. You may also examine or dissect organs or tissues from animals like sheep or cows. Whenever you handle any biological material you must wear disposable gloves and wash your hands thoroughly afterwards with disinfectant and soap. Similarly, the bench you have been working on should be cleaned properly to prevent bacteria or viruses infecting other students.

Your MYP Science teacher may have a 'checklist' which details particular points that your teacher is watching for. You may score marks for each task you do properly.

2.4.7 LABORATORY TECHNIQUES FOR PHYSICS

Here are some specific suggestions for MYP Science Investigations involving Physics

Glass tubing

- Never attempt to push glass tubing (or glass thermometers) through a hole in the bung. Ask your MYP Science teacher or technician to do it for you – they will have a special tool for doing this.

Safe support

- When clamping a test tube, do not overtighten the clamp. Make sure the clamp has soft cork or plastic pads to touch the glass. This also applies when clamping a glass thermometer.
- In investigations where you have to suspend a load, make sure that the supporting clamp stand is stable enough to take the heaviest load you will be using. You may need to weigh it down.

Electricity

- Before making any changes to the wiring in your circuit, always switch off the power pack or disconnect the battery.
- Low voltage circuits may not give you an electrical shock, but they can cause burns if the current is too high and a wire overheats.
- *Never* make a direct connection across the terminals of a battery or power pack. Do *not* put wires or tools, for example, a screwdriver, across the terminals or electrodes.

Eye protection

- Always wear safety goggles when stretching metal wires or plastic cords or heating liquids.

Light

- Do not look directly into a laser beam or other source of bright light. Do not stand where the laser light could be reflected into your eyes. Never look at the sun directly through binoculars or a telescope.

Fire

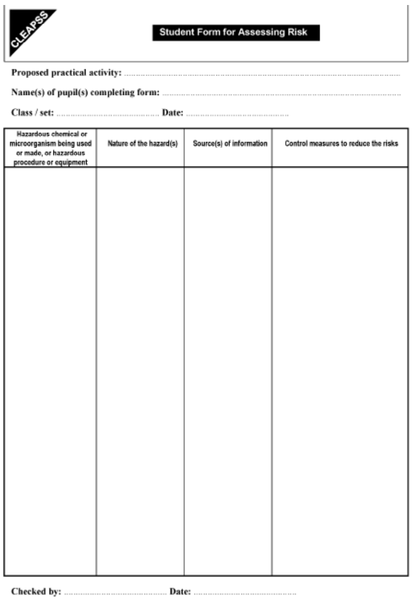
- Do not heat flammable liquids, for example, alcohol (ethanol) or methylated spirits (meths) directly over a Bunsen flame. A water bath should be used – a beaker filled with hot water from a kettle.

2.4.8 CHECKING SAFETY

Before you start any practical work that you have planned you must show your MYP Science teacher your detailed method. He or she will need to approve your plan and ensure that is safe. One of the best ways is to carry out a Risk Assessment. For an MYP Chemistry investigation, a Risk Assessment (*Figure 236*) identifies all the hazards associated with the chemicals you will be using, and those that you might prepare, and looks for ways to reduce the risks from them, by giving the safety precautions that need to be taken.

The Stages in carrying out a Risk Assessment for an MYP Chemistry Investigation

- Write down the chemicals and procedures you will be using (chemicals used or made, quantities, concentrations (if solutions), techniques and non-chemical hazards).
- Use reference sources to identify any hazardous chemicals you are planning to use or make. Warning symbols will be printed on reagent bottles and in suppliers' catalogues.
- Record the type of hazards involved and the way you might be exposed to the hazard. There are standard reference sources with this information, such as the 'Hazcards' (*Figure 237*) published in the United Kingdom by CLEAPSS. In North America MSDS (Material Safety Data Sheets) sheets should be read (*Figure 238*). You should not trust much of the information on the Internet.
- Decide what protective or control measures to take so that you can carry out your practical work healthily and in safety.
- Find out how to dispose safely of any hazardous residues from your practical work.
- Check your plans with your MYP Science Teacher before starting any practical work.


CLEAPSS

Student Form for Assessing Risk

Proposed practical activity: ...

Name(s) of pupil(s) completing form: ...

Class / set: ... Date: ...

Hazardous chemical or microorganism being used or made, or hazardous procedure or equipment	Nature of the hazard(s)	Source(s) of information	Control measures to reduce the risks

Checked by: ... Date: ...

Figure 236 CLEAPPS (©) Risk assessment form

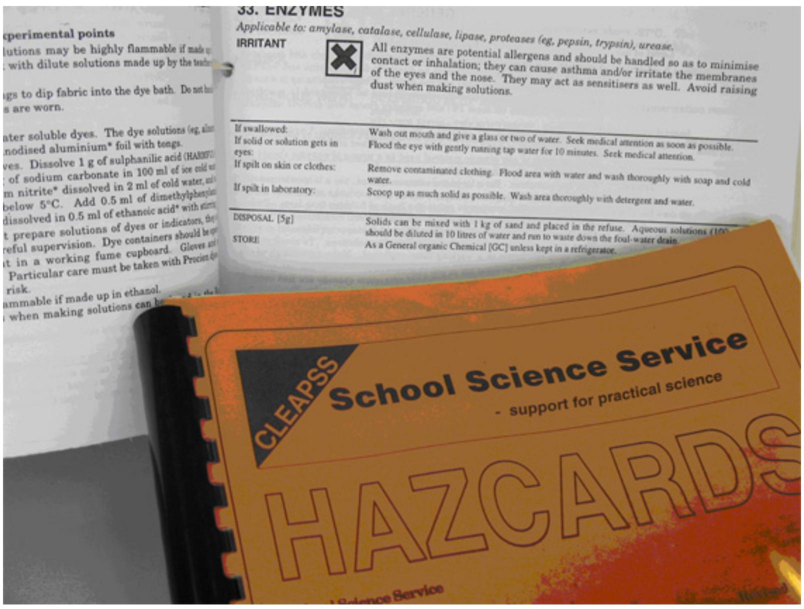


Figure 237 CLEAPSS Hazcards

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD:
Slight fire hazard when exposed to heat or flame.
Dust/air mixtures may be explosive above the flash point.
Vapour from molten benzoic acid may form an explosive mixture with air.

FIREFIGHTING MEDIA:
Dry chemical, carbon dioxide, water spray or regular foam

TOXICITY

CARCINOGEN STATUS: None.
LOCAL EFFECTS: Irritant- eye.
ACUTE TOXICITY LEVEL: Moderately toxic by ingestion.
TARGET EFFECTS: Poisoning may affect the respiratory and central nervous system.

HEALTH EFFECTS AND FIRST AID

INHALATION:
ACUTE EXPOSURE- Dust may cause mild respiratory irritation with sore throat and coughing.
CHRONIC EXPOSURE- No data available.

FIRST AID- Remove from exposure area to fresh air immediately. If breathing has stopped, perform artificial respiration. Keep person warm and at rest.
Treat symptomatically and supportively. Get medical attention immediately.
(Copyright Environmental Health & Safety, United States)

Figure 238 Selected parts of an MSDS on benzoic acid

An example of an MYP Science Investigation Risk Assessment form is shown in *Figure 239*.

<table>
<tr><td colspan="4">Title of the MYP Science Investigation
____</td></tr>
<tr><td colspan="4">Outline of the procedures
1.
2.
3.
4.</td></tr>
<tr><td>Hazardous substances being used or made</td><td>Nature of the hazards (e.g. highly flammable, toxic)</td><td>Quantities and concentrations being used or made</td><td>Safety measures (precautions)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Any non-chemical hazards and precautions to be taken</td><td>Signed (student)
....
Signed (MYP Science Teacher)
.....................................</td></tr>
<tr><td colspan="3">Disposal of residues</td><td>Date:
.....................................</td></tr>
</table>

Figure 239 Risk assessment form

2.4.9 WORKING WITH LIVING THINGS

Ethics

If you are designing an MYP Biology investigation that requires the use of living organisms, then you must consider whether it is necessary to use living organisms. If you do have to use them, then you must ensure that the treatment they receive is ethically and morally acceptable.

If you are carrying out an ecological investigation, then you must consider the effect your investigation could have on the environment. Does it disturb the animals? Will you have to trample on fragile or delicate plants in order to take your measurements? Are there any long term effects of taking samples repeatedly from an area? It is also very important to consider the laws of the country your school is located in. For example, the Republic of Singapore is very strict about any interference with the local animals and plants on the island. You must ask your MYP Science teacher about local laws and acts of parliament in the country where your school is located.

Plants

Whole plants should not be picked or uprooted from their natural environment. If your plan requires the use of leafy stems and flowers, you should make sure that they are obtained from gardens or from commercial sources or have been bred for the purpose. Great care must be taken that plants are not trampled or damaged during the sampling process. *Figure 240 (a)* shows a commercially bought plant (petunia) with variegated leaves which is ideal for photosynthesis experiments.

Figure 240 (a) A commercially bought plant

Animals

No experiments should be carried out which may cause harm or suffering to animals. In no circumstances should animals be subjected to such extreme conditions that they are killed. It is not acceptable to carry out experiments that measure the amount of force or heat needed to knock off limpets or other molluscs from rocks on a beach.

Any animal removed from its environment for the purpose of counting or measurement should be returned as soon as possible. Particular care should be taken when sampling invertebrates found in rivers, ponds and on beaches. Some investigations may involve the use of 'mark/recapture' sampling. Before this is carried out, think about the effects upon individuals and populations of the organism. Some ecological investigations may involve the use of pitfall traps. These traps should be checked several times daily to ensure animals are not trapped for long periods of time. The animals should be given protection from the weather and also food and water. Experiments involving live vertebrates, for example, mice, cats and rats, are not recommended. *See Figure 240 (b).*

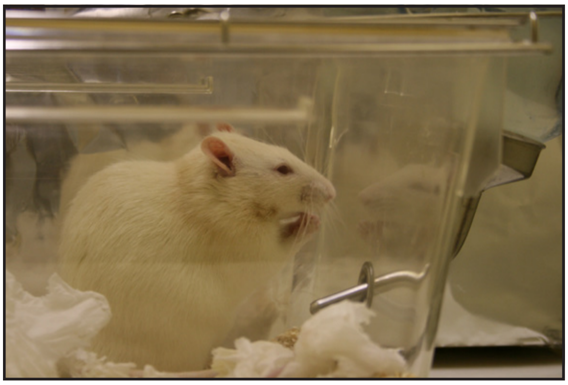


Figure 240 (b) A laboratory rat

(from https://upload.wikimedia.org/wikipedia/commons/f/f2/Rat_eating.jpg)

Humans

Some investigations may be carried out where the subject is one of the students in the school. You cannot carry out investigations where students are given cigarettes or alcohol or anything else harmful. All students should give their consent to any activities before they are undertaken. It is also a good idea to obtain written parental permission after your MYP Science teacher has approved your Investigation.

When carrying out investigations into fitness and heart rate, you will need to make sure that the subject is fit and healthy and does not have any medical problems such as asthma, which could put them at risk. In addition, think carefully before any investigations are carried out where the other students may make comments. This includes exercise experiments, reaction times, memory tests and testing for various genetic phenotypes.

Some investigations compare different age groups. Again, you must take great care to make sure that none of the subjects may be upset by the results of the investigation, for example, slow reaction times or reduced memory in older people. Any investigation that requires subjects to fill in a questionnaire must ensure that none of the questions are of a personal nature and that there is always an option not to answer any or all of the questions.

OBJECTIVES

Students should be able to:

1. correctly collect, organize, transform and present data in numerical and/or visual forms
2. accurately interpret data and explain results using correct scientific reasoning
3. evaluate the validity of a hypothesis based on the outcome of a scientific investigation
4. evaluate the validity of the method based on the outcome of a scientific investigation
5. explain improvements or extensions to the method that would benefit the scientific investigation.

Level	Descriptor
0	The student does not reach a standard identified by any of the descriptors below.
1-2	The student is able to: i. **collect and present** data in numerical and/or visual forms ii. **interpret** data iii. **state** the validity of a hypothes is based on the outcome of a scientific investigation iv. **state** the validity of the method based on the outcome of a scientific investigation v. **state** improvements or extensions to the method.
3-4	The student is able to: i. **correctly collect and present** data in numerical and/or visual forms ii. **accurately interpret** data and **explain** results iii. **outline** the validity of a hypothesis based on the outcome of a scientific investigation iv. **outline** the validity of the method based on the outcome of a scientific investigation v. **outline** improvements or extensions to the method that wou ld benefit the scientific investigation.
5-6	The student is able to: i. **correctly collect, organize and present** data in numerical and/or visual forms ii. **accurately interpret** data and **explain** results **using scientific reasoning** iii. **discuss** the validity of a hypothesis based on the outcome of a scientific investigation iv. **discuss** the validity of the method based on the outcome of a scientific investigation v. **describe** improvements or extensions to the method that would benefit the scientific investigation.
7-8	The student is able to: i. **correctly collect, organize, transform and present** data in numerical and/or visual forms ii. **accurately interpret** data and **explain** results **using correct scientific reasoning** iii. **evaluate** the validity of a hypothesis based on the outcome of a scientific investigation iv. **evaluate** the validity of the method based on the outcome of a scientific investigation v. **explain** improvements or extensions to the method that would benefit the scientific investigation. ©IBO 2014

SECTION 3.1 COLLECTING AND PRESENTING DATA

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2	**collect and present** data in numerical and/or visual forms
3-4	**correctly collect and present** data in numerical and/or visual forms
5-6	**correctly collect, organize and present** data in numerical and/or visual forms
7-8	**correctly collect, organize, transform and present** data in numerical and/or visual forms

Introduction

Processing refers to students organizing, processing and interpreting quantitative and qualitative data. Evaluating refers to students assessing the implications and limitations of their experimental method and explaining improvements or extensions that would benefit their scientific investigation. Suitable assessment tasks for criterion C include scientific investigations carried out by students, as well as laboratory reports and studies that provide students with sufficient raw data for processing and further analysis.

Key Terms

Data: measurement of a parameter that can be quantitative (volume, temperature, pH etc) or qualitative (colour, shape, texture etc).

Extensions to the method: developments for further inquiry as related to the outcome of the investigation.

Numerical forms: may include mathematical calculations, such as averaging, or determining values from a graph or table.

Qualitative data: refers to non-numerical data or information that it is difficult to measure in a numerical way.

Quantitative data: refers to numerical measurements of the variables associated with the investigation.

Transforming data: involves processing raw data into a form suitable for visual representation. This process may involve, for example, combining and manipulating raw data to determine the value of a physical quantity (by adding, subtracting, squaring or dividing), and taking the average of several measurements. It might be that the data collected is already in a form suitable for visual representation, for example, distance travelled by a woodlouse. If the raw data is represented in this way and a best-fit line graph is drawn, the raw data has been processed.

Suitable format: may include tables with appropriate headings and units, large, clearly labelled diagrams or concisely worded observations.

Visual forms: may include drawing graphs of various types appropriate to the kind of data being displayed (line graphs, bar graphs, histograms, pie charts, and so on).

3.1.1 COLLECTING AND RECORDING DATA

The first step in the scientific method is observation: what you see, hear, feel or smell. Initially, this raw data may just be collected. A famous example of a scientist who collected large amounts of raw data was the naturalist Charles Darwin who travelled to many parts of South America collecting fossils and many specimens of different plants and animals. Later, back in England, Darwin recorded the data in published books and papers and interpreted the data to develop his theory of evolution by natural selection.

Scientists often enhance or extend their senses by using instruments, for example, the microscope and the telescope.

Simple observations are very important in science and often stimulate the development of a hypothesis (see **Chapter 2, Criterion B**). For example, noticing that shrimp populations vary in a stream may lead to a search for a hypothesis as to why that it is the case, and an investigation to test that hypothesis. Observation is one of the key links between the 'real world' and the abstract ideas of science.

Recording raw data

Raw data is the actual data you measure and may include qualitative and quantitative data. It is acceptable for you to convert handwritten raw data into word-processed form. The term quantitative data refers to numerical measurements of the variables associated with your investigation. Qualitative data refers to things that you see, hear, smell or feel (general observations).

The accurate and careful recording of observations is an important part of MYP Science coursework. Simple observations are often the starting point for more detailed quantitative investigations.

When doing an MYP Science investigation involving chemicals, record the following with as much detail as possible:

- **Colour changes** – record initial and final colours. There may also be colour changes during the reaction – these should be recorded. If a solution loses its colour, then state that the solution was decolourised, rather than 'it went clear'. Never describe a solution as white, it will either contain a precipitate (the substance is insoluble) or suspension (the substance is slightly soluble and has particles floating in solution). Emulsions, such as milk and emulsion paint, may also be white.
- **Changes of state or form**, for example, melting, freezing, condensation, boiling and sublimation, change in crystal size or hardness.
- **Production of a gas** – odour, smell, colour and intensity. For example, chlorine gas, prepared in a fume cupboard, at high concentrations is pale green. It has a 'bleachy' smell.
- **Formation of a precipitate**. For example, describing the colour of a precipitate as pale yellow is better than just yellow.
- **Temperature** changes associated with exothermic and endothermic reactions.
- **Crackling noises** (known as decrepitation) when substances are heated and undergo decomposition.

Do not overlook any change taking place and do not forget to record it. It is possible to slowly and carefully add solutions to a test tube in such a manner that layers will form. Reaction will only occur at the boundaries giving a banded appearance. Remember to mix your reagents thoroughly before describing your observations. This can be achieved by gently tapping the tube against a finger, gently shaking the tube from side to side or stirring the mixture with a clean glass rod.

Be careful when assessing the colour of a precipitate: a white solid at the bottom of a test tube or boiling tube containing highly coloured solution often looks coloured.

Here is an example of the observations recorded by an MYP Science student when she heated hydrated cobalt(II) chloride crystals, $CoCl_2.6H_2O$ and then added water to the cooled residue. It will give you a clear idea of the detail required when making observations. *Figure 301* shows pink hydrated cobalt(II) chloride crystals (on the left) and blue anhydrous cobalt(II) chloride crystals (on the right).

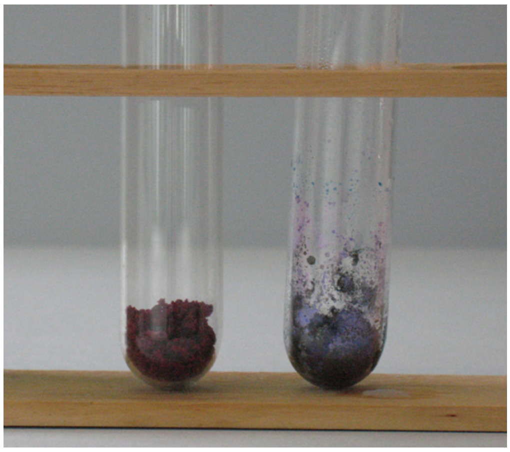


Figure 301 Cobalt(II) chloride crystals

The pink crystals turned to a dark blue liquid which boiled and a colourless and odourless liquid condensed on the top of the test tube. A pale blue powder remained. When the water was added, a hissing sound was heard, the temperature rose and steam was seen leaving the mouth of the test tube. The colour of the residue became dark blue and then pink and finally the residue dissolved forming a pink solution.

3.1.2 UNITS

Measurement	Unit name	Symbol of unit
Length	**metre**	**m**
	millimetre	mm
	centimetre	cm
Mass	**kilogram**	**kg**
	gram	g
Time	**second**	**s**
	minute	min
	hour	h
Amount of substance	**mole**	**mol**
Temperature	**kelvin**	**K**
Energy	**joule**	**J**
Current	**ampere**	**A**

Figure 302 Selected SI base units

Scientists generally use SI units when recording raw data. You need to be familiar with the base units (shown in bold in *Figure 302*), some of the derived units (*Figure 303*) and common prefixes (*Figure 304*). Note that the term 'per' means 'divided by' or 'for every'.

Measurement	Unit name	Symbol of unit
Area	square centimetre	cm^2
	square metre	m^3
Volume	cubic metre	m^3
	cubic decimetre	dm^3
Pressure	pascal (newton per square metre)	Pa (N/m^2)
Density	kilogram per cubic metre	kg/m^3 or $kg\ m^{-3}$
Molar concentration	mole per decimetre cubed	mol/dm^3 or mol/dm^{-3}

Figure 303 Selected derived units

Measurement	Unit name	Symbol of unit
Potential difference (voltage)	volt	V
Frequency	reciprocal second (hertz)	1/s or s^{-1}(Hz)
Heat capacity	joule per kelvin	J/K or J K^{-1}
Specific heat capacity	joule per kilogram per kelvin	J/kg/K or J kg^{-1} K^{-1}
Velocity	metre per second	m/s or m s^{-1}
Acceleration	metre per second per second	m/s/s or m/s^2 or m s^{-2}

Figure 303 Selected derived units (cont.)

