INTRODUCTORY Chemistry

Study Guide

Chemistry Fundamentals & Calculations

Michael Lucarelli • David Proctor

Academic Associates

Periodic Table of the Elements

1 *Alkali Metals*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 *Noble Gases*
1 H Hydrogen 1.008	*Alkali Earth Metals*															*Halogens*	2 He Helium 4.003
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31	TRANSITION ELEMENTS										13 Al Aluminium 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.96	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium 226.0	89 Ac Actinium (227)	104 Rf Rutherfordium 101.1	105 Db Dubnium (281)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (270)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)							

- Solid
- Liquid (at 25º)
- Gas
- Synthetically prepared

6	*Atomic Number*
C	*Symbol*
Carbon	*Element Name*
12.01	*Relative Atomic Mass (Atomic weight)*

RARE EARTHS (LANTHANIDES)

58 Ce Cerium 140.1	59 Pr Praesodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.1	71 Lu Lutetium 175.0
90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

ACTINIDES

( ) = mass number of the isotope with the longest half life   Atomic weights from data published by IUPAC