Conversion Of Units

The outcome of calculations may depend upon using the correct units for quantities involved in the calculation. This often means that a quantity specified in one unit may need to be converted to a different unit.

Consider a length, 2.7 metres. It can be written as follows:

$2.7\text{ m} = 2.7 \times 1\text{ m}$

This expression is showing a pure number, 2.7, multiplied by a length of 1 m. If you wanted to convert this into centimetres, then simply insert 100 cm in the place of 1 m:

$2.7\text{ m} = 2.7 \times 100\text{ cm} = 270\text{ cm}$

To convert an area of 2.6 m^2 to cm^2

$2.6\text{ m}^2 = 2.6 \times 1\text{ m} \times 1\text{ m}$ or $2.6 \times (1\text{ m})^2$

Again, inserting 100 cm in the place of 1 m gives:

$2.6\text{ m}^2 = 2.6 \times 100\text{ cm} \times 100\text{ cm} = 2.6 \times 10^4\text{ cm}^2$

EXERCISE 3.1

Convert a density of 8.8 g/cm^3 to kg/m^3. Show your working.

Note that 1 m^2 is 10 000 cm^2 not 100 cm^2 and that 1 m^3 is 1 000 000 cm^3, not 100 cm^3.

SI factors

Sometimes it will be easier for you to use multiples or sub-multiples of the base unit if the figures are very large or small (*Figure 304*).

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10^3	kilo	k
10^{-3}	milli	m	10^6	mega	M
10^{-6}	micro	µ	10^9	giga	G
10^{-9}	nano	n	10^{12}	tera	T

Figure 304 SI factors

Rules for units

- Symbols do not have a full stop unless at the end of a sentence.

For example, 2.5 g of ethanol was measured into a beaker.

- The symbols are not written in plural.

For example, 25 kg, but not 25 kgs.

- A space separates the number and the unit.

For example, 55 g and not 55g.

- Capital units are not used for symbols unless the unit is named after a person. For example, the newton, N, is named after Sir Isaac Newton. The name of the unit is written in lower case, but the symbol is upper case.

For example, 5 N and 5 newtons

ADDITIONAL COMMENTS AND GUIDANCE

Mass and weight

It is important to distinguish between mass and weight: mass is a measure of the quantity of matter present, whereas the weight of an object is the force (the 'push') it exerts on a supporting object. This force is generated by the Earth's gravitational field. Mass is measured in kilograms (kg) and weight is measured in newtons (N).

Volume

Volume is derived from length and in the SI system is expressed in cubic metres, m^3. However, the usual unit is the cubic decimetre (1 dm^3), which is commonly termed a litre (symbol L). There are 1000 dm^3 in one cubic metre (1 m^3). Each decimetre can be divided into 1000 cubic centimetres (cm^3).

Note that mL is widely used in the United States and can be regarded (to a good approximation) as interchangeable with cm^3, but it is not an SI unit and cubic centimetres should be used instead.

Length

Strictly speaking, all measurements of length should be expressed in metres but often such measurements are expressed in centimetres (cm) and millimetres (mm), where 100 cm = 1 m and 1000 mm = 1 m.

Mass

Strictly speaking, all masses should be expressed in kilograms, but often such measurements are expressed in grams or milligrams, where 1 kg = 1000 g; 1 g = 1000 mg.

Temperature

Strictly speaking, all temperatures recorded during investigations should be expressed as thermodynamic or absolute temperatures in kelvin but temperatures are usually expressed in degrees celsius. Temperatures only need to be expressed in kelvin if calculations are being performed with the gas laws.

EXERCISE 3.2

1. Convert the following figures to the correct SI units.
   (a) A temperature of 25 degrees celsius.
   (b) A temperature of 298 kelvin.
   (c) The volume of a cubical box with all dimensions 3.0 cm.
   (d) A gas pressure equivalent to 10 N m^{-2}.
2. Correct the following, showing your answers as SI units;
   (a) The energy of a dried peanut is 500 J per gm.
   (b) The density of the liquid is 2 Kilogram per cubic metre.
   (c) The solution contained 0.5 Moles/Litre of sucrose.

3.1.3 TABLES

Tables are an excellent way of recording the raw data or results of an MYP Science investigation. You should design your table(s) before you start your MYP Science investigation.

Outlined below are some 'rules' for constructing good tables of data.

- The units are written in the column heading – they should not be written alongside the numerical value.
- Units should not be mixed.
- The numbers are presented in decimal form – they should not be presented as fractions.
- A consistent number of significant figures should be used to record data.
- The independent variable(s) of the raw data is/are always recorded in the left hand column of the results table.
- The dependent variable of the raw data is always recorded in the right hand column of the results table.
- Processed data are always displayed on the right hand side of the results table. Processing may involve displaying the average or mean, square (x^2), square root ($\sqrt{x}$) or reciprocal ($1/x$ or x^{-1}) of a dependent variable x. Squaring or square rooting data often allows a linear graph to be plotted.
- There is a simple informative title for the results table.

Shown are three examples of incorrect data tables, with comments, from MYP Chemistry, Biology and Physics investigations.

CHEMISTRY

Time for metal to finish reacting with acid/ sec	Metal
220	Zn
55	Mg
30	Ca
350	Fe

Figure 305 A data table recording the reactions between selected metals and 2 mol dm^{-3} hydrochloric acid

Refer to Figure 305. The times should be located in the right hand column since time is the dependent variable. The data about the metals should be located on the left hand side of the table since it is an independent variable. It is best to write the name of the metal: zinc, magnesium, calcium and iron. Chemical symbols should be used in chemical equations, but not by themselves in data tables. The abbreviation for seconds is 's' not 'sec'.

BIOLOGY

Temperature	Rate of evaporation of water/ mg cm^{-2} h^{-1}	
	Centipedes	Millipedes
15	5.00	0
25	7.5	0.5
35	10	2.0
45	14.5	3.5
55	20.0	13.5

Figure 306 A data table recording the loss of water from myriapods

Refer to Figure 306. The temperature column does not have units. It is obviously celsius (°C) and not kelvin, which is only used in gas law calculations. Presumably, the rate of evaporation is measured using the same apparatus. Therefore all data should be expressed to the same number of decimal places, presumably two.

PHYSICS

Number of paper clips picked up	Electromagnet
6	30 turns of wire
15.5	45 turns of wire
33	60 turns of wire
59	75 turns of wire

Figure 307 A data table recording the number of paper clips picked up by a simple electromagnet

Refer to Figure 307. The number of paper clips should be located in the right hand column since it is the dependent variable. The data about the number of turns should be on the left since it is an independent variable. The 15.5 suggests that the data value is an average number. If average data is to be calculated and displayed then the raw data should be included in a new column located on the far left of the table. 'Turns of wire' should be written once as a table heading.

SECTION 3.2 INTERPRETING DATA AND OUTLINING RESULTS

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **interpret** data

3-4 **accurately interpret** data and **explain** results

5-6 **accurately interpret** data and **explain** results **using scientific reasoning**

7-8 **accurately interpret** data and **explain** results **using correct scientific reasoning**

3.2.1 PROCESSING DATA

Calculations

Use the following approach when carrying out calculations on your raw data.

- Write out each line of a calculation in full, making sure that it is clear where each number has come from.
- Write down any formula or equation you use in words and then substitute numbers into the formula or equation on the next line.

For example

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density} = \frac{10.0\ \text{g}}{10.0\ \text{cm}^3} = 1.0\ \text{g cm}^{-3}$$

- If you are using symbols then define any symbols that you use.

For example

$T = 2\pi\sqrt{\frac{L}{g}}$, *where T represents the period of a swing of a simple pendulum, L represents the length of the pendulum and g represents the gravitational field constant.*

When you are using a calculator check the answers it gives to ensure that they are sensible.

For example

If you multiply 2.1 by 39.6 and get an answer of 831.6, then look closely. Your answer should be roughly the same as 2 × 40 which is 80. You have pressed a wrong button on the calculator. The correct answer is 83.16.

- Make sure you have expressed your final answer with an appropriate number of significant figures.
- You can work out the units from calculations if you write them into every line and do the correct arithmetic on them. A slanting line can also be used to mean 'per'.

For example

the units of acceleration are m/s/s or m/s^2.

Ratios

Making dilutions

You may carry out some MYP investigations, for example, involving osmosis, where you must first make dilutions of a solution. Consider a 1 molar (mol/dm^3) solution of glucose. This is prepared by adding distilled water to 1 mole of glucose (180 g) to make 1000 cm^3 of solution.

To make a 0.5 M or 50% solution then a 1:1 mixture of water and glucose solution needs to be prepared. In the same way, you could easily make 20 cm^3 of 30% or 70% solutions by diluting in the correct ratio (*Figure 308*).

Concentration of glucose, mol / dm^3	Volume of water added / cm^3	Vol. of 1 mol/ dm^3 glucose soln. added / cm^3	Ratio of glucose solution to water (by volume)
0.30	14	6	1:2.3
0.35	13	7	1:1.9
0.40	12	8	1:1.5
0.45	11	9	1:1.2
0.50	10	10	1:1
0.60	8	12	1.5:1

Figure 308 Preparation of different glucose concentrations from a 1.00 mol dm^{-3} solution

Chromatography

You may carry out an investigation to separate leaf pigments or pen inks using simple paper chromatography. This is where a solvent, or solvent mixture, carries substances different distances along a sheet of chromatography or filter paper. You can calculate a retention factor (R_f value) for each spot observed on the chromatogram (*Figure 309*). The retention factor is the distance travelled by the chemical divided by the distance travelled by the solvent.

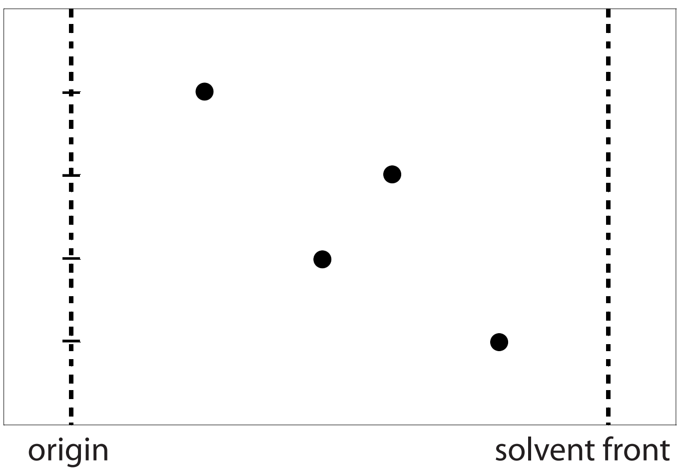


Figure 309 Chromatographic separation of pigments (R_f values: 0.25, 0.47, 0.60 and 0.90)

3.2.2 GRAPHS

Graphs can be used to either display data from your investigation, or to interpret and derive further information from it. There are many different types of graphs that you might need to use for an MYP Science investigation:

- Scatter graphs
- Bar charts
- Pie charts
- Line graphs

It is important to know when to use the appropriate type of graph.

Line graphs

Line graphs are drawn when the data is continuous and there is a known relationship between the two variables.

Remember the following rules when plotting graphs:

- The independent variable is plotted along the horizontal (x) axis; the dependent variable is plotted up the vertical (y) axis.
- Give the graph a suitable title.
- Choose a scale which makes full use of the graph paper. A useful rule is that if you can double the scale (either along the x or y axis) and still fit all the points on the paper, you should do so.
- Choose a convenient scale, for example, 1 cm = 1 unit, 2 units, 5 units or 10 units.
- Label each axis and include units. The quantity and units should be separated by a solidus (/).
- The points should be joined up with a straight line (line of best fit) or a smooth curve (curve of best fit). You will not get perfect straight lines or smooth curves because of errors that are always present in your results.

Bar graphs

A bar graph is used for plotting means or percentages for different values of a categoric variable, where the variable is classified into categories. Usually, the mean or percentage is on the y-axis, and the different values of the categoric variable are on the x-axis, yielding vertical bars. Bar graphs are most likely to be needed to present data from an MYP Biology Investigation.

Drawing bar graphs with *Excel*

Enter the values of the independent variable (the categoric variable) in one column, with the dependent (measured) variable in the column to its *right*. The first column will be used to label the bars or clusters of bars (*Figure 310*).

Type of bird species	Number of bird species
Bombay Hook	125
Cape Henlopen	136
Middletown	105
Milford	115
Rehoboth	134
Seaford-Nanticoke	95
Wilmington	98

Figure 310 Raw data for the generation of a bar graph with one independent variable

Select all cells that have data in them, including the first column with the categoric data. From the "Insert" menu, choose "Chart". Choose "Column" as your chart type, and the picture of bars next to each other (not on top of each other) as the "Chart sub-type." The next screen shows the 'Data range', the cells that contain your data; you should not need to change anything here.

On the "Titles" tab of the "Chart Options" screen, enter titles for the *x*-axis and *y*-axis, including the units for the *y*-axis. A chart title is essential for a graph used in an MYP Science report. Because each bar or cluster of bars will be labelled on the *x*-axis, you may not need an *x*-axis title.

On the "Gridlines" tab of the "Chart Options" screen, you can remove the gridlines; they are not necessary. On the "Legend" tab of the "Chart Options" screen, remove the legend if you only have one set of *y* values. If you have more than one set of *y* values, remove the legend if you are going to explain the different bar patterns in the title; leave the legend on if you think that is the most effective way to explain the bar patterns (*Figure 311*).

A multiple bar graph depicting data using two independent variables (*Figure 312*) is created in the same way as a simple bar graph.

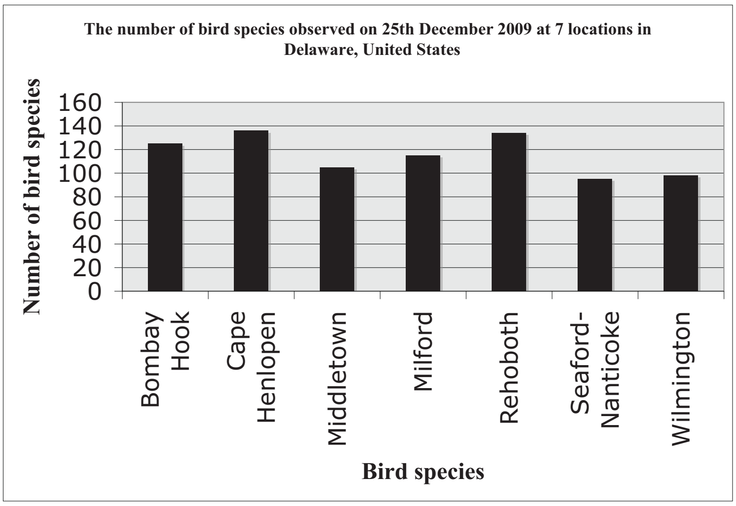


Figure 311 An Excel generated bar graph with one independent variable

Mammal	Count	
	Week 1	Week 2
Bear	45	34
Arctic fox	240	187
Timber wolf	88	92
Mink	134	154

Figure 312 Raw data for the generation of a bar graph with two independent variables

Some points to note when creating this multiple bar graph *(Figure 313)*

- The first independent variable, (Mammal) is still in the first column, with the dependent variable values (Count) in columns two and three. The second and third columns represent dependent variable values at two different levels of the second independent variable, (Week).
- Make sure to select all of the data when creating the graph. The Chart wizard will automatically recognise that you have a second independent variable.
- When you get to the last step of the Chart Wizard, keep the legend turned on, since it shows the coding for the two levels of the second independent variable (*Figure 313*).

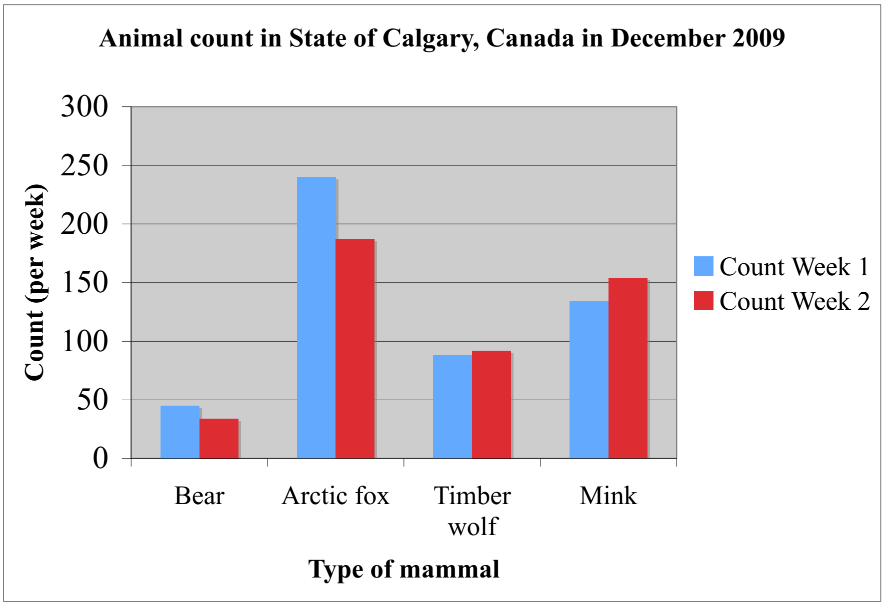


Figure 313 An Excel generated bar graph with two independent variables

Histograms

Histograms are used to represent continuous data (*Figure 314*). The bars represent ranges within which your data points fall.

The Data Analysis 'Toolpak' must be installed. To do this, pull down the 'Tools' menu, and choose 'Add-Ins'.

You need to have a column of numbers in the spreadsheet that you wish to create the histogram from, and you need to have a column of intervals or "Bin" to be the upper boundary category labels on the x-axis of the histogram.

Tree number	Height of tree/m	Bin
1	65	56
2	70	58
3	65	60
4	73	62
5	68	64
6	59	66
7	63	68
8	67	70
9	65	72
10	63	74
11	64	
12	71	
13	59	
14	61	
15	70	
16	68	
17	66	
18	65	
19	69	
20	71	
21	67	
22	64	
23	63	
24	70	
25	61	

Figure 314 Raw data for the generation of a histogram

Pull down the 'Tools' menu and choose 'Data Analysis', and then choose 'Histogram' and click OK. Enter the 'Input Range' of the data you want and then enter the 'Bin Range'. Choose whether you want the output (*Figure 315*) in a new worksheet, or in a defined output range on the same spreadsheet.

The next step is to make a histogram (*Figure 316*) of the Frequency column. Block the frequency range, click on the graph Wizard, and choose Column Graph, click on Finish. Delete the Series legend, right click on the edge of the graph and choose Source Data, and enter the Bin frequencies for the x-axis Category labels. Right click on any of the bars and choose Format Data Series. Choose the Options tab, reduce the Gap Width to zero and click OK. This turns the bar chart into a histogram.

Bin	Frequency
56	0
58	0
60	2
62	2
64	5
66	5
68	4
70	4
72	2
74	1
More	0

Figure 315 Data output

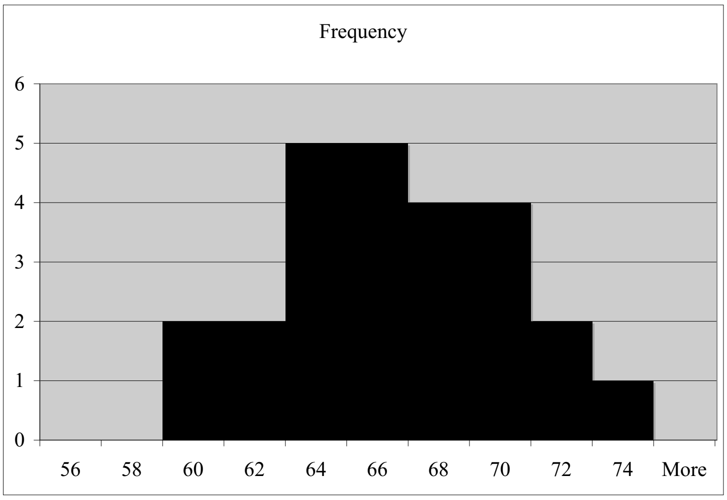


Figure 316 An Excel generated histogram

Pie charts

Pie charts are used when dealing with data which is in the form of percentages (*Figure 318*). It is usual practice to put the data in a pie chart into ascending or descending order, so that each slice of the pie chart is bigger or smaller than the previous one as you go clockwise round the pie chart. The data for a pie chart can be entered into *Excel* either vertically or horizontally. For example, you could use the first two rows or first two columns. The amount of water vapour has been ignored.

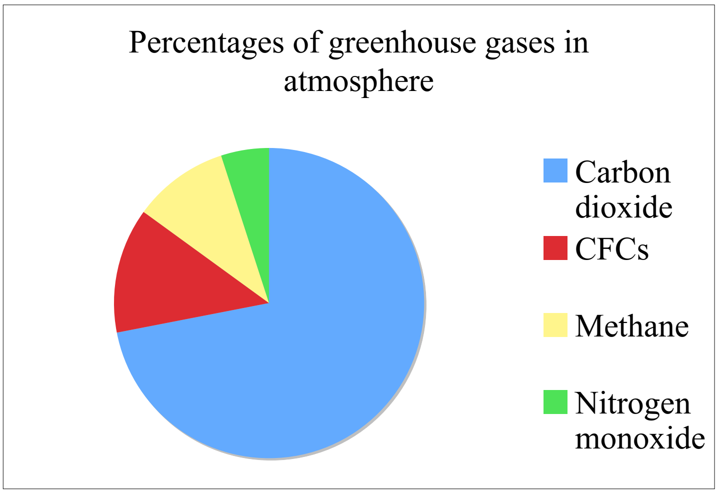


Figure 317 An Excel generated pie chart

Gas	Carbon dioxide	CFCs	Methane	Nitrogen monoxide
Percentage	72	13	10	5

Figure 318 Raw data for a pie chart

To draw a pie chart in *Excel* highlight the data, then click on the Chart Wizard and select Pie from the list shown in Standard Types. Now select the first of the six choices shown. Lastly, click Next to display your graph (*Figure 317*). You can now add a Title and other information as required.

Embedding Excel tables and graphs into a Word document

Open your *Excel* file, select the table and graph and click on Control C or Edit/Copy. Now open your Word document and when you come to the space where you want to add your Excel document.

Press 'Control/V' or 'Edit/Paste'. To save, click on 'File' and then click on 'Save'.

3.2.3 ARITHMETIC WITH UNITS

- During addition and subtraction the units do not change.

For example: 20 kg + 30 kg = 50 kg; 512 m – 10 m = 502 m

- The units must be identical before adding or subtracting is done.

For example: 4.001 kg + 112 g = 4.001 kg + 0.112 kg = 4.113 kg

- During multiplication and division the units multiply and divide too.

For example: $4\ m \times 4\ m = 16\ m^2$; $1\ kg \times 9.8\ m/s^2 = 9.8\ kg\ m/s^2$

- Units may also cancel.

For example: $\frac{5\ g}{10\ g} = 0.5$

3.2.4 SIGNIFICANT FIGURES

A knowledge of significant figures is not formally assessed by the MYP Assessment Criteria. A detailed knowledge of significant figures is required by the IB Diploma Programme Group 4 subjects. However, the use of significant figures will allow you to record your data to the correct precision and to present final answers.

Compare the following data

- An *Elodea* plant takes 20 minutes to release 4 cm^3 of oxygen-enriched air.
- A cart takes 10.29 seconds to cover 5.000 metres.

The cart's data has been measured more precisely than that of the plant. This is indicated by the greater number of significant figures in the second set of data.

Which figures are significant?

A significant figure is an integer (whole number) or a zero that follows an integer.

- The volume '4 cubic centimetres' has one significant figure.
- The time '21 minutes' has two significant figures.
- 10.29 seconds and 5.000 metres both have four significant figures.

A zero that comes before any integer, however, is not significant. For example

- the value 0.0009 g has only one significant figure, whereas the value 0.0900 g has three significant figures. The zeros that come before the integer 9 are not significant, whereas those that follow the integer are significant.

Using significant figures

You will often need to calculate a value from a set of data obtained during your MYP investigation. It is important to remember that the final value is only as precise as your least precise piece of data.

For example: a chemical reaction releases 3.5 cm³ of hydrogen in 4.0 seconds. The average rate

$= \frac{3.5}{4.0} = 0.875\ cm^3 / s.$

Because the data has only two significant figures, the figure for the average rate needs to be adjusted to two significant figures so that it has the same degree of precision as the data.

When adjusting the number of significant figures, if the integer after the least significant figure is equal to or greater than '5', then the last significant figure is rounded up. Otherwise, it is rounded down.

Therefore in this example, 0.875 cm³/s is adjusted to 0.88 cm³/s.

Here is a Physics example: in an electrical circuit you measure a voltage of 2.3 V and a current of 1.2 A. The resistance (in Ohms) is calculated by dividing the voltage by the current.

$$\text{Resistance } (\Omega) = \frac{\text{Voltage } (V)}{\text{Current } (I)} = \frac{2.3\text{ V}}{1.2\text{ A}} = 1.9166667\ \Omega$$

This should be reported as 1.9 Ω since both the voltage and current are recorded to two significant figures.

EXERCISE 3.3

Underline the significant digits in each of the following measurements of length:

(a) 10.0 cm

(b) 0.030 cm

(c) 78.02 cm

(d) 7.200 cm

(e) 0.002 cm

(f) 3.110 cm

(g) 1.09 cm

(h) 94.0 cm

3.2.5 RECOGNISING PATTERNS IN DATA

In everyday language, a pattern is a shape or structure that is repeated. In Science, you are looking for repeatable changes. In other words, you are looking to see how a variable changes when another variable is changed. When looking for patterns, you only usually look at two sets of numerical results, perhaps averages, to see how one variable changes as you change the other variable.

A number of patterns form simple relationships where there is a precise mathematical relationship between two variables.

Proportional

If variable B is proportional to A, then B increases in direct proportion to the increase in A (*Figure 319*). That is, a doubling of variable A leads to a doubling of variable B.

A	B
1	5
2	10
3	15
4	20
5	25

Figure 319 Directly proportional data

In this example, A is proportional to B, even though B increases by 5 when A increases by 1, because when A doubles, the numerical value of B doubles. *Figure 320* shows a proportional relationship graph.

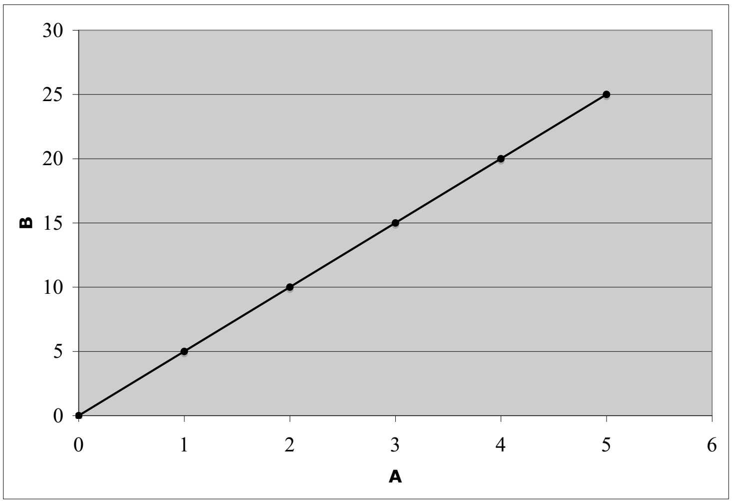


Figure 320 Proportional relationship graph

Mathematically, a proportional relationship can be written in the form $B = k \times A$, where, for this relationship, $k = 5$.

Examples of proportional relationships

CHEMISTRY

Concentration and rate; for example, the rate of reaction between zinc and excess hydrochloric acid.

BIOLOGY

Light intensity and photosynthetic rate (until limiting factors, e.g., carbon dioxide become relevant).

PHYSICS

Potential difference and current (at constant temperature) (Ohm's Law).

Inversely Proportional

A	B
2.0	7.5
1.0	15
0.5	30
0.25	60

Figure 321 Inversely proportional data

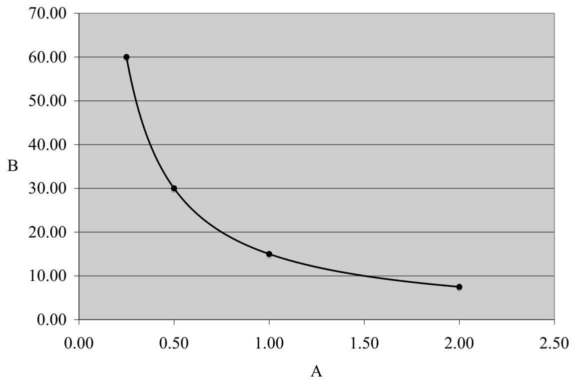


Figure 322 Inversely proportional graph

This is the relationship between two quantities whose product ($A \times B$) is a constant (*Figure 321*). When two quantities are in inverse proportion, their graph is a curve called a hyperbola (*Figure 322*).

Mathematically, an inversely proportional relationship can be written in the form $A \times B$ = constant (k), where for this relationship $k = 15$.

Complex relationships

Some relationships, especially biological, may not be straightforward and may be caused by a number of variables. For example, the abundance or size of a species of lichen is an indicator of air pollution, but other environmental factors, such as the type of soil, and air movement can also affect the distribution of lichens.

3.2.6 STATISTICS WITH EXCEL

Excel has a number of useful formulas that can be used to calculate some simple descriptive statistics for raw data (*Figure 323*).

Formula	Description
=AVERAGE (range)	Average or mean
=MEDIAN (range)	The median is the value halfway through the ordered data set, below and above which there lies an equal number of data values.
=MODE (range)	The mode is the most frequently occurring value in a set of discrete data. There can be more than one mode if two or more values are equally common.
=MAX (range)	Maximum value from a set of data
=MIN (range)	Minimum value from a set of data
=STDEV (range)	A measure of the 'spread' of a set of data (standard deviation)

Figure 323 Statistical formula

Cell B12	Formula =SUM(B2:B11)
B13	=AVERAGE(B2:B11)
B14	=MEDIAN(B2:B11)
B15	=MIN(B2:B11)
B16	=MAX(B2:B11)
B17	=STDEV(B2:B11)

Figure 324 Spreadsheet formula for Figure 325

The spreadsheet in *Figure 325* contains numbers stored in cells B2 to B11 and in cells D2 to D11. There are labels in cells A12 to A17. The formulas for the left hand analysis of the data is shown in *Figure 324.*

1				
2		124		131
3		120		60
4		153		160
5		98		212
6		123		117
7		142		65
8		156		155
9		128		160
10		139		145
11		117		95
12	Total	1300		1300
13	Average	130		130
14	Median	126		138
15	Minimum	98		60
16	Maximum	156		212
17	Standard deviat	17.67609811		47.01536392
18				
19				
20				

Figure 325 Screenshot of Excel performed statistics on two sets of data

3.2.7 WRITING YOUR CONCLUSION

Describe in words what you found out, usually by reference to a graph. Look for a trend, pattern or relationship in your results and describe what this is, for example:

- The graph is a straight line through the origin. Therefore the extension of the steel spring is directly proportional to the load (up to the elastic limit). The steel spring extends by 0.23 mm per newton.
- The graph shows an inverse relationship between the concentration of hydrochloric acid and the time taken for the cross to be hidden by the precipitate of sulfur formed from sodium thiosulfate.
- The graph shows that as the distance between the lamp and the plant increases, the number of bubbles of oxygen decreases.

In addition, you *must* quote figures (with appropriate units) from your data to support your conclusion, for example, if a directly proportional or inversely proportional relationship is shown by the data then quote numbers from the line or curve of best fit to demonstrate this relationship.

- For example, consider an investigation into finding the relationship between the volume and temperature of a fixed mass of air (at constant pressure).
- The volume of gas is 1 cm^3 at 500 kelvin and 2 cm^3 at 1000 K. The gas volume is doubled: 1 $cm^3 \times 2 = 2$ cm^3 when the absolute temperature is doubled: 500 K $\times$ 2 = 1000 K.
- This relationship also holds at the highest values of temperature: the volume of gas is 4 cm^3 at 200 K and 8 cm^3 at 400 kelvin: 4 $cm^3 \times 2 = 8$ cm^3; 200 K $\times$ 2 = 400 K. A linear relationship has been demonstrated.

Consider an investigation into finding the relationship between the pressure and volume of a fixed mass of air (at constant temperature).

- The volume of gas is 16 cm^3 at a pressure of 1 atmosphere and 8 cm^3 at 2 atmospheres. The gas volume is halved: 16 $cm^3/2 = 8$ cm^3 and the pressure is doubled: 2 × 1 atm = 2 atm. This relationship also holds at reasonable values of pressure: the volume of gas is 2 cm^3 at 8 atm and 1 cm^3 at 16 atm: the gas volume is halved: 2 $cm^3/2 = 1$ cm^3 and the pressure is doubled: 8 atm × 2 = 16 atm. An inversely proportional relationship has been demonstrated.
- These are ideal or perfect results - you will be doing this analysis with averaged experimental data with some scatter due to random errors. More complicated relationships may be encountered in MYP Biology investigations, for example, those involving enzymes. For more complicated relationships, consider whether there is a general increase or decrease along the curve. Any peaks or troughs should be identified and whether the curve levels off as a plateau should be noted.

Consider whether you can obtain more results from your graph by finding the area under the line or the gradient. For example, if you have a graph of speed against time the area under the graph gives the total distance travelled and the gradient gives the acceleration.

- Also consider whether you can plot another graph based on the same results. For example, if you have used data to plot a graph of concentration against time, then plot a graph of concentration against 1/time (rate). This will transform a curved graph into a more useful linear graph.
- Also consider whether your graph should go through the origin (0,0).

Observation	Hypothesis	Prediction	Experimental test
A plant has yellow patches on its leaves	The yellowing is caused by lack of nitrogen	If you deprive a plant of nitrogen (in the form of nitrate) it will develop yellow leaves	Grow two groups of plants, the control group in a solution containing all necessary nutrients, the other in a solution containing all nutrients (except nitrate).

Figure 326 An observation and its use in a scientific investigation

SECTION 3.3 EVALUATING THE VALIDITY OF A HYPOTHESIS

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **state** the validity of a hypothes is based on the outcome of a scientific investigation

3-4 **outline** the validity of a hypothesis based on the outcome of a scientific investigation

5-6 **discuss** the validity of a hypothesis based on the outcome of a scientific investigation

7-8 **evaluate** the validity of a hypothesis based on the outcome of a scientific investigation

3.3.1 EVALUATE THE VALIDITY OF YOUR HYPOTHESIS BASED ON THE OUTCOME

Look at your hypothesis and prediction. State if your results validate or invalidate it. If they agree or disagree then state clearly what you have found out and how this relates to the scientific knowledge and your background information. Consider whether there are other ways of explaining your results.

For example, when explaining why the rate of a chemical reaction increases with temperature, you might describe how the average kinetic energy of the particles increases as the temperature increases and, because they are moving around more quickly, they are likely to collide more often (in the same time period) and with more kinetic energy. Hence, when they do, the collision is more likely to be effective.

For example, if finding out the osmotic potential of potato tissue, you must show how the intercept you found on the graph can be used to determine the osmotic potential of the sap in the potato cells. Explain this using scientific knowledge about osmotic potential. Also, explain clearly what is happening to the cells before this point and again after this point.

You do not have to repeat all your background information in your planning or design section but you must refer back to this and you must write something like 'as I showed in paragraph 2 on page 6', or 'as the graph of my prediction from my hypothesis showed (see page 5)'.

In general, the scientific method starts with an observation followed by a hypothesis to explain the observation. A prediction or a series of predictions is/are then made from the hypothesis. For a hypothesis to be a scientific hypothesis it has to be testable. *Figure 326* shows an example of a testable hypothesis.

The results of an investigation should ideally either validate (support) the hypothesis or invalidate (not support) the hypothesis. If the hypothesis is not supported by the data then a new hypothesis should, if possible, be generated.

Figure 327 shows the speed of sound measured in different materials. It is predicted that the speed of sound (at 25 °C) will decrease from solids, to liquids to gases. The hypothesis is based on kinetic or particle theory.

Material	Speed of sound m/ s
Steel	6000
Water	1500
Air	340

Figure 327 The speed of sound (at 25 °C) in various materials

The particles (atoms or molecules) in a solid are touching each other and are bonded together in fixed positions. Since the particles are bonded together, a sound wave moving one particle, immediately transfers the movement to the one touching it.

In a liquid, the particles are touching each other, but they are not bonded to each other quite so strongly as they are in a solid. Some of the sound energy is 'wasted' pushing the particles around because they can slide past each other.

In a gas, the molecules are rather far apart. For sound to travel through a gas, the molecules must move quite a distance before they collide with other molecules. Sound energy cannot move as quickly when the molecules are not in contact with each other.

The limited results are said to support the hypothesis. A hypothesis cannot be proved, but can receive further support if similar measurements in a range of other materials result in the same relative differences between the three states of matter.

Treatment of leaf	Loss in mass per leaf/g
Untreated	0.21
Upper surface vaselined	0.16
Lower surface vaselined	0.06
Both surfaces vaselined	0.00

Figure 328 Results from an experiment on transpiration in leaves under different conditions

The initial student hypothesis was that 'stomata are only present on the upper surface of the leaf'. The prediction was that the application of vaseline on the upper surface would prevent transpiration (by blocking the stomata) and there would be no water loss. Refer to *Figure 328.*

However, the results invalidate this hypothesis and suggest a new hypothesis that 'stomata are present on both the upper and lower sides'.

SECTION 3.4 EVALUATING VALIDITY BASED ON THE OUTCOMES

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **state** the validity of the method based on the outcome of a scientific investigation

3-4 **outline** the validity of the method based on the outcome of a scientific investigation

5-6 **discuss** the validity of the method based on the outcome of a scientific investigation.

7-8 **evaluate** the validity of the method based on the outcome of a scientific investigation.

3.4.1 EVALUATING THE VALIDITY OF YOUR METHOD

When you have drawn your conclusions, you should now think about how well you carried out your MYP Science investigation.

Ask yourself these questions to see if you could have improved your Investigation

- Were my results accurate?
- Did any seem 'strange' compared to the others? (These are called anomalous data). For example, one point may not lie near the straight line or curve.
- Should I have repeated some tests to get more reliable results?
- Could I improve the method I used?
- Did I get a suitable range of results?
- Is there a pattern in my results?
- Would it be useful to check your graph by taking readings between the points?
- How would I change my investigation to get the answers to the questions above?

Two important concepts associated with an evaluation of an MYP Science investigation are reliability and validity.

For example, consider an MYP investigation concerned with comparing different brands of paper towels and their ability to absorb water. For the data to be reliable you would need to consider the errors in the balance used to measure the mass of the towels and consider any spillage or evaporation of water that might have occurred.

Data is only valid if it allows you to answer your focused problem or research question.

For example, measuring the distance travelled by a model car at different angles on a ramp will not answer a research question about how speed varies with the angle of the ramp. However, measurements of bubbles per minute released by a piece of cut pond weed are sufficiently valid data that will allow you to compare the rates of photosynthesis under significantly different conditions.

In the following section is an example of the outline of an evaluation from the previously described relatively simple investigation into the solubility of sodium chloride. Note how the outline of the evaluation relates to the requirements of **Criterion C: Processing and Evaluating**

The questions have been added to help the student address the Criterion C requirements.

EXERCISE 3.4

When copper(II) carbonate is heated the following decomposition reaction occurs:

$CuCO_3$ (s) → CuO (s) + CO_2 (g)

Five test tubes each containing exactly 12.5 g of copper(II) carbonate were heated, cooled and weighed by an MYP Science student. Each tube was then reheated, cooled and reweighed three more times. The MYP Science student made a mistake and forgot to heat one of the copper(II) carbonate samples and made another mistake in weighing another of the samples. His results are shown in the Figure below.

(i) Which tube did the MYP Science student forget to heat?

(ii) Which set of results contained the weighing mistake? Explain your answer.

(iii)Explain why there was no change in mass in trials 3 and 4 of Sample A.

Sample	Trial 1 Mass of solid after heating/g	Trial 2 Mass of solid after heating/g	Trial 3 Mass of solid after heating/g	Trial 4 Mass of solid after heating/g
A	8.7	8.5	8.0	8.0
B	9.9	9.6	8.4	8.0
C	16.0	9.6	9.2	8.0
D	8.0	8.0	8.0	8.0
E	12.5	12.5	12.5	12.5

(iv) In which test tube has the most copper(II) carbonate decomposed after the first heating?

(v) What mass of copper(II) oxide can be obtained from 12.5 g of copper(II) carbonate (*based upon the table of data*)?

3.4.2 EVALUATING THE METHOD

- Did you plan and carry out a fair test?

  Controlling the variables was easy. We have used the same mass of sodium chloride and same volume of water throughout the investigation. We also controlled the external temperature. I believe that our investigation is a fair test.

- Do you think you have accurate results? What did you do to ensure that you obtained accurate results? (or) What problems did you encounter that made it difficult to obtain accurate results? Did you carry out any changes (modifications) to your method?

  Judging when to stop the electronic stop clock was difficult because it was hard to see whether all the sodium chloride powder had dissolved. I think that this difficulty might have affected our time reading by around five seconds. To solve this problem, in the next trial, we placed the beaker with the water and salt on top of a piece of black paper. The contrast in colour made it easier for us to see whether all the salt had dissolved. This, I think, has improved the accuracy of the results.

- Do you think you have enough data? Did you do repeat measurements? How do these measured values compare with each other? How do your measured values compare to the accepted values? (if available)

  We were able to test 6 different temperatures. For each temperature, our group did three trials. Therefore, we have enough data to support our conclusion. Also, there was not much difference amongst the 3 readings. For example, at a temperature of 40 °C the measured times were 5.5, 6.0 and 5.8 minutes. At a temperature of 90 °C, the results were 3.2, 3.8 and 3.5 minutes. On the average, there was no more than 0.5 minutes difference between readings. The averaged values when graphed showed a clear pattern. The data points were very close to the line of best fit. Therefore I think that our results are reliable.

SECTION 3.5 EXPLAINING IMPROVEMENTS OR EXTENSIONS

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **state** improvements or extensions to the method

3-4 **outline** improvements or extensions to the method that would benefit the scientific investigation

5-6 **describe** improvements or extensions to the method that would benefit the scientific investigation

7-8 **explain** improvements or extensions to the method that would benefit the scientific investigation.

Here is an example of an outline of some improvements to a method and extensions to an investigation from the previously described relatively simple investigation into the solubility of sodium chloride. The questions have been added to help the student address the Criterion C requirements.

3.5.1 IMPROVEMENTS TO THE METHOD

- Did you do enough trials? If you did only one, then suggest that you will repeat the measurement two more times and calculate an average. Was your range of values acceptable?

  The temperatures tested were all above room temperature. I can increase the range of temperature by using cold water and test temperatures around 10-20 °C. This will make the relationship obtained more reliable.

- What do you think is the greatest source of uncertainty?

  When to stop the stop clock was difficult. It was difficult to see whether all the sodium chloride had dissolved. It may be good to place the beaker on top of dark paper so it will be easy to see whether all the sodium chloride has dissolved.

  In this experiment, the main difficulty lies in deciding when all the sodium chloride has dissolved. Next time, I will use a retort stand and a clamp to hold the beaker and I will shine a strong light (100 W lamp) above the solution. The lamp will be placed at a constant distance from the beaker.

  The sodium chloride particles will then form enlarged shadows. The shadows will provide me with a better method in deciding whether all the sodium chloride crystals have dissolved. I will then stop the stop watch once there is no longer any shadow.

3.5.2 SUGGESTIONS FOR EXTENDING THE INQUIRY

- A related investigation that I can do is finding out how the mass of sodium chloride affects the time it takes to dissolve.
- Distilled water can be made acidic or alkaline by adding acid or alkali. One investigation I would like to do in the future is to investigate how the pH of water would affect how fast the sodium chloride particles will dissolve, under constant temperature.
- Test other chlorides, for example, calcium chloride $CaCl_2$.

3.5.3 SECONDARY DATA

It is possible that your MYP Science teacher may ask you to process, present and analyse data from a secondary source, such as a text book or a website on the Internet. This may be used as practice prior to a formal assessment centred around a personal practical investigation. Such an exercise could also appear in a school exam or test, but can only be used to generate a partial score for Criterion C: Processing and Evaluating.

For example, you may be given the following data about inhaled and exhaled air. This could be presented in a random manner as shown below.

oxygen 20.96% (inhaled)	carbon dioxide 4.0% (exhaled)
nitrogen 79.00% (exhaled)	nitrogen 79.00% (inhaled)
oxygen 17.00% (exhaled)	carbon dioxide 0.04% (inhaled)

This data can be presented in the form of a table (*Figure 329*) and the data processed to show the percentage differences between inhaled and exhaled air.

Gas	Air inhaled / %	Air exhaled / %	Percentage difference / %
Oxygen	20.96	17.00	-18.8
Carbon dioxide	0.04	4.0	+100
Nitrogen	79.00	79.00	0

Figure 329 A table showing processed data

The percentages for the inhaled and exhaled air could also be presented in the form of a bar chart or two separate pie charts.

Analysis of the results would involve describing the process of aerobic respiration, focussing on the consumption of molecular oxygen and the production of carbon dioxide. The unreactivity or inertness of nitrogen should be mentioned. The structure and function of alveoli in the lungs would need to be described, preferably with some suitable diagrams illustrating gas exchange.

EXERCISE 3.5

In 1822 a Canadian man, Alexis St. Martin, was accidentally shot in the stomach while working at a fur trading post. A US army doctor called William Beaumont looked after him as the wound healed. The wound did not heal completely and left a small hole opening into his stomach. Beaumont contracted St. Martin to work for him as a servant and performed the following experiments on him:

Experiment 1

Beaumont tied a piece of boiled beef to a silk thread and pushed the beef into St. Martin's stomach. The piece of beef was completely digested in two hours.

Experiment 2

Beaumont removed some of St. Martin's gastric juices and placed them in a test tube maintained at thirty seven degrees Celsius. He placed a piece of raw beef in the test tube. The piece of beef was completely digested in two hours.

1. Why did Beaumont keep the test tube at thirty seven degrees celsius?

2. Identify the dependent variable in both experiments.

3. What control should Beaumont have performed in Experiment 2?

4. What conclusions can you draw about digestion from these experiments?

OBJECTIVES

Students should be able to:

1. explain the ways in which science is applied and used to address a specific problem or issue
2. discuss and evaluate the implications of using science and its application to solve a specific problem or issue, interacting with a factor
3. consistently apply scientific language to communicate understanding clearly and precisely
4. document sources completely.

Level	Descriptor
0	The student does not reach a standard identified by any of the descriptors below.
1-2	i. **outline** the ways in which science is used to address a specific problem or issue ii. **outline the implications** of using science to solve a specific problem or issue, interacting with a factor iii. **apply** scientific language to communicate understanding but does so with **limited success** iv. **document** sources, with **limited success.**
3-4	The student is able to: i. **summarize** the ways in which science is applied and used to address a specific problem or issue ii. **describe the implications** of using science and its application to solve a specific problem or issue, interacting with a factor iii. **sometimes apply scientific language** to communicate understanding iv. **sometimes** document sources correctly.
5-6	i. **describe** the ways in which science is applied and used to address a specific problem or issue ii. **discuss** the implications of using science and its application to solve a specific problem or issue, interacting with a factor iii. **usually apply** scientific language to communicate understanding clearly and precisely iv. **usually** document sources correctly.
7-8	The student is able to: i. **explain** the ways in which science is applied and used to address a specific problem or issue ii. **discuss and evaluate** the implications of using science and its application to solve a specific problem or issue, interacting with a factor iii. **consistently apply** scientific language to communicate understanding **clearly and precisely** iv. document sources **completely.** *©IBO 2014*

SECTION 4.1 EXPLAINING WAYS IN WHICH SCIENCE IS APPLIED

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **outline** the ways in which science is used to address a specific problem or issue

3-4 **summarize** the ways in which science is applied and used to address a specific problem or issue

5-6 **describe** the ways in which science is applied and used to address a specific problem or issue

7-8 **explain** the ways in which science is applied and used to address a specific problem or issue

Introduction

Students gain global understanding of science by evaluating the implications of scientific developments and their applications to a specific problem or issue. Varied scientific language will be applied in order to demonstrate understanding. Students are expected to become aware of the importance of documenting the work of others when communicating in science. Students must reflect on the implications of using science, interacting with one of the following factors: moral, ethical, social, economic, political, cultural or environmental, as appropriate to the task. The student's chosen factor may be interrelated with other factors.

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Criterion D assumes that you have some knowledge about how science works and are familiar with important concepts in science. This section will give you some relevant background so you will be more familiar with the scientific method. Reflecting on the impacts of science (Criterion D) enables students to gain a better understanding of the role of science in society and allows them to explore how scientific developments and applications are applied and used to address specific problems or issues in local and global contexts.

Key Terms

Outline: give a brief account.

Apply: use knowledge and understanding in response to a given situation or real circumstances.

Document: credit sources of information used by referencing (or citing), following one recognized system. References should be included in the text and also at the end of the piece of work in a reference list or bibliography.

Summarize: abstract a general theme or major point(s).

Describe: give a detailed account or picture of a situation, event, pattern or process.

Discuss: offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.

Evaluate: assess the implications and limitations; make judgments about the ideas, works, solutions or methods in relation to the selected criteria.

Explain: give a detailed account including reasons or causes.

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4.1.1 WHAT IS SCIENCE?

The first section is a simple summary about science and its important concepts and features. The second section then lists certain concepts and their implications.

Theory

A theory is a way of explaining the relationship between variables, using data. A useful theory must allow us to make predictions that can be tested. Scientific theories should be as simple as possible.

Observation

An observation is what scientists see, hear, smell, touch or taste when they are looking for evidence. Initially, this may just involve observation but will often involve recording measurements.

Experiment

An experiment should properly control the variables so that observations and measurements can be collected. Only one variable is changed so it is a fair test. Before scientists carry out an experiment to see if there is a relationship between two variables, they usually have an idea of what the relationship might be. An idea based on scientific reasoning that has not been tested is called a hypothesis (see Chapter 2, Criterion B).

Evidence

The evidence that scientists need to support their theories is simply the results of their observations or experiments. Sometimes, the evidence that scientists obtain from their experiments suggests that the original hypothesis was wrong. The theory then needs to be modified, or changed completely.

Models

The real world is extremely complex and scientists create models to help them understand difficult ideas. A model (see Chapter 2, Criterion B) is simpler than the real thing, but describes how it works. Models can be mathematical (equations), graphical (drawings, graphs or flow charts), a physical representation or even an analogy (saying something is like something else, for example, an atom with its nucleus and its electrons in shells is like the solar system). Because the model is usually much simpler than the real thing, we have to remember that what we learn from the scientific model may not always give us accurate information about the real thing.

4.1.2 KEY FEATURES OF SCIENCE AND THEIR IMPLICATIONS

- Know that you can never be sure that a measurement gives the true value of the quantity being measured.

This is based on the idea that every measurement has a small error in the reading. This concept is discussed under Criterion B.

- Know that we can have more confidence in the average of several repeated measurements than in a single measurement, and that the variation in repeat measurements enables us to identify the range within which the true value probably lies.

Averaging raw data reduces the errors. Averaged data is used to draw graphs (see Chapter 3, Criterion C).

- Recognise that data can indicate that an explanation is incorrect (falsification) but cannot prove conclusively that an explanation is correct.

Scientific laws are never proved, they are simply never disproved. Hence, any scientific hypothesis or law can always can be overturned by new experimental evidence.

- Understand how observation and experiment are used in science to rule out alternative explanations, with the aim of reaching a single, agreed explanation.

The concept of a 'control' is an important idea, especially for MYP Biology investigations. It is also important to control the 'controlled variables'. These concepts are defined in the Glossary and discussed under Criterion B in Chapter 2.

- Appreciate that many scientific explanations are based on models that may involve things that cannot be directly observed.

Scientific models are discussed under Criterion B. The most familiar scientific model may be atomic structure: atoms being composed of electrons, protons and neutrons. Individual atoms can now be detected and manipulated. The idea of energy and its conservation are very important scientific concepts.

- Recognise and appreciate the reasons for scientists' reluctance to reject a well-established explanation in the face of apparent anomalies, until a better explanation is available.

The normal steady progress of science is interrupted occasionally by 'scientific revolutions' through which ideas in a particular area of science break new ground. These are called paradigm shifts. Darwin's idea of evolution by natural selection is a biological paradigm shift–a new way of scientific thinking.

- Understand that reported findings and explanations must withstand critical examination by other scientists, before they are accepted as scientific knowledge.

At the end of an MYP investigation you will compare your results to those of other groups as part of your evaluation. This is assessed under Criterion C.

4.1.3 WHY SHOULD WE REFLECT ON THE IMPACTS OF SCIENCE?

- It gives a student a real-world view of science.

  The study, method and practice of science are influenced by various cultural, ethical and political factors. Science, in its aim to discover the truth, requires that its findings be exposed to verification and exchange of ideas, not only within, but also outside of the scientific community. The discoveries, including the methods are therefore evaluated both on academic and ethical grounds. Criterion D tasks, therefore, allow students to appreciate the interactions between science and society on any issue that is presented in class or found outside on their own.

- It is a venue where a student can express opinions that are explicitly supported by a scientific theory and/or a cultural or political belief.

  Criterion D tasks provide students with the opportunity to discuss the problem, that is, to present both sides of the issue at hand, if possible with equal clarity and emphasis. Further to this, students should offer a range of supported arguments for or against the issue within the social, economic, cultural and ethical perspectives.

- It requires a lot of planning and initiative from students.

  Every Criterion D task demands a large element of resourcefulness and ingenuity from students. It is common for many students to find these tasks overwhelming, especially if it is the first time for them to work on it. The key in this activity is for the student to decide what is relevant. However, as daunting as it may appear to be, with the appropriate preparation and planning, completing Criterion D tasks can be straightforward.

The **Criterion D task** is *not* an English essay. Although students are encouraged to use guidelines from MYP language classes, they can achieve the highest descriptors by stating the required issues and presenting them mechanically and without emotion.

4.1.4 EXPLAINING HOW SCIENCE CAN ADDRESS A SPECIFIC PROBLEM

Many of the local and global issues or problems today can be better appreciated if the underlying science behind it is understood. To obtain the maximum score in this aspect of Criterion D, the *appropriate* scientific principles behind the issue being studied need to be **explained clearly**. A few examples of some suitable issues with relevant information is given below.

Global warming (a global issue)

- Small quantities of greenhouse gases occur in the Earth's atmosphere and keep the planet at a suitable temperature for living organisms
- Due, in part, to a sustained increase in carbon dioxide levels in the atmosphere (Enhanced Greenhouse Effect)
- Increase in carbon dioxide levels is due to combustion of fossil fuels since the Industrial Revolution
- Carbon dioxide molecules absorb infrared radiation causing their bonds to vibrate; trapping heat in the atmosphere (the Greenhouse Effect)
- Researching and educating people about global warming and the concept of a 'carbon footprint', for example, switching from personal transport to public transport; the use of carbon-offsetting by people in developed countries
- Carbon-capture and storage technology (sequestration)–the capture and storage of carbon dioxide in fossil fuel-based power stations
- Other anthropogenic (man-made) sources, for example, chlorofluorocarbons (CFCs) contribute to the Enhanced Greenhouse Effect
- Development of sustainable energy sources as alternatives to fossil fuels e.g. solar power and fuel cells

Corrosion of iron (a global issue)

- Many millions of tonnes of iron are used annually in steel girders for construction and the manufacture of car bodies
- A redox reaction involving liquid water and oxygen
- Results in the formation of hydrated iron(III) oxide
- Rust does not adhere to iron and allows further corrosion to occur
- Simple rust-proofing methods include painting, greasing and oiling
- More sophisticated approaches include: sacrificial protection, electroplating and negative earthing

Eutrophication of a lake (a local issue)

- Caused by excessive levels of artificial fertilisers
- Promotion of excessive plant growth; their decay by bacteria reduces the dissolved oxygen content of water (leading to the death of organisms that rely on dissolved oxygen)
- The water is less attractive for boating, swimming and fishing
- Algae create problems of water colour, taste and odour, resulting in increased costs of water treatment
- Removal of nutrients from waste waters, a very costly procedure
- Removal of excessive weeds and debris, and dredging of lake sediments
- Application of chemicals to destroy algal growth, copper(II) sulfate and chlorine (both toxic) being commonly used for this purpose

As well as explaining the science behind your chosen issue, the ways in which science (or technology) is applied to address the issue needs to be clearly explained. A good 'rule of thumb' is to assume that you are writing or presenting your Criterion D task for a classmate, and not for your teacher. This means that any technical scientific terminology needs to be explained in your own words in a way that a classmate could understand. Explanations should be supported with facts and figures (which could be in the form of charts, tables or diagrams) that are discussed within your report and appropriately referenced.

Possible solutions to feeding a growing world population (a global issue)

Entomophagy (eating insects): Insects are cold-blooded and so produce significantly less greenhouse gas emissions than warm-blooded livestock. Insects are more efficient at converting feed to edible 'meat' than warm-blooded livestock. Insects can be grown in plastic or metal trays containing a bed of wheat bran (or other grain by-product) and therefore require far less space than livestock. Compared to livestock, insects contain comparable levels of protein and fat, but also provide a source of carbohydrates. Some of the proteins contained in edible insects are the same as those found in house dust mites, which may cause asthma.

'Lab-grown' (*in vitro*) meat: using a growth medium (a solution containing proteins and other essential growth factors) stem cells (undifferentiated cells that can develop into a range of cell types) are grown into strips of muscle.

Genetically modified crops: crops which have had their DNA modified, using genetic engineering techniques, to introduce a new trait that does not occur in the naturally occurring species (e.g. pest, disease or herbicide resistance, reduction of spoilage or changes to the nutrient content of the crop). There is a range of techniques for introducing DNA into a crop species, including gene guns and agrobacterium. A gene gun, as the name suggests, 'shoots' DNA, which is attached to small particles of gold or tungsten, into plant cells under high pressure. *Agrobacterium tumefaciens* is used as a vector (carrying agent for the gene to be inserted into the plant cell). Agrobacteria are natural plant parasites and contain circular DNA fragments called plasmids, which are inserted into the genome of a host cell and cause tumours. If the tumour-causing DNA is removed and replaced with a desired foreign gene it can be inserted into the genome of the plant, to introduce the desired trait.

Aeroponics: involves growing plants in an air or mist environment without the use of soil. A nutrient rich solution is sprayed onto the growing plants as a fine mist. Crops can be grown in desert areas and do not require large plots of land as they use significantly less water and fertilizer than traditional agricultural techniques.

Edible algae: algae provides significant levels of protein, fat and carbohydrates and it grows quickly. It can be grown in open ponds or in photobioreactors (transparent vessels exposed to a light source for photosynthesis).

Much of technology, especially recent developments, is based on science. The differences are that science produces ideas, theories and hypotheses (See **Chapter 2: Criterion B**) whereas technology results in the production of usable objects, such as a laser or GPS tracking system. Engineers use scientific knowledge to solve practical problems.

Science has always been heavily dependent on the available technology, both for ideas and for apparatus or equipment. Technology has had a huge influence on science. For example, the detection of the microwave radiation in space in 1965 from the 'Big Bang' was a technologically-motivated investigation. Many of the recent developments and discoveries in nanotechnology have been the result of the development of new technological instruments, such as the atomic force microscope and the cluster beam apparatus. The development of molecular biology genetic engineering techniques also relied upon advances in technology and engineering, in such areas as the development of ultracentrifugation, electrophoresis, protein and DNA sequencing methods and computer systems.

There were also a number of technologies that were predicted in advance from scientific theories including:

genetic engineering, radio, atomic energy, television, lasers, mobile telephones, computer design and designer drugs

The motivations behind technology and science are very different. The final product of science is an idea, or information, probably in a scientific paper; the final product of technology is a useful device, for example, a computer or MP3 player. Unlike science, the product of technology is measured not against nature but in terms of its novelty and the value that a particular culture puts on it. The path from scientific knowledge to technological devices can take a long time, and often has stops, starts, and changes of direction. Lots of devices went into production quite quickly e.g. micro-circuits, jet engines, radar.

SECTION 4.2 IMPLICATIONS OF USING SCIENCE TO SOLVE A SPECIFIC PROBLEM

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **outline the implications** of using science to solve a specific problem or issue, interacting with a factor

3-4 **describe the implications** of using science and its application to solve a specific problem or issue, interacting with a factor

5-6 **discuss** the implications of using science and its application to solve a specific problem or issue, interacting with a factor

7-8 **discuss and evaluate** the implications of using science and its application to solve a specific problem or issue, interacting with a factor

4.2.1 THERE ARE ISSUES WHICH SCIENCE CANNOT CURRENTLY SOLVE

Global warming: Most of our current energy production technology is dependent on the combustion of fossil fuels. The infrastructure for alternative energy sources is expensive to implement and some technologies are still inefficient, for example, solar cells.

Organ Transplant: Organ rejection is reduced by administering immunosuppressant drugs to the patient. However, the drugs lower the immunity of the patient and increase the chances of him or her acquiring infections and diseases. Furthermore, the lack of donors is one problem over which science has no control. This is a political and cultural issue. Some tissues can be cultured *in vitro*, but technologies to develop whole organs (both natural and synthetic) are still developing. Organs can be kept viable for a few hours and there is a limit to transport distance.

Nuclear energy as an alternative source of energy: nuclear waste disposal and long term storage. Nuclear fusion is currently very expensive and inefficient: the output energy from current experimental fusion reactors is less than the input energy. There are also engineering issues related to the containment of the plasma and hence sustaining and controlling the fusion reactions.

Child nutrition: There is sufficient food in the world to feed all the world's children and prevent malnutrition. The issue of global malnutrition is a political and economic problem.

Some technological contributions of science have drawbacks (environmental, economic, political)

Hydroelectric power as an alternative energy–damage to the environment and ecosystem

Gas powered electric generators–noise pollution and environmental damage

Leaded petrol–the lead particles emitted causes brain damage in young children

Science cannot be expected to solve ethical issues. Furthermore, some ethical issues arise from the application of science.

Global warming: The Kyoto Protocol suggests that some countries cut down on their carbon dioxide emission to slow down global warming. This means closing down some industries which means that a number of people would lose their jobs (an economic issue).

Intra-uterine devices as a method of contraception. One controversial issue is the use of the intra-uterine device (IUD). Most researchers believe that the IUD interferes with the implantation of a fertilised ovum in the uterine wall. To a person who believes that human personhood begins at the instant of conception, there is no ethical difference between using an IUD or having a first trimester abortion.

Abortion as a method of contraception. Science has helped us understand how the fetus develops inside the womb. However, whether it is right or wrong to terminate the fetus due to an unwanted pregnancy is determined by cultural, moral and social rules.

Embryonic stem cell therapy: Embryonic stem cell therapy has the potential to generate new cells, tissues and organs and to treat a variety of diseases. The harvesting of embryonic stem cells results in the destruction of the human embryos from which they are harvested. One issue here is the moral status of the embryo: a person, a potential person, God's creation, or simply organic chemicals?

Global warming: the relationship between carbon dioxide levels and average global temperatures shows a strong, but not a perfect, correlation; there are natural cycles due to changes in the Earth's orbit and uncertain factors in climate models, such as the cooling/warming effect of clouds and the ability of the oceans to absorb carbon dioxide. Another limitation is the difficulty associated with an accurate assessment of positive feedback effects which even a slight warming might produce. For example, increases in methane production due to permafrost melting and declines in polar snow and ice cover. The relatively short time frame over which detailed and reliable climatic observations have been made is another limitation, together with the difficulty of including all relevant data when computer modelling climate change. Proving beyond doubt that global warming is actually happening and that human activities are responsible for it, may take so long that the process may be irreversible for hundreds of years.

Science cannot answer questions of morality

The problem of deciding what is good and bad or right and wrong, is outside the determination of science. This is why expert scientific witnesses can never help us solve the dispute over abortion: all a scientist can tell you is what processes occur as a fetus develops; the question of whether it is right or wrong to terminate a pregnancy is determined by cultural and social rules–in other words, morality. Scientific knowledge cannot help here. Scientists are not exempt from consideration of the moral issues surrounding what they do. Like all humans, scientists are accountable morally and ethically for the work they do.

Social factors

Most scientists try to achieve personal satisfaction and professional success by forming intellectual alliances with colleagues and by seeking respect and rewards, status and power in the form of publications, grant money, employment, promotions, and honours such as the Nobel Prize.

Economic factors

Scientific research that has obvious commercial applications may receive preferential funding from a government or a private company. Very expensive projects, such as the *Large Hadron Collider* may require financial contributions from a number of countries in order to occur.

Political factors

Scientific research is often funded by governments. Hence, they can influence the direction of research via selective funding. Scientific research into nuclear weapons may be restricted by international conventions or treaties.

Environmental factors

A number of technologies and applications of science have greatly impacted the environment. For example, development of CFCs (ozone depletion) and artificial fertilisers (eutrophication of lakes). However, science and in particular chemistry, are at the forefront of developing technologies and processes which minimise the impact on the environment ('green' chemistry).

Cultural factors

The most obvious effect of science has been its medical and technological applications, with the accompanying effects on health care, lifestyles, and social structures. In many modern societies, science also influences culture by playing a major role in shaping cultural world views, concepts, and thinking patterns. Often cultural or religious beliefs influence attitudes towards scientific or technological development.

Ethical factors

Scientists are meant to follow certain ethical principles, such as honesty, objectivity, integrity, confidentiality, openness, respect for intellectual property, social responsibility, non-discrimination, legality and animal care.

4.2.2 AN INTRODUCTION TO MORALITY

This section will give you some relevant background so you will be able to successfully incorporate ethical issues into the Criterion D tasks.

A person's morality is a 'code of conduct' which allows a person to know whether something is 'right' or 'wrong'. However, it is not sufficient in a Criterion D task to simply write that something is 'right' or 'wrong' without supporting your view with reasons.

Morality and ethics are important themes in the Theory of Knowledge (ToK) course in the IB Diploma Programme, but a very basic understanding of ethical theories will allow you to write a better argued and more informed Criterion D Task. Ethics is the philosophical study of morals.

There are three different theories of ethics: religious ethics, utilitarianism and duty ethics which will be briefly discussed.

Religious ethics

Religious ethics are the moral principles that guide religions or faiths and that set the standard for what is and is not acceptable behaviour. These are often similar from one religion to the next, these fundamental principles flow from the core beliefs of the religion, as well as its teachers and traditions. In nearly all the world's religions, personal morality begins with this simple concept: treat others as you would like to be treated. This 'golden rule' is perhaps the most basic aspect of personal morality.

Utilitarianism

Utilitarianism is the idea that an act is moral if it creates more 'happiness' than 'unhappiness'. Given two choices you should always choose the one that has a better overall consequence. For example, it can be argued on utilitarian grounds that, while they are alive, healthy people should agree to be organ and tissue donors after they die. The large amount of 'happiness' created by giving other people back their eyesight or living longer and healthy lives more than outweighs the small amount of 'unhappiness' on behalf of the organ donors family.

It should also be noted that some cultures and faiths do not approve of organ donation. Gypsies are a people of different ethnic groups without a formalised religion. They share common folk beliefs and tend to be opposed to organ and tissue donation. Their opposition is connected with their beliefs about the afterlife. Traditional belief contends that for one year after death, the soul retraces its steps. Thus, the body must remain intact because the soul maintains its physical shape. Criterion D also expects students to explore cultural issues.

Duty ethics

Duty ethics is the idea that people have moral duties. The German philosopher Immanuel Kant (1724 - 1804) based his duty ethics on reasoning (logic). In duty ethics, moral rules have no exceptions. Killing is always wrong; lying is always wrong. Duty-based ethics are concerned with what people do, not with the consequences of their actions. Kant said that you should always act in such a way that you would be willing for it to become a general law that everyone else should do the same in the same situation.

Some people believe that a person's moral values are determined by the society they grow up in and there are no common moral values. They think that moral values are simply customs that are different for every culture and change over time.

Ethical problems

Ethical problems occur when two or more values suggest conflicting actions or conflicting judgements about an issue or action. Your Criterion D topic may involve discussing biomedical ethics.

Here is a simple example: the use of pig organs as replacement parts for humans (xenotransplantation). Relevant scientific information includes the following: pig anatomy is very similar to humans, there is a shortage of human donors and pig viruses may be transferred to humans. These are not ethical issues – they are scientific facts.

Moral arguments against pig transplants might include: it is wrong to exploit animals in this way and it violates the 'laws of nature' or the 'rights of animals'. Religious arguments can also be used, for example, pigs are 'unclean' animals in Islam.

Biomedical ethical questions usually revolve around the following issues

- The right of people to make their own decision (autonomy)
- What it means to be a human being (personhood)
- Doing good to other humans (and living organisms) (beneficence)
- Not harming other humans (and living organisms)
- Justice or being fair to all, or as many as possible
- Consequences, or the effect of the chosen action

Here is a story for you to practice on

A man is told that his liver is damaged beyond repair and he needs a liver transplant otherwise he will die. However, the liver was damaged in part because of alcoholism. The man can only receive a liver from a dead donor. Normally people go on a waiting list and wait many weeks to several years before getting a new liver – many die. However, the man underwent a successful transplant within two days. He was a famous footballer.

Many hospitals and universities use ethics committees – groups of people who meet to discuss ethical issues as they arise. How do the appointed people make their minds up about complex issues like these? Well, there are two approaches to dealing with ethics: looking at the rights of an issue, and considering the consequences.

The purpose of an ethics committee is to protect the dignity, rights, safety and well-being of the individuals or patients involved. Ethics committees have been used in medical research for many years – they are set up by local health authorities and government agencies to make sure that no harm (physical or mental) comes to people or patients taking part.

IVF (*in vitro* fertilisation) is a treatment available to couples who are having trouble getting pregnant naturally. It involves combining the sperm and the ovum (egg) outside the body, then implanting any resulting embryos back into the woman.

Here are some potential ethical questions related to IVF

- Should a married convicted child molester or murderer be allowed to undergo IVF?
- Should unmarried couples get IVF treatment?
- Should gay and lesbian couples be allowed to undergo IVF?

Other ethical questions can also arise, such as whether parents should be able to select the gender, eye colour, hair colour or any other feature of their child. This can include selecting children in order for them to be suitable as donors (bone marrow, kidney) for older siblings who may suffer from a genetic disorder or disease. This younger sibling is known as a 'saviour sibling'. This issue was explored in the film, 'My Sister's Keeper'.

It can be argued that the parents are not treating this saviour sibling as a human being of equal worth to other humans–it is a commodity. The parents are not creating this saviour sibling to be a child in its own right. They have created it–designed it–to be a source of spare parts for an existing child.

It could also be argued it is wrong to create a child with whom to perform this particular procedure, because the child would grow up knowing that it had been created for this particular function and this knowledge could be psychologically damaging.

While there is potential harm, it is not without potential benefits to the saviour sibling. The donor child might derive pleasure from knowing that s/he has saved his/her sibling's life and would benefit from the saved child's company. You should recognise that the interests and concerns of society influence the directions of scientific research and developments in technology. This is often achieved by politicians controlling the extent of funding for research in different areas.

EXERCISE 4.1

Draw up a list of bioethical arguments to argue whether or not the man (i.e. in the first paragraph) should have been given a new liver.
Use the list of biomedical issues shown above to help you.

4.2.3 GLOBAL WARMING

Economics: The extraction and processing of crude oil is a multi-billion dollar industry. If there are major reductions in fossil fuel use then there will be an impact on many industries, for example, the car industry and air and sea travel. In the colder areas of the U.S. farm belt, global warming has allowed for a longer growing season. Polar caps melting along the Northwest Passage will allow for cheaper shipping costs.

Political: Kyoto Protocol – the agreement has found the most support in countries whose governments are on the 'political left'. Some of the 'political right' oppose the Kyoto Protocol or dispute the scientific consensus on global warming. Canada has predicted that the Northwest Passage will be open to shipping in ten years time. Scientists in Canada have announced an increase in defence spending to defend its sovereignty. The political cost to a government of radically changing their country's fossil fuel policy, could cause them to lose elections at home and to lose out economically as their exports could become more expensive than other countries who do not choose to change their fossil fuel policy.

Cultural: The cultures that are the most at risk in the face of climate impacts are those that are unable to adequately prepare for or adapt to the changes that will affect them. Often this means that the poorest people in the world will suffer the most. For instance, nations with large populations near sea-level, like small islands, may be forced to relocate urban centres as sea levels gradually rise. The Inuit culture of the Arctic faces numerous threats to their culture due to climate change, in part because their culture relies so heavily on predictable weather patterns. Cultures that depend on agriculture may be forced to change their crops to species more suitable to an altered regional climate.

Environmental: Sea levels may rise due to the melting of the ice caps. This will cause flooding in many low-lying areas of the world. There may also be changes in the frequency and distribution of hurricanes. The range of insect pests may also change.

Ethical: should rich, developed countries contribute the majority of the money needed to develop reasonably priced alternative fuels and help low-lying countries like Bangladesh and the Maldives cope with the effects of rising sea levels? Should rich countries accept 'global warming refugees'?

4.2.4 BIOFUELS

Ethical: large tracts of agricultural land is now being turned over to growing crops for biofuels (ethanol from sugar cane and biodiesel from oil seed rape), when malnutrition is still a significant global issue. *See Figure 401.*

Economics: Some economists believe that global food prices have risen partly because of this trend.

Figure 401 A car which runs on biofuels

from https://commons.wikimedia.org/wiki/Category:Biofuel-powered_vehicles#/media/File:Bio_Powered_Benz.jpg

EXERCISE 4.2 (a)

You have seen several examples of topics which have been briefly discussed in terms of cultural, ethical, political, economic and environmental factors. The topics discussed were global warming and, very briefly, biofuels.

Consider the issue of 'GM crops'. Do some research on the Internet and read some relevant books in the library and then summarise your findings under the following headings:

- Cultural
- Ethical
- Political
- Economic
- Environmental

This kind of exercise could be the very first steps in preparing to write a Criterion D Task. The next step would to be the use the Criterion D task planner described in the next section.

OR

EXERCISE 4.2 (b)

You have seen several examples of topics which have been briefly discussed in terms of cultural, ethical, political, economic and environmental factors. The topics discussed were global warming and, very briefly, biofuels.

Consider the issue of 'The use of drugs in sport'. Do some research on the Internet and read some relevant books in the library and then summarise your findings under the following headings:

- Cultural
- Ethical
- Political
- Economic
- Environmental

This kind of exercise could be the very first steps in preparing to write a Criterion D Task. The next step would to be the use the Criterion D Task planner described in the next section.

(no suggested answers are given)

4.2.5 RESEARCHING AND DRAFTING A CRITERION D TASK

Reading and note-taking

- In your science notes, always mark someone else's words with a highlighter. Record the author and page number.
- Indicate in your notes which ideas are taken from sources, and which are your own ideas or thoughts.
- When information comes from sources, record relevant documentation in your science notes (book and article titles; URLs on the Web).

Writing paraphrases or summaries

- Use a statement that credits the source somewhere in the paraphrase or summary, e.g. 'According to Smith... '
- If you are having trouble summarising, try writing your paraphrase or summary of a text without looking at the original, relying only on your memory and notes.
- Check your paraphrase or summary against the original text; correct any errors in content accuracy, and be sure to use quotation marks to set off any exact phrases from the original text.
- Check your paraphrase or summary against sentence and paragraph structure, as copying those is also considered plagiarism.
- Put quotation marks around any unique words or phrases that you cannot or do not want to change, e.g., 'Only within the moment of time represented by the present century has one 'species': man–acquired significant power to alter the nature of his world' (Smith, 95).

Writing direct quotations

- Keep the source author's name in the same sentence as the quote.
- Mark the quote with quotation marks, or set it off from your text in its own block; follow the style guide of your school.
- Quote no more material than is necessary; if a short phrase from a source will suffice, do not quote an entire paragraph.
- Use quotes that will have the most rhetorical, argumentative impact in your paper; too many direct quotes from sources may weaken your credibility, as though you have nothing to say yourself, and will certainly interfere with your style.

Writing about another's ideas

- Note the name of the idea's originator in the sentence or throughout a paragraph about the idea.
- Use parenthetical citations, footnotes, or endnotes to refer readers to additional sources about the idea, as necessary. Be sure to use quotation marks around key phrases or words that the idea's originator used to describe the idea.

Revising, proofreading, and finalising your paper

Proofread and cross-check with your notes and sources to make sure that anything coming from an outside source is acknowledged in some combination of the following ways:

In-text citation

- Bibliography, References, or Works Cited pages
- Quotation marks around short quotes; longer quotes set off by themselves, as prescribed by a research and citation style guide.
- Indirect quotations: citing a source that cites another source.

Criterion D brochures

Your Criterion D task does not have to be presented in the form of an essay. Your MYP Science teacher may ask you to produce a poster or brochure. If this is the case, you may still be required to submit the text to turnitin.com (see Section D 3.8) and you will need to reference your work according to the guidelines of your MYP Science teacher or school.

Here is one possible scenario for a Criterion D brochure

SCENARIO

You are a scientific consultant who has been employed to write a report on the problems and solutions relating to the issue of the corrosion of iron and steel in the construction industry.

Your report will take the form of a brochure.

AUDIENCE

The audience for your piece of work is a manager in the construction or oil industry. They may not have a scientific background so the scientific content and terminology in your report must be carefully explained.

In a brochure you must include a number of annotated diagrams and chemical equations, as appropriate, to illustrate the basic principles of corrosion and rusting. Try to avoid including large paragraphs of text – use diagrams and equations to get your ideas across and then clearly explain them where required.

Here are some stimulus questions with a few 'skeleton answers' that can be explored in more detail

- Why does iron corrode (rust)? What is the chemistry involved? *Refer to Figure 402*.

Give the conditions and equations. Rusting is actually a complex electrochemical process.

- What are iron and steel used for in construction, and why are they used despite the likelihood of them corroding?

Reinforced concrete contains steel bars for tensile strength. They are relatively cheap and can be rust proofed.

- In what environments is corrosion of iron a problem? Give examples of places or situations where corrosion prevention is particularly important.

Environments that contain salts, have a high humidity and have cold winters and hot summers. Bridges and oil rigs.

- How can metallic corrosion be prevented? Explain the science behind at least two methods of corrosion prevention.

Sacrificial protection, galvanising and coating with zinc phosphate.

- What are the economic problems of corrosion? How do they affect your chosen industry? What costs are involved?

A number of bridges have collapsed due to rusting; reinforced concrete can be weakened by rusting. Large amounts of money are spent annually on rust prevention.

- What are the environmental problems of corrosion? Is corrosion always bad? Is corrosion worth preventing?

A number of bacteria can grow in areas where there are high levels of iron ions, but this will be harmful to plants.

Figure 402 The rusting of iron is a serious problem

4.2.6 CRITERION D TASK - PLANNING GUIDE

It is very important that you plan an outline of your Criterion D report before you start writing it. The section below shows a partially completed Criterion D Planner for the issue of photochemical smog written by a student living in Singapore.

CRITERION D – TOPIC PLANNER.

Student name: ______________________________

Teacher name: ______________________________

Title of topic: Photochemical smog

Some of the key problems/issues associated with this topic that i will discuss, are:

1. Conditions required for production of photochemical smog
2. Chemicals present in photochemical smog
3. Effect on human health
4. Reducing photochemical smog levels

Some examples of how science is applied to solve the problem(s) are:

1. Catalytic converters
2. Use of compressed natural gas (CNG)
3. Use of public transport
4. Use of electric and hybrid vehicles

The reasons why I chose each of the examples above are

1. Three way catalytic converters are compulsory for all petrol-based cars in Singapore and their operation is well described in text books
2. A fleet of taxis in Singapore have been retrofitted to run on CNG
3. Excellent public transport is provided in Singapore
4. Hybrid vehicles are becoming increasingly popular with consumers

Explanation of how science is applied and used to address the problem

1. Photochemical smog is produced when sunlight shines on nitrogen oxides and volatile organic compounds in the lower atmosphere producing airborne particles and ground-level ozone (key chemical equations and formulas should be included).

2. A catalytic converter converts toxic pollutants in exhaust gas into less toxic pollutants by catalysing a redox reaction. A catalytic converter contains transition metal elements that provide a surface for the pollutant gases to adsorb and undergo reactions with a lower activation energy than would be the case without the catalyst.

Some key points related to my discussion of the implications of using science and its application to solve a specific problem or issue interacting with a factor: (a) social (b) economic (c) political (d) environmental (e) cultural (f) ethical

Chosen factor: Economic costs associated with retrofitting catalytic converters and economic factors associated with the health and environmental effects of photochemical smog.

Some examples of key scientific vocabulary that I will use in this topic

Primary pollutant, secondary pollutant, photochemical, temperature inversion, ozone, peroxyacyl nitrates (PAN), particulates, anthropogenic (man-made), fossil fuel, volatile organic compound (VOC), ozone and troposphere.

Details of key sources of information that I have chosen to use in my essay

1.

2.

3.

4.

5.

How I will communicate my ideas effectively e.g. how I will structure and format my report and what types of table/graph/chart I will use

Conditions required for photochemical smog formation; summary of chemical products; health effects of products; graph showing pollutant levels during a day; approaches to reducing photochemical smog levels: catalytic converters, basin and inversion layer.

4.2.7 CRITERION D TASK EXEMPLAR

The new science of nanotechnology is an excellent topic for you to explore in a Criterion D report. A 'skeleton' of a Criterion D report is reproduced to give you a 'feel' for the style and approach required by Criterion D. Suitable diagrams and photographs must be added (and referenced). The maximum word count for a Criterion D report is 1,200 words.

Nanotechnology – threat or promise?

Molecular nanotechnology is a 'bottom up' approach to manufacturing in which individual atoms and molecules are assembled to build tiny machines or useful materials. This is in contrast to the traditional 'top down' approach where a large piece of material is cut down or etched to the required size. The realm of nanotechnology is the nanometre (10^{-9} m) scale. To set this in context, a red blood cell is 2.5 micrometres in diameter (a micrometre is equal to 1000 nanometres); the head of a pin is approximately 1 million nanometres across (Bonsor and Strickland).

In 1959 Richard Feynman delivered a talk entitled "There's Plenty of Room at the Bottom", in which he demonstrated that there was sufficient room on the head of a pin to write all 24 volumes of the Encyclopedia Britannica (Feynman 117). He described ways in which it might be possible to construct computer circuitry and machinery of tiny dimensions via the manipulation of individual atoms. He speculated that one day it might be possible to inject tiny mechanical surgeons into a blood vessel and have them repair our organs and tissues from inside our bodies. Miniaturization was an underlying technological trend in the electronics and computer industries and therefore the move towards nanotechnology was inevitable (Nanotopia).

In 1981 Gerd Binnig and Heinrich Rohrer of IBM's Zurich laboratory developed the Scanning Tunneling Microscope (STM) which scans an atomically fine probe across the surface of a material and detects small electrical currents (which arise due to a phenomenon called quantum mechanical tunneling). The changes in current that occur as the probe moves are used to develop an image of the surface (Mongillo 57). Due to the thermal motion (vibration) of the atoms at room temperature the original images were fuzzy. Cooling the material being scanned to low temperatures using liquid helium helped somewhat, but the images were still spoiled because loose atoms jumped onto the tip of the probe. If the charge on the tip is changed, the atoms can be moved around and dropped off at will (Nanotopia). On April 5th, 1990 in the journal *Nature*, scientists from IBM's Almaden Research Centre announced that they had spelled out the IBM logo using individual xenon atoms on a nickel surface. Many copycat feats of atomic and molecular manipulation were to follow (Regis 225).

In 1986 K. Eric Drexler published *Engines of Creation*, in which he set forth a vision of how nanotechnology could revolutionize manufacturing and explored the potential impacts of the technology on society. Drexler realized that (at the cellular level) a cow is a machine for converting grass into beef steak and suggested that the laws of physics do not preclude taking grass and water and reassembling their molecules into a steak using nanoscopic machines called 'assemblers'. Drexler's assemblers consist of a nano-sized computer attached to an atomic probe (similar to the STM probe described above). The assemblers would first replicate themselves, rapidly multiplying in a geometric progression (1, 2, 4, 8, 16, 32 etc.) until there were a sufficient number to produce objects (Bonsor and Strickland).

Many products on the market are already benefiting from nanotechnology. Sunscreens containing nanoparticles of zinc oxide or titanium oxide have been developed; the smaller particles are less visible which means the sunscreen does not give the person who applies it a whitish tinge. Clothing can also be impregnated with zinc oxide nanoparticles which impart enhanced protection from ultra-violet radiation to the wearer (Bonsor and Strickland). Pilkington's Activ Glass has a thin (<20 nm thick) coating of nanoparticles which are hydrophilic and photocatalytic. The photocatalyst absorbs ultra-violet light and becomes energized in such a way that it is able to break down organic contaminants on the glass. The hydrophilic (water loving) nature of the coating decreases the contact angle between water droplets and the surface allowing the water to spread out more evenly and clean the surface. Using nanoparticles to achieve the opposite effect (i.e. an increase in the contact angle between water droplets and the surface, which has been dubbed the Lotus effect) creates a 'self-cleaning' hydrophobic surface. Even something as sticky as honey runs off a spoon treated with a 'Lotus-Effect®' surface, leaving nothing behind. Another example of bio-inspired nanotechnology are the artificial gecko adhesives which emulate the tiny bristles on a gecko's foot that allow it to cling to smooth surfaces even when hanging upside down (Forbes 79). Nanotechnology is finding many potentially beneficial applications in medicine. Investigators at Rice University have developed so called nanoshells (silica spheres coated in gold). It is possible to attach antibodies to the surface of the nanoshells so that they bind selectively to cancer cells. When the nanoshells are irradiated with infra-red radiation the gold coating superheats and destroys the cancer cell. Trials have been conducted in mice and human trials are scheduled to commence within a few years. Nano-sized biosensors are being developed to monitor glucose levels in the bloodstream of diabetes patients and silver nanoparticles are being used in surgical bandages and dressings to kill micro-organisms (Mongillo 103).

Nanoparticles are finding their way into more and more products and applications. There is a concern that some nanoparticles may be toxic and that they may be able to cross the blood-brain barrier which protects the brain from harmful chemicals in the bloodstream (Bonsor and Strickland). More research is required into the potential physiological effects of nanoparticles. There is also a technical barrier to the development of nano-size products such as gears, bearings, transistors and nanowires. Whilst engineers like Eric Drexler have been able to design many of these components, the ability to assemble them from simple molecular precursors still eludes us.

Organizations such as the 'Foresight Institute', 'The Centre for Responsible Nanotechnology (CRN)' and 'The Nanoethics Group' have worked to highlight the social and ethical implications of nanotechnology. It is important that rigorous technical standards and policies are developed to ensure that nanotechnology is used ethically and safely. Eric Drexler has pointed out that unless there are stringent controls on the programming and release of nano-sized assemblers they could malfunction and replicate out of control, consuming the resources of the entire planet in the process and turning it into 'grey goo'. The potential of nano-robots as weapons of mass destruction should not be overlooked and must be carefully guarded against. *Conversely*, nanotechnology may actually help to restore anthropogenic (man-made) damage to the environment and could bring about an end to pollution. Nano-assemblers may one day be used to repair the ozone layer and clean up toxic organic molecules such as dioxins by rearranging the molecules into safer products. Nano-robots might be used to collect toxic heavy metals from the soil so they can be disposed of down the shafts they were originally mined from. Landfills would become a thing of the past as all refuse could potentially be recycled.

Nanotechnology has the potential to significantly improve human life. If nano-assemblers are developed that can cheaply fabricate virtually any object from the abundant elements in the Earth's crust, biosphere and atmosphere it would potentially spell the end of poverty and materialism. Using nanotechnology to repair and enhance our bodies could significantly extend human life spans. However, as Bonsor and

Strickland point out: 'since almost every new technology starts off as very expensive, would this mean we'd create two races of people – a wealthy race of modified humans and a poorer population of unaltered people'? Molecular manufacturing could potentially have a significant impact on the world economy. If any item could be manufactured using molecular assemblers, this would presumably lead to widespread unemployment in the manufacturing sector. Currency might be devalued to such an extent that it completely disappears.

Nanotechnology carries the promise of improved health and quality of life, but lurking beneath is the threat of the exact opposite if the technology is not safely and ethically employed.

Works cited

Bonsor, Kevin, and Jonathan Strickland. "HowStuffWorks "How Nanotechnology Works"." Howstuffworks "Science Channel". 23 Feb. 2009 <http://science.howstuffworks.com/nanotechnology.htm>.

Chen, Andrew. "The Ethics of Nanotechnology (ActionBioscience)." ActionBioscience–promoting bioscience literacy. 23 Feb. 2009 <http://www.actionbioscience.org/newfrontiers/chen.html>.

Drexler, Eric. Engines of Creation: The Coming Era of Nanotechnology. New York: Anchor, 1987.

"Ethics of Nanotechnology." Nanotechnology. 7 Feb. 2007. 23 Feb. 2009 <http://www.nanotech-now.com/ethics-of-nanotechnology.htm>.

Feynman, Richard P. The Pleasure of Finding Things Out: The Best Short Works of Richard P. Feynman. New York: Basic Books, 2000.

Forbes, Peter. The Gecko's Foot: How Scientists Are Taking a Leaf from Nature's Book. New York: Harper Perennial, 2006.

Mongillo, John. Nanotechnology 101 (Science 101). New York: Greenwood Press, 2007.

Nanotopia. Horizon BBC London August 8th 1995.

Regis, Edward. Nano!. New York: Bantam Books, 1997.

A teacher's comments about this essay

The nanotechnology essay (above) achieves in the top band of **Criterion D: Reflecting on the impacts of Science** as it:

- Explains how science is applied in nanotechnological applications (see, for example, paragraph 5).
- Discusses and evaluates the implications of the use and application of nanotechnology interacting with the following factor: environmental (paragraph 7). Note that discussion requires a range of arguments from different viewpoints (note the use of the key word 'conversely' in paragraph 7).
- Consistently applies scientific language to communicate understanding clearly and precisely.
- Fully documents sources of information completely and correctly (this requires crediting fully all sources of information used, following a recognized referencing system, in this case MLA). Note that references are included in-text and also at the end of the essay in a reference list (bibliography).

SECTION 4.3 APPLYING SCIENTIFIC LANGUAGE EFFECTIVELY

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **apply** scientific language to communicate understanding but does so with **limited success**

3-4 **sometimes apply scientific language** to communicate understanding

5-6 **usually apply** scientific language to communicate understanding **clearly and precisely**

7-8 **consistently apply** scientific language to communicate understanding **clearly and precisely.**

4.3.1 CONSISTENTLY APPLYING SCIENTIFIC LANGUAGE TO COMMUNICATE UNDERSTANDING CLEARLY AND PRECISELY

Reasoning is an activity that requires putting together thoughts that combine data and logical arguments. Scientific thinking depends on language; in other words, you need words and grammar to effectively communicate what you are thinking and/or doing during an MYP Science investigation, MYP Science test or writing a Criterion D report.

You should aim to meet the following expectations when writing in scientific language by being:

- **Precise in its use of terminology;** for example, do not use the word 'weight' when 'mass' should be used
- **Explicit**; for example, the function of a water bath is to maintain a reaction mixture at a fixed temperature, so that a change in temperature (which would affect the rate) does not occur.
- **Analytical and critical**; for example, the graph shows an approximate linear relationship, but there is some scatter
- **Explanatory** (explains); for example, 'short wavelength visible radiation absorbed by the Earth's surface is re-emitted at a longer wavelength in the infra-red region of the electromagnetic spectrum'
- **Objective** – stick to the facts
- **Impartial** – not biased
- **Concise** (brief); for example, 'the data supports the hypothesis that global temperatures are correlated with atmospheric carbon dioxide concentration'
- **Responsible** - claims carefully made, supported where possible and use of sources acknowledged

The language used by scientists to communicate their work reflects the nature of science. Scientific language used by scientists in written reports includes the following.

- Appeals to evidence. For example, 'Based upon the raw data gathered in this investigation, ...'
- Expressions about the validity and reliability of the evidence. For example, 'The design for the investigation into amylase activity with substrate concentration needed the temperature to be controlled ....'
- Refers to accepted literature. For example, 'My textbook (suitably referenced) suggests that....'
- Expressions of uncertainty. For example, 'This was an initial study ...', 'The sample size was small ...'

4.3.2 STYLE, VOCABULARY AND GRAMMAR

- 'I' or 'You' are avoided in most scientific writing
- Contracted verb forms avoided: can't, doesn't should be cannot, does not
- Formal rather than colloquial English; vague/imprecise words should be avoided: stuff, things, loads, lots - materials, issues, significant number/ large quantities
- Spoken negatives should be avoided: 'there are not many' better to write 'few'
- Common use but not overuse of passive: 'Two cubes of liver were then selected...' rather than 'I then selected two cubes of liver.....'
- Complex sentence structure (with more than one clause) to relate ideas and improve the flow of ideas.

4.3.3 USE OF SCIENTIFIC TERMS

Science uses a specialised vocabulary with many technical words and definitions. For example, *osmosis* is defined as the diffusion of water across a selectively permeable membrane from a region of low concentration of solute to a region of high concentrations of solute. Solute, concentration and selectively permeable are also technical words with their own definitions.

Hence, the learning of scientific language can be regarded as like learning a 'foreign language', even if you are a native English language speaker. Many students find it is not the scientific content that is difficult, but the way science teachers and textbooks talk or write about it. Many scientific words, such as force and power, can only be understood in the context of their scientific use.

Perhaps the most difficult words to understand and apply are polysemic words - words that carry a specific technical meaning in science, but a different meaning in everyday use. A number of misunderstandings may occur:

Scientific confusion

This may arise due to a partial and confused understanding of the underlying concept. For example, students may confuse 'volatile' with 'condensing', 'mass' with 'weight' and 'concentrated' with 'dilute'.

Scientific obscurity

Terms, such as **element** (in the context of chemistry), **momentum** (in the context of physics) and **tissue** (in the context of biology) may have no meaning, or quite a different meaning, to students.

Scientific/everyday confusion

With this group of words, students may be confused by the precise scientific meaning of the word and its everyday usage. Examples include: conservation, law and work. For example, the scientific concept of conservation of mass is sometimes confused by students with the idea of depletion (using up). Similarly, a word such as 'work', as used in physics, is sometimes confused with mental work.

A helpful approach to scientific terms in your Criterion D report is to write a glossary of new technical and scientific terms and append the glossary to the end of the Criterion D report. Three entries are shown in *Figure 403* for a small part of a stem cell glossary. Many textbooks have a glossary of terms located at the back of the book; specific science glossaries are also available in print form or on-line.

Somatic stem cells

Non-embryonic stem cells that are not derived from gametes (egg or sperm cells).

Stem cell

Cells with the ability to divide for indefinite periods in culture and give rise to specialised cells.

Trans-differentiation

The process by which stem cells from one tissue differentiate into cells of another tissue.

Figure 403 A small selection of a stem cell glossary for a Criterion D report

4.3.4 DISSECTING WORDS

Some words, including many scientific words, can be dissected or broken down into different parts.

Many words have three parts to them:

a **prefix** - comes first, a **root** - goes in the middle a **suffix** - on the end.

For example, expiration *ex-* is the prefix, which means 'out' or 'out of', *spiri-* is the root, means 'breath' and *-ation* is the suffix, means 'act of'. Hence, the whole word means the 'act of breathing out'.

Figures 404 shows a small selection of prefixes and roots of words.

ab-	from
ad-	to
aero	air, oxygen
an-	without
anti-	against
auto-	self, same
bi	two
bio	life
bis	twice
cardio	heart
chrom	colour
co	with
cyto	cell
dia	across
eco	environment
geo	earth
hetero	different
hyper-	above normal
hypo-	below normal
inter-	between
intra	within
pre-	before (in time)
pro-	before (in place)
sub-	under
super-	over, above, better
syn	with, together
ultra-	more than

Figure 404 The meanings of some prefixes

Some common meanings of roots and suffixes of scientific words are:

-able, -ible capable of; *-al, -ary* belonging to; *-ation* act of ;*-cide* death, kill; *gram* drawn; *-ic* to do with;

-ism belief in; *-ology* study of

Your MYP Science teacher should indicate what constitutes acceptable evidence for 'sometimes', 'usually' and 'consistently' apply scientific language to communicate understanding.

Remember the 'rule of thumb' that you are writing your Criterion D report for a classmate, not your teacher. Therefore all technical scientific terms must be clearly and precisely defined and explained. These terms might include: plasmid, penicillinase, penicillin, MRSA, natural selection, binary fission, conjugation, cross resistance, mutation, gene, DNA, antibiotic, cell wall, phage therapy and bacterium.

4.3.5 COMMUNICATION IN YOUR CRITERION D TASK

A Criterion D task does not have to be presented in the form of a traditional essay. It could be presented as a PowerPoint presentation, a podcast with accompanying slides, video and web site. However, remember the importance of including appropriately acknowledged pictures, diagrams, charts or tables to support your presentation.

Here is a sample Criterion D task that lends itself well to alternative forms of presentation

You are to design a presentation that will illustrate the science behind a modern form of communication technology and the impact that the technology has had on society.

Guidance questions

- How does your chosen technology work? What principles of physics are involved? What role do light, electromagnetic and/or sound waves play in making the chosen device function?
- How did your chosen technology impact on people's lives at the time it was invented? How were people's lives different before and after the technology was invented?
- What were the wider implications for society as a whole, for example, globalisation, mass media, privacy issues?
- How has your chosen technology contributed to globalisation and the ability to communicate and share ideas on a global scale?
- Describe in detail how science has been used to develop your chosen technology. What are the benefits of the technology compared to the previous technology it replaced (for example, magnetic versus optical storage, digital versus analogue signals)?
- What are the current limitations of the science/technology? How might it be further developed or improved in the near future?
- Discuss in detail some current and potential issues related to your technology (include both the pros and cons and a range of arguments including your own opinion): social, economic, political, cultural or ethical. Are there possible solutions to these issues?

SECTION 4.4 DOCUMENTING SOURCES CORRECTLY

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 document sources, wilh **limited success**

3-4 **sometimes** document sources correctly

5-6 **usually** document sources correctly

7-8 document sources **completely.**

4.4.1 WHAT IS REFERENCING AND WHY IS IT NECESSARY?

Referencing is a standardised method of acknowledging the sources of information you have consulted for writing your MYP Criterion D report or your MYP Science investigation. Words, paragraphs, quotes, figures, tables, theories, ideas, facts - originating from another source and used in your assignment must be referenced (i.e. acknowledged).

Referencing is done for the following reasons:

- to avoid plagiarism
- so that the teacher can verify quotations
- so that the teacher can follow up on the original author's thinking by consulting the source you used.

There are many ways to acknowledge sources of information appropriately, for example, MLA (Modern Language Association), and none is mandated by the IBO.

We recommend a bibliography at the end of the MYP assignment together with in-text referencing. The style we have adopted is the MLA (Modern Language Association) format. However, what is important is that the method used is consistent. Do not switch from one method to another.

Familiarise yourself with the format and terms (Figure 405) that your MYP Science teacher expects you to use.

Paraphrasing	This is explaining in your own words what the original source wrote.
Quoting	"To repeat (words) exactly from (an earlier work, speech or conversation), usually with an acknowledgement from the source" (Collins Paperback English Dictionary, 1998, p. 665). Put in quotations everything that comes directly from the text especially when taking notes. (Collins Paperback English Dictionary, 1998, p. 136).
Citing or In-Text Referencing	1. To quote or refer (to a passage, book or author). 2. To bring forward as evidence. When citing your sources, you are telling your MYP Science teacher who/what the original source was. You are giving credit where credit is due.
Bibliography	This is a list of cited works.
Common Knowledge	These are facts that are located in several sources and probably known by many scientists. You do not have to document these facts, for example, bacteria do not have a nucleus.

Figure 405 Some terms to know

4.4.2 IN-TEXT REFERENCING

In-text referencing is when you provide information about the source in the text of your MYP assignment. The bibliography at the end of your essay shows the reader which sources were researched but sometimes that is not enough. That is when you use in-text referencing inside your essay. Usually the author's last name and a page reference are enough to identify the source. With this information, the reader can find the complete publication information in your citation list at the end of your Criterion D report.

Tips for in-text referencing

When you find a useful resource for your MYP Criterion D report, note down all the details required in your bibliography (e.g. author, title, publication details, date of access, URL etc.) before you start taking notes.

When reading a resource highlight key words, main ideas or make bullet point notes that you might want to include in your Criterion D report.

If you use the exact words from the writer, put them inside quotation marks so you do not accidentally plagiarise, and if possible note down the page number. But always remember that a Criterion D report should be mostly in your own words.

Examples of in-text referencing

Signal phrase: introduces where the idea or quote comes from and usually has the author's name in the text.

According to Trivedi, if certain bacteria are introduced into our stomachs we may be able to eat what we like and still be slim (68-69).

(Signal phrase = According to Trivedi)

Paraphrase or Summary: the idea in your own words or the main ideas only.

Current research suggests that some intestinal bacteria will allow us to eat whatever we want and not become obese (Trivedi 68-69).

Direct Quote: show that these are the exact same words used in the source with quotation marks.

"*We are in a new world where the bacteria might be in much more control of us than we can possibly imagine*" *(Trivedi 47).*

Citation in Bibliography: this is the source with the full publication details.

Homewood, Jon "The effect of global warming on amphibians". New Scientist. 1 October 2009: 38-41.

Because Internet sources typically have no page or paragraph numbers, and websites often list no author, people are often confused about how to refer to these sources within their papers. The answer is to cite the author's name whenever possible, and use the source's title otherwise (or a shortened version of the title). If no page or paragraph number is provided, leave that portion of the citation blank. Keep in mind that the primary purpose of an in-text citation is simply to point readers to the correct entry on the "Works Cited" page.

Online Encyclopedia Article

Author. (family name first) "Title of article". Magazine title . Date of Magazine: Page numbers. Product Name. Date researcher visited site. <Electronic Address, or URL, of the source>.

e.g.: Churchman, Deborah. *"Be a Nature Detective"*. Ranger Rick March 1999: 28-31. MasterFILE Premier on-line. EBSCO Publishing. 30 Feb. 2004.

<http://www/epnet.com/ehost/login.html>.

4.4.3 WEBSITE EVALUATION CHECKLIST

It is important that you select your websites carefully and you evaluate them before using the information from them in your Criterion D report. Below is a useful list of questions to ask yourself.

Accuracy

- Are there any factual, grammatical, spelling or language errors on the site?
- Is the information correctly cited?

Authority

- Is the person or organisation putting up the information a qualified expert?
- Can the author(s) be contacted (email, postal address)?

Objectivity

- Is the motive of the author/publisher clear?
- Are all opinions treated fairly?

Currency

- Can you find a date on the website?
- Has the information been updated recently?
- Do all the links on the website work?

Coverage

- Is there a good balance between text and graphics?

■ 4.4.4 HOW TO PREPARE A BIBLIOGRAPHY

How to cite sources

Books
Author's name (put family name first). Title. Place of publication: Publisher, Year of Publication.
Note: titles can be underlined or put into italics
e.g.: Andrew, John. Chemistry in Focus. United Kingdom: Hodder and Stoughton, 1999.

Two authors (note the order of names for the second author)
McKissack, Patricia, and Frederick McKissack. Modern Biology. United Kingdom: Oxford University Press, 1995.

Three or more authors
Adams, Roger *et al.* Encyclopedia of Science. New York: Consolidated Press, 1994.

Encyclopedia article
'Article title'. Title of Encyclopedia. Year of Publication.
Note: put title of article in speech marks
e.g.: "Ozone layer". World Book Encyclopedia. 2009.

Interview
Name of the person interviewed. The kind of interview (personal, telephone, email). Date or dates of interview.
e.g.: Martin, J. K. Email interview. 8-12 May 2008.

Magazine Article
Author. "Article title". Magazine title. Date of Magazine: Pages.
Note: the use of speech marks and underlining
e.g.: Churchman, Deborah. "Global warming: the sceptic's view". New Scientist. March 1999: 28-31.

Remember also that:

- citations should not be numbered
- citations should not be separated into different formats (e.g. books, websites, interviews, etc.)
- citations should be in alphabetical order by the main entry (e.g. author's surname, title, article title, etc.)
- ignore 'a', 'an', 'the'.

Website
Author (if available). "Title of the article." (in speech marks) Title of whole site. Date of visit to site. <URL of Page>.

e.g. "Using MLA Format." Purdue University Online Writing Lab. January 23, 2006. <http://owl.english.purdue.edu/handouts/research/r_mla.html>

4.4.5 BIBLIOGRAPHY SELF-CHECKLIST

Acknowledging sources of information appropriately is an essential component of **Criterion D: Reflecting on the impacts of science.** *Figure 406* (below) is a checklist that you can use to review your bibliography before you submit your Criterion D report to your MYP Science teacher for grading.

Alphabetical order of entries (ignore 'the', 'a')	
All font sizes and styles are the same, e.g. all Times New Roman 12	
All the words in black, there are no blue URLs	
Family name of author comes first	
If there are two authors, the second author's name is in the normal order	
The URL is not underlined	
The URL has < > brackets around it	
The acronym 'URL' is not part of the entry	
Website titles are used as well as the article title and they are the only item underlined	
All separate parts of an entry are divided off by full stops	
Book titles and website titles are underlined or in italics	
Date of access is included in all website entries (no full stop after it, the months are shortened to three letters)	
"Article titles" from magazines and websites have speech marks around them	
Place of publication is followed by a colon	
Publisher comes after place of publication followed by a comma	
Year of publication is the last part of a book entry followed by a full stop	
No subheadings are used in the bibliography	

Figure 406 A Bibliography checklist

If you wish, there are several on-line bibliography makers. Try them out but you are advised to use the MLA version (unless your school prescribes another format) and take care with the data you enter otherwise you may lose marks.

Try: 'Landmarks Citation Machine', <www.bibme.org> or <www.easybib.org> for example:

<http://www.killerstartups.com/Web20/bibme-org-the-quickest-way-to-build-a-bibliography>

<http://citationmachine.net/>

EXERCISE 2.1 (CHAPTER 2, PAGE 28)

The value of the resistance could be measured. Relationships could be established between resistance and temperature, cross-sectional area and length. The resistance of a variety of metals could be measured and compared and accounted for by a simple metallic bonding model.

EXERCISE 2.2 (CHAPTER 2, PAGE 28)

1. To find the relationship between the rate of oxygen release from hydrogen peroxide by catalase (from a potato strip) and the concentration of hydrogen peroxide.
2. To find the relationship between the length of the rubber band and the load suspended from it.
3. To find the relationship between the rate of reaction between zinc and hydrochloric acid and the temperature of the acid.
4. To find the relationship between the rate of photosynthesis (as measured by the number of bubbles released) and the intensity of visible light.

EXERCISE 2.3 (CHAPTER 2, PAGE 36)

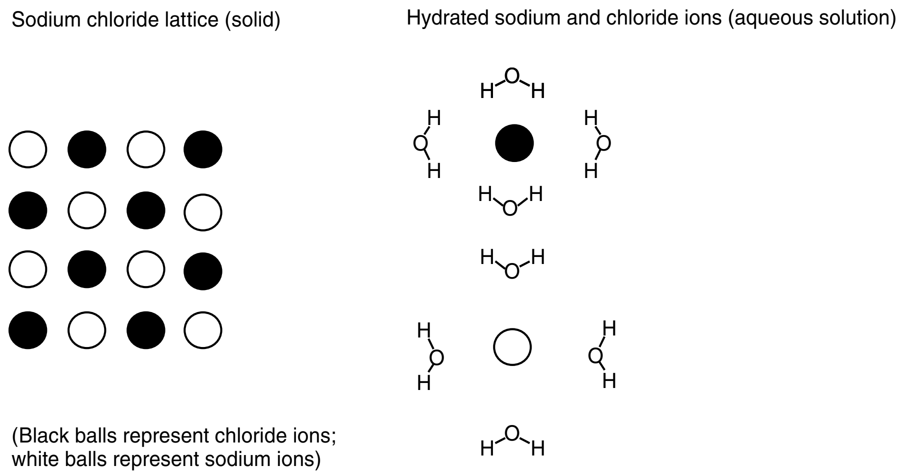
In this Investigation, I predict that when the temperature of the water increases, the time it takes for sodium chloride to dissolve in it decreases.

- What happens when salt dissolves in water

When salt dissolves in water, the ions making up sodium chloride (Na^+ and Cl^-) are separated from each other by their interaction with water molecules. In this interaction, the water molecule collides with the ion and they join together. The ions are therefore spread out between water molecules and salt gets dissolved. (see below).

- Effect of temperature on the dissolving process

At a higher temperature, the water molecules have more kinetic energy and move faster. Thus the collisions between the water molecules and the ions will happen more often. Also, at faster speeds, the impact of the collisions will be stronger and successful collisions will occur at a faster rate. Therefore salt will dissolve faster or the dissolving process will take less time.



(Black balls represent chloride ions; white balls represent sodium ions)

EXERCISE 2.4 (CHAPTER 2, PAGE 38)

Aim	Independent variable	Dependent variable
1. How do different types of exercise affect my pulse rate?	Type of exercise	Pulse rate
2. In this Investigation, I will investigate the effect of the type of surface on the height the ball bounces.	Type of surface, for example, rubber, carpet etc.	Height of bounce
3. In this Investigation, I will investigate the effect of mass of fertiliser on the growth of grass.	Mass of fertiliser	Height of grass
4. In this Investigation, I will investigate the effect of light on the rate of photosynthesis.	Intensity of light	Number of oxygen bubbles (per minute)
5. In this investigation I will find the relationship between the amount of acid and the amount of hydrogen gas (Is this a good statement of the aim? Why or why not?) Yes, but the acid needs to be specified and whether the reaction is stoichiometric (reacting proportions or limiting reagent) needs to be clarified.	Volume of acid (of known concentration) e.g. hydrochloric or nitric acid	Total volume of hydrogen gas collected

EXERCISE 2.5 (CHAPTER 2, PAGE 41)

In order: continuous, ordered, categoric and discrete.

EXERCISE 2.6 (CHAPTER 2, PAGE 42)

The leaves of the same plant could be confined in flasks with a chemical that absorbs carbon dioxide, while other leaves need to be put inside flasks with a carbon dioxide supply. The control is to establish whether: The biological material (in this case leaves) are healthy. The apparatus or other conditions may be involved in determining the results.

EXERCISE 3.1 (CHAPTER 3, PAGE 69)

Density = 8.8 g/cm^3

1 g = 0.001 kg and 1 cm = 0.01 m

1 cm^3 = 1 cm × 1 cm × 1 cm = 0.01 m × 0.01 m × 0.01m = 0.000001 m^3

1000 g = 1 kg   1 g = 0.001 kg

Density = 8.8/0.000001 × 1000

Density = 8 800 kg/m^3

EXERCISE 3.2 (CHAPTER 3, PAGE 71)

1. (a) 25 °C.

   (b) 298 K.

   (c) 27.0 cm^3.

   (d) 10 Pa.

2. (a) 500 J g^{-1} or J/g.

   (b) 2 kg m^{-3} or 2 kg/m^3.

   (c) 0.5 mol dm^{-3} or 0.5 mol/dm^3.

EXERCISE 3.3 (CHAPTER 3, PAGE 81)

(a) 10.0 cm

(b) 0.030 cm

(c) 78.02 cm

(d) 7.200 cm

(e) 0.002 cm

(f) 3.110 cm

(g) 1.09 cm

(h) 94.0 cm

EXERCISE 3.4 (CHAPTER 3, PAGE 89)

(i) Test tube E.

(ii) Sample C; Trial 1. Only 12.5 grams of copper (II) carbonate was used in each case. This will not increase on heating so a mass of 16.0 g cannot be expected.

(iii) The reaction had gone to completion.

(iv) Test tube D; largest decrease in mass in Trial 1.

(v) 8.0 g; this is the value after the test tubes are heated to constant mass.

EXERCISE 3.5 (CHAPTER 3, PAGE 93)

1. This is the internal body temperature.
2. Time to digest the beef completely.
3. Piece of beef in water at 37 °C or piece of beef in boiled gastric juice at 37 °C.
4. Stomach juice (gastric juice) contains chemicals that can digest beef and possibly other proteins.

EXERCISE 4.1 (CHAPTER 4, PAGE 106)

1. Autonomy

Did the person whose liver was donated choose to donate his organ to the man? If this occurred, then autonomy was maintained, but this is not typical of organ donation. Usually the person's family decide whether organs should be 'harvested'. This decision might coincide with the dying person's wishes.

2. Personhood

Organ transplantation is unnatural or goes against God's laws or nature's laws.

It could also be argued that it is more important to heal a person than to worry about whether using someone else's organ makes us less human.

3. Beneficence

The person whose liver the man received made a beneficent organ donation. Did the donor or donor's family object to the 'mutilating' of the body? This is against the culture of some groups, for example, Japanese of the Shinto faith.

4. Non-harm

What about people who had been waiting for a liver much longer than the man? Were they harmed?

5. Justice

The man did not wait a normal length of time. If he had not abused alcohol his liver might well have

stayed healthy. Alcoholism appears to have a genetic basis.

6. Consequences

Has a precedent been set?

EXERCISE 4.2 (a) and (b) (CHAPTER 4, PAGE 108)

Suggested answers are not given.

Inquiry, in the broadest sense, is the process that is used to move to deeper levels of understanding. Inquiry involves speculating, exploring, questioning and connecting. In all IB programmes, inquiry develops curiosity and promotes critical and creative thinking.

The MYP structures sustained inquiry in sciences by developing conceptual understanding in global contexts. Teachers and students develop a statement of inquiry and use inquiry questions to explore the subject. Through their inquiry, students develop specific interdisciplinary and disciplinary approaches to learning skills.

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A **concept** is a 'big idea' that provides a framework for exploring the essence of the sciences and for student inquiry into issues and ideas of personal, local and global significance. The prescribed key concepts for MYP Sciences are *change*, *relationships* and *systems*.

Change is a conversion, transformation, or movement from one form or state to another. Inquiry into the concept of change involves understanding and evaluating causes, processes and consequences. Change can be both qualitative (e.g. a colour change in a chemical reaction or changes in the appearance of an organism as it grows) or quantitative (such as a numerical variable or rate).

Relationships are the connections and associations between properties, objects, people and ideas, including the connections of human beings to the world in which we live. Relationships in sciences indicate the connections found among variables that can be tested observationally or experimentally.

Systems are sets of interacting or independent components. Systems can either be closed where resources are not removed or replaced, or open, where necessary resources are renewed regularly. Modelling often uses closed systems to simplify or limit variables.

Related concepts are grounded in specific disciplines and are useful for exploring the key concepts in greater detail. Inquiry into related concepts helps students to develop deeper conceptual understanding.

Related concepts in MYP Sciences		
Balance	Evidence	Models
Environment	Interaction	Transformation
Function	Patterns	Conditions
Movement	Energy	Consequences
Development	Form	Models
Transfer		

Global contexts direct learning toward independent and shared inquiry into our common humanity and shared guardianship of the planet. The six MYP global contexts are: identities and relationships, orientation in time and space, personal and cultural expression, scientific and technical innovation, globalization and sustainability and fairness and development. Each MYP unit that you study should have a clearly identified global context that will help you explore the relevance of your inquiry (why it matters either personally, locally or globally). Many inquiries into science concepts naturally focus on scientific and technical innovation, however you should have the opportunity to explore other global contexts in relation to the aims and objectives of MYP Sciences, e.g. a unit on evolution, geology or the universe might be explored through the context of orientation in time and space, or a unit on energy or food resources might be explored through the context of globalization and sustainability or fairness and development.

Statements of inquiry set conceptual understanding in a global context in order to frame classroom inquiry and direct purposeful learning. Some possible statements of inquiry for possible units of work in MYP Sciences are tabulated below.

Statement of inquiry	Key concept Related concepts Global context	Possible project/ study
Organisms interact with the natural environment by transferring matter and energy	• Systems • Interaction, environment, energy • Scientific and technical innovation	Ecology
Scientists observe patterns and use them to construct systems that explain how the world works	• Systems • Patterns, development, models • Personal and cultural expression	Periodic Table
Increasing electrical energy production to meet the needs of an expanding global population can have environmental consequences	• Change • Environment, consequences, development, energy • Globalization and sustainability	Magnetism and Electricity

Teachers and students use statements of inquiry to help them identify factual, conceptual and debatable inquiry questions. Inquiry questions give direction to teaching and learning, and they aid in the development of a sequence of learning experiences (lesson plans). The table below shows some possible inquiry questions for MYP Sciences units.

FACTUAL questions: Remembering facts and topics	CONCEPTUAL questions: Analysing big ideas	DEBATABLE questions: Evaluating perspectives and developing theories
What is the difference between endothermic and exothermic reactions?	How can the particle model of matter and kinetic theory be used to explain changes of state, as well as chemical reactions and rates?	How much data is 'enough' to accept a hypothesis?
How are plant and animal cells different?	How do organs in the circulatory and respiratory systems interact with one another for human survival?	To what extent is classifying chemical reactions as a particular type useful or even necessary?
How are voltage, current, resistance and power related?	How are magnetism and electricity related?	Should the use of nuclear energy be increased to meet the planet's energy demands?

PROBLEM

You are asked to investigate a candle burning inside an inverted beaker sealed with plasticine (*Figure 501*).

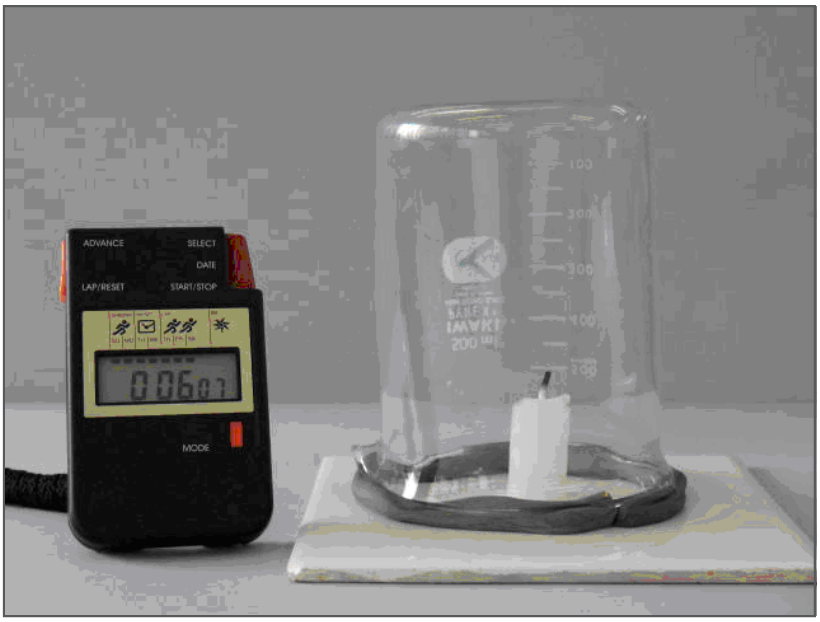


Figure 501 Combustion of a candle inside an inverted beaker sealed with plasticine

Focused problem or research question

To establish the relationship between the volume of air in an inverted glass beaker sealed with plasticine and the time a small candle burns for.

The research question indicates the point and scope of the investigation. The research question clearly indicates the independent variable (volume of the beaker) and dependent variable (the time).

Background

Candle wax is a mixture of hydrocarbons which when combusted in excess air will form carbon dioxide and water (assuming complete combustion). Combustion or burning is an oxidation process involving the addition of oxygen. Air itself is a mixture of gases with oxygen forming 21% by volume. The candle will be extinguished when the percentage of remaining oxygen falls below a certain value, which is not known, but likely to be greater than zero.

This is important information to put the investigation into context and to provide relevant scientific background for the formulation of a scientific hypothesis.

Hypothesis

It is predicted that there will be a directly proportional relationship between the volume of the glass beaker and the time a small candle burns before being extinguished.

A beaker with double the capacity will supply double the volume of air and hence oxygen for combustion. It is therefore predicted that the combustion time will double. Conversely, if the beaker capacity is halved then the volume of air and hence oxygen will be halved. It is therefore predicted that the combustion time will halve.

A hypothesis is a prediction (and associated scientific explanation, reason or validation) which can be tested experimentally. It might be qualitative, e.g. the candle will burn longer in a larger beaker, or, better still, it may be quantitative, as above, with a precise mathematical relationship predicted.

Your investigation should gather sufficient observations and/or numerical data to either validate or invalidate the hypothesis. A hypothesis cannot be half right. You must have a clear and testable hypothesis to score levels 7-8 for **Criterion B: Inquiring and designing**.

Variables

The **dependent** variable is the combustion time of the candle and the independent variable is the volume of the glass beaker. All other variables, known as controlled variables, including the dimensions of the candle and the temperature of the surrounding air in the laboratory.

The **independent** variable is the variable changed or manipulated by you during the investigation; the dependent variable are the results or measurements. A fair test means that your experiment has only one independent variable.

Independent variable

The volume of the laboratory glass beaker is measured in cubic centimetres. It will be changed by selecting five different sized beakers. The volume of the beakers is determined by filling the beaker to the brim with water using a measuring cylinder.

Dependent variable

The combustion time of the candle will be measured in seconds using a hand held electronic stopwatch. Due to human reaction times and difficulties in judging when the candle is extinguished, all times will be recorded to the nearest second.

Controlled variables

Controlled variable	How it will be controlled	Why it needs to be controlled
Same size candle	A candle with the same dimensions (i.e., cross-sectional area and length) will be used.	To ensure that the candle burns in the same volume of air and hence oxygen.
Same colour candle	The same colour of candle will be used to record the raw data.	Candles of different colours will contain different dyes which may affect the combustion time. This could be due to different molecular masses or molecular interactions between the dye and wax.
Room temperature	Set the air conditioner to 25 °C. Monitor the temperature with a thermometer..	Small temperature variations should not have a significant effect on the combustion time for the candle.
Same amount of plasticine	Sufficient plasticine will be used to seal the base of the beaker.	To ensure that the beaker is completely sealed and that times are close in value and hence reliable.

PROBLEM

You are asked to investigate the behaviour of a spring when stretched.

Focused Problem or Research Question

To establish the relationship between the force applied to a steel spring and its extension (the increase in length following an application of a load).

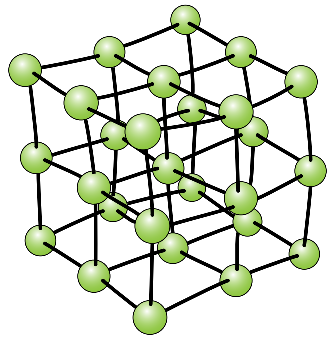
The research question indicates the point and scope of the investigation. This research question clearly indicates the independent and dependent variables.

Hypothesis

It is predicted that there will be a directly proportional relationship between the size of the force applied to the steel spring and its extension, that is, the increase in length. In other words, if the load is doubled, the extension will be doubled; if the load is halved; the extension is halved.

This behaviour is expected to be observed (at least over relatively small loads) since, according to kinetic theory, once the force is removed the steel spring is expected to return to its original length due to the action of the attractive forces operating between adjacent metal atoms in the spring.

Model



In solids the particles are attracted to each other and vibrate around fixed positions and the bonds or intermolecular forces behave like springs (*Figure opposite*), whilst in liquids and gases they are free to move. The added masses to the spring oppose these attractive forces.

A hypothesis is a prediction (and associated explanation, reason or validation often based upon a scientific model) which can be tested experimentally. It might be qualitative, e.g., the spring's extension increases with the force applied, or, better still, it may be quantitative, as above, with a precise mathematical relationship predicted. You will often be verifying or 'proving' a known scientific law – in this case Hooke's Law.

Your investigation should gather sufficient observations and/or numerical data to either support or not support your hypothesis. However, if your hypothesis is rejected, then you are expected, if possible, to come up with a new hypothesis that is consistent with your data. A hypothesis cannot be half right. You must have a clear and testable hypothesis to score levels 7-8 for **Criterion B: Inquiring and designing**.

Variables

The dependent or responding variable is the extension of the spring and the independent or manipulated variable is the load or force applied to the end of the spring. All other variables, known as controlled variables, such as the apparatus, type of spring and laboratory conditions etc. will be kept constant to ensure the investigation is a fair test.

The independent variable is the variable changed by the student during the investigation; the dependent variable is the source of the results or measurements. A fair test means that your experiment has only one independent variable. The clear identification and classification of variables is assessed under **Criterion B: Inquiring and designing.**

Independent

The load or force applied to the end of the spring, measured in newtons. It will be changed by adding masses from 100 g up to 700 g to the end of the spring. The force is calculated by multiplying the mass in kg by 10 (m/s^2) which will be used as an approximation to the acceleration due to gravity. The masses will be checked using a set of digital scales calibrated in grams.

Dependent

The extension of the spring. First the length of the spring will be measured in millimetres using a metre ruler from the top of the spring to the top of the mass and the unextended length in millimetres will be subtracted to obtain the extension. If we are measuring to the top of the suspended mass, as extra masses are added, this place will change.

You also need to explain in detail in the variables section exactly how the variables will be changed, measured or controlled (see Table below).

Controlled variable	How it will be controlled	Why it needs to be controlled
Same apparatus	The same clamp and clamp stand will be used to support the spring each time	To ensure the spring is rigidly held in place to allow precise measurement of the extension
Same spring	The same type and material of spring will be used to gather all measurements	Springs of different materials will have different spring constants and extend by different amounts when masses are added to the end
Room temperature	Set the air conditioner to 25 °C. Monitor the temperature with a thermometer.	Small temperature variations should not have a significant effect on the extension of the spring but the spring would be expected to expand as the temperature rises
Same technique for measuring extension.	The length of the spring will be measured between the same two points each time and the unextended length will be measured again at the end to ensure that it has not changed	If the spring is over-extended, its behavior will deviate from Hooke's Law, so we need to ensure that the force-extension relationship is being measured at extensions below the elastic limit of the spring.
Same size masses	The same size masses will be attached to the spring each time (brass mass 100g). Measure on an electronic balance	To ensure that the data points obtained are evenly spread out to improve the reliability of any relationship established

Method

The apparatus was set up as shown below in *Figure 502*. The length of the spring was measured using a wooden ruler with a millimetre scale (± 0.05 cm). A load of 1 newton (100 grams) was added to the spring. The spring used was a steel spring with dimensions of 16 × 20 mm (diameter × length).

The length of the spring was then measured again using a wooden ruler, and the increase in length, that is the extension, was calculated. For example, if the length is 12.0 cm and an additional 100 grams causes the length to increase to 12.5 cm, then the extension is 0.5 cm.

The measurements and calculations were then repeated with loads that increased by 1 newton (100 grams) up to a maximum of 7 newtons (700 grams). For precise measurement, the eye should be aligned with the bottom of the pointer on the ruler scale.

The method should ideally be written in the past tense, since the experiment has already been performed. It should be possible for a teacher or student to repeat the experiment and obtain the same results (within experimental error). However, a method written as a numbered or bulleted list (like a 'recipe') is also acceptable. You should also indicate how your raw data will be processed.

Results

These should be an organised record of what you observed and/or measured. It will normally consist of one or more tables of data and one or more graphs of various types. No interpretation or explanation of the results should be attempted in this section. Your results will be assessed under **Criterion C: Processing and evaluating.**

Figure 502 Apparatus for investigating the stretching of a spring

Figure 503 (below) does not record the raw data – the individual extensions – at least two trials for each mass. You must record all raw data. Figure 504 shows a graph of this data.

Force applied to the end of the spring/N	Average extension of spring/mm
0.0	0
1.0	16
2.0	34
3.0	50
4.0	67
5.0	**73***
6.0	102
7.0	119

Figure 503 The effect of a load on the extension of a spring

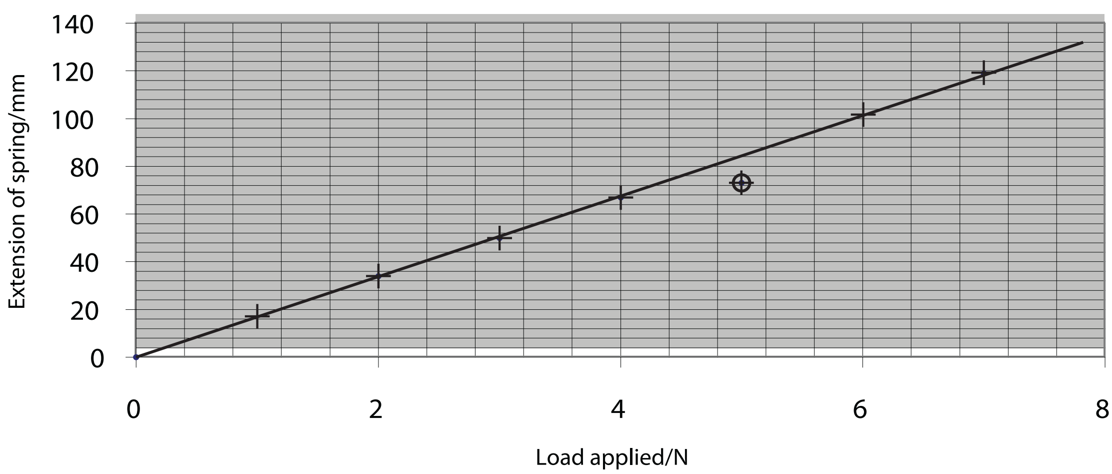


Figure 504 A graph of the results

Note the following points about this table of results:

- The column headings include the name of the variable and its associated units.
- The independent variable of the raw data is always recorded in the left hand column of the results table.
- The dependent variable of the raw data is always recorded in the right hand side column of the results table. In many investigations, time is the independent variable.
- There is a simple informative title for the results table.
- Anomalous data has been marked with an asterisk (*). This is data that appears to be inconsistent with the other data. It may be the result of an error – such data should be re-checked/verified.
- Note the consistent use of figures (decimal places and significant figures) for the expression of values of force applied, namely, two significant figures or one decimal place.
- Processed data, e.g. averages or means or rates (1/time) are placed in the right hand side of the results table.

Note the following points about this graph:

- Graphs may be drawn by hand on graph paper or drawn using the spreadsheet *Excel* – this is best as a separate sheet rather than embedded. Ensure a graph has a title (which identifies the two variables being plotted) and labels for both the x and y axes, together with associated units.
- The independent variable (often time) is plotted along the horizontal or x axis; the dependent variable (your measurements) are plotted up the vertical or y axis.
- Use a solidus(/) and the correct abbreviated form of the units when labelling both axes.
- To improve the accuracy of the graph ensure it is as large as possible. Your scales do not necessarily need to start at zero.
- Draw a small dot or cross for each data point at the appropriate place on the graph. If you plot two or more different sets of data on the same axes, then ensure that the two lines or curves are clearly distinguished.
- A straight line should be drawn through the points including the origin (0,0) but the highlighted anomalous data point should be ignored.
- If your data has points that lie on a smooth curve then usually those points should be joined together by a smooth freehand curve and not a series of small straight lines.
- A smooth curve may give rise to an inversely proportional relationship, where one variable decreases as the other increases.
- A minimum of five data points should be obtained before a straight line can be drawn on the graph.
- If there is some 'scatter', in other words, if the points do not lie on a perfect straight line (due to small errors in the measurement process), then draw a line of 'best fit' that passes as close to as many points as possible, including the origin (0,0). Note that the line of best fit should only pass through the origin if (0,0) is a valid data point.

Conclusion

This can be regarded as a summary of any relationship indicated by your results. You should refer to your research question and hypothesis. Did you record sufficient data to answer the research question of the investigation? Has your hypothesis been validated or invalidated? Examine your table of results and graphs very carefully before you write a conclusion.

The graph (*Figure 504)* indicates that, within experimental error, there is a directly proportional or linear relationship between the size of the force applied to the spring and its extension (the increase in length), that is, if the force doubles, the extension doubles.

You must also quote values that confirm the relationship.

The extension for a 2 N load was 34 mm and that for a 4 N load was 67 mm which is double the extension (within experimental uncertainty).

Evaluation

Improvements to the investigation could include

- the precision of the extension measurements could be improved by replacing the wooden ruler with a metal ruler with a finer scale and using a magnifying glass to estimate between the points on the scale
- repeating the investigation and measuring the extension when a force of 5.0 N is applied
- repeating each of the individual experiments or trials a minimum of three times and calculating average (or mean) extensions
- repeating the experiments with five identical springs
- repeating all of the experiments (up to the same limit of 700 grams) with 50 gram masses to double the number of data points

Extensions to the investigation could include

- repeating the experiment, but increasing the load to above 700 grams and repeating the experiment until the spring breaks (N.B. safety hazard);
- repeating the experiment with two identical springs used side by side;
- repeating the experiment with two springs joined together – one below the other;
- replacing the spring by an elastic band and observing whether similar behaviour was observed;

The evaluation is perhaps the most important part of the 'Write-up' or 'Investigation Report'. It is often poorly done by MYP Science students. You need to evaluate your results, the design and the method.

Points to consider include

- Did I control all of the important variables that should be kept constant/fixed?
- Were some variables impossible to control? (This is frequently the case if the experiment involves humans or biological materials, e.g., enzymes).
- What more could I have done to control or avoid these?
- Did the precision of my apparatus/equipment introduce significant errors into the results?
- What improvements could be made to overcome weaknesses or limitations in the method?
- Are there any further investigations that could be performed?
- Were any data points anomalous? Why might this be?
- Do the results confirm the background theory?
- If you have determined a numerical value from you data, for example the spring constant, does it agree with the 'expected' value?

INTRODUCTION

You may be using data-logging for some of the investigations that you perform during your MYP Science course. These may not be formally assessed according to the MYP assessment criteria.

Data-logging is an electronic method of gathering and recording physical measurements; electrical sensors (*Figure 505*) provide signals which are calibrated and recorded by a computer system. Data-logging software not only automates the process of data collection but also provides tools that help in the process of analysing and interpreting the data.

EXAMPLES OF SENSORS (PROBES)

- pH sensor
- motion sensor
- light intensity sensor
- infrared sensor
- absolute pressure sensor
- force sensor
- voltage-current sensor
- temperature sensor
- photogates (for timing of moving objects)
- conductivity sensor
- exercise heart rate sensor
- dissolved oxygen sensor
- carbon dioxide sensor
- sound level sensor
- relative humidity sensor
- strain gauge (position)

Figure 505 Data-logging apparatus (PasPort Explorer and USB link)

ADVANTAGES OF DATA-LOGGING

- The experimental results can be seen on the computer screen (*Figure 506*) as the experiment is being monitored.
- Accurate readings can be taken frequently in a short space of time.
- Time is not wasted collecting raw data.
- The computer can automatically plot an appropriate graph.
- The data can, if necessary, be transferred to other software, for example, a spreadsheet for appropriate analysis.

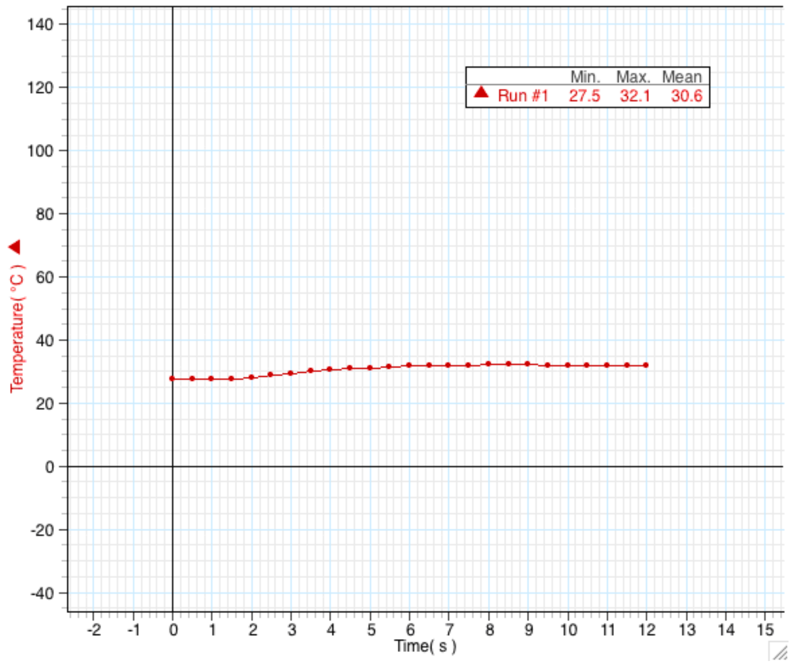


Figure 506 Raw data from a Pasco temperature sensor displayed by DataStudio

The software tools available for analysing and manipulating the data vary according to the data-logging software but may include:

- zooming
- joining and unjoining points
- displaying and calculating the gradient (slope) of a graph
- to fit a curve or line to data points
- performing statistics, for example, identifying maxima and minima
- smart tool to show a coordinate pair of data points
- autoscaling of the graph

A small sample of investigations that are suitable for data logging given the appropriate software and probes

- Investigating the sound made by a 'singing' kettle
- Investigating the rate of a chemical reaction
- Investigating conditions in an aquarium, a fridge or a greenhouse
- Investigating current and voltage in an electrical circuit
- Investigating temperature changes during chemical reactions e.g. neutralisation and physical changes
- Investigating freezing, melting, boiling, condensation and evaporation of a substance
- Investigating pH changes during neutralisation
- Motion of objects along surfaces including collisions, freely falling objects and oscillating objects
- Behaviour of gases (involving pressure measurements)
- Monitoring of enzyme activity
- Monitoring of transpiration (water loss from plant leaves), respiration and photosynthesis
- Monitoring of plant growth

When designing a data logging activity you need to answer the following questions

1. What variable do I want to measure?
2. What sampling rate and/or special start and stop options should I use?
3. How should the data be displayed?
4. How should the data be analysed?

Once the data have been collected and a graph drawn by the software, then a process of inquiry should begin, for example, some or all of the following questions may be appropriate

- For each part of the graph, what was happening during the investigation?
- What caused that peak?
- What are the highest and lowest values?
- How large was a particular change and how long did it take?
- How quickly are the values changing?
- What is the underlying trend?
- What sort of pattern is present in the results?
- How does one variable seem to depend on another?

Absolute error

An absolute error is an error expressed in physical units.

Accurate measurement

An accurate measurement is one which is close to the true value.

Accuracy

A measure of the total error in your measured value. The accuracy of a measurement depends on the experimental techniques and equipment used. Accuracy can be improved by removing or minimising error.

Anomalous data

Data that is odd or strange. Anomalous data has unexpected values that do not match the relationship predicted by the hypothesis. Anomalous results can be due to experimental error, faulty apparatus or unexpected scientific phenomena.

Bar chart

A method of displaying categoric independent variables. Draw with bars separated by spaces.

Calibration

Standardisation of the measurement scale of an instrument or apparatus. This involves fixing known points and then marking a scale on a measuring instrument, between these fixed points.

Categoric variable

A categoric variable has values which are described by labels.

Conclusion

A conclusion is an interpretation of experimental data. The conclusion should, if possible, show whether the data support, or reject, any hypothesis put forward.

Continuous variable

A continuous variable is one which can have any numerical value (within a restricted range).

Control group

Control groups are used to ensure that any effects observed are due to the independent variable and not some other unidentified variable.

Controlled variable

A controlled variable is one which may, in addition to the independent variable, affect the outcome of the investigation. This means that you should keep these variables constant; otherwise it may not be a fair test.

Data

Collected measurements and observations.

Datum

The singular of data.

Dependent variable

The dependent variable is the value which you measure in response to changes in the independent variable.

Discrete variable

A type of variable whose values are restricted to finite (usually whole integer) numbers.

Error

An error in a measurement is the difference between the measured value and the true value.

Evaluation

This involves the consideration of all errors, random and systematic, which may affect the results, identifying weaknesses and limitations in the method, calculating the total error present in the results and explaining how the errors can be minimised.

Extrapolation

To estimate (a value of a variable outside a known range) from values within a known range by assuming that the estimated value follows logically from the known values.

Evidence

This comprises data which have been subjected to some form of validation.

Factor

Another name for a variable.

Fair test

A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis

A scientific explanation for an observation, phenomenon, or chemical problem whose predictions may be tested by further investigation.

Independent variable

The independent variable is the variable for which values are changed or selected by the investigator.

Inference

An inference is a tentative conclusion drawn from a series of observations. It may lead to the formulation of a hypothesis.

Interpolation

To estimate the value of a variable between two or more known values. This is frequently done graphically.

Justify

Using scientific ideas to explain why something happens; not just to state what does happen.

Key variable

An important variable, or one which has a large effect.

Law

A scientific law is a generalisation that scientists make from an extensive body of research findings. A useful scientific law can be used to accurately predict what will happen in a range of situations.

Limitations

The restrictions of a particular experimental technique or set of apparatus. Limitations encountered during an investigation could influence the results and would need to be addressed in the evaluation.

Line graph

Data is plotted as (x,y) coordinates. A line or curve of best fit is drawn through the plotted points.

Line or curve of best fit

A single line drawn through a series of data points as a best representation of the underlying trend. It can be a straight line or curve.

Literature value

A value from the scientific literature of a physical constant or experimental measurement.

Measurement

A numerical value and units.

Observation

Observations are what can be measured, seen, heard, smelt, tasted or felt during an investigation. It is usually a visual description.

Ordered variables

An ordered variable has values which are descriptions, labels or categories, but these categories can be ordered or ranked.

Precision

The precision is the total amount of uncertainty present in a measurement. The precision of a measurement is determined by the limits of the scale on the instrument being used. Precision is related to the smallest scale division on the measuring instrument that you are using. This is also indicated by how close together repeated measurements are to each other.

Percentage error

A percentage error is an error expressed as a percentage of the value measured or of the true value.

Prediction

Predictions are a consequence of a hypothesis and are descriptions of the results you expect to obtain from an investigation.

Processed data

Raw data which have been organised and/or mathematically or graphically transformed.

Propagation of errors

Calculating the overall error from a series of mathematical operations.

Qualitative data

Qualitative data refers to observations made without quantitative measurements.

Qualitative relationship

A relationship between variables that is only described in very general terms.

Quantitative data

Quantitative data refers to numerical measurements.

Quantitative relationship

A relationship between variables that can be described in a numerical way, with an equation.

Range

The extent of values covered by the independent (or dependent) variable. The difference between the smallest and largest values.

Regression

Mathematical term for calculating a line of best fit.

Reliability

The results of an investigation may be considered reliable if the results can be repeated. If someone else can carry out your investigation and get the same results, then your results are more likely to be reliable.

Repeat

Taking and recording measurements or observations more than once to improve reliability and accuracy.

Replication

This involves repeating a test, or observation, a number of times.

Random error

Random errors are present every time a measurement is recorded. Their effects can be reduced by repeating the measurement and averaging.

Raw data

This is unanalysed data which have not yet been processed or analysed.

Reliability

A measure of the confidence that can be placed in a set of observations or measurements. The reliability of a set of observations or measurements depends on the number and accuracy of the individual observations or measurements. Reliability can be improved by replicating observations and measurements and then averaging.

Resolution

The resolution is the smallest division of a scale which can be easily read.

Risk assessment

A consideration of the possible safety hazards and associated precautions that could be encountered during an investigation.

Scatter graph

A graph where all the (x,y) data points are plotted, rather than just the average value.

Scientific model

A mathematical or verbal description that only includes the most important variables.

Secondary data

Data collected by other people.

Sensitivity

The sensitivity of an instrument is a measure of the amount of error present in the instrument or measuring device.

Significant figures

The significant figures in a number are those that are meaningful.

Standard deviation

A measure of spread, providing an estimate of the average deviation of data points from the mean.

Systematic error

These cause readings to be spread about some value other than the true value; in other words, all the readings are shifted one way or the other way from the true value. Systematic errors cannot be reduced by repeating the measurement and averaging. Systematic errors are a consequence of experimental design or apparatus limitations.

Tests

Investigations are usually composed of a number of tests where one variable is manipulated or changed.

Theory

A set of statements or principles devised to explain a group of facts or phenomena, especially one that has been repeatedly tested or is widely accepted and can be used to make predictions.

Trend

The general direction, tendency or patterns shown by a set of measurements or observations.

Trend line

Another name for a line of best fit.

Trial run

A trial run can be used to establish the scale, range and number of variables and help in choosing apparatus and instruments.

True value

This is the accurate value which would be found if the quantity could be measured without any errors at all.

Uncertainty

An uncertainty is the range that will likely contain the true value of whatever is being measured.

Unit

The unit of measurement for a physical quantity.

Validity

Data is only valid for use in coming to a conclusion if the measurements taken are affected by a single independent variable only. Data is not valid if, for example, a fair test is not carried out or there is observer bias.

Variable

The conditions or factors that can vary and may be varied during an experiment. As far as possible only one variable should be changed or manipulated at a time.

Variability

The degree to which the observations or measurements differ from one another.

Zero error

Zero errors are a type of systematic error. They are caused by measuring instruments that have a false zero.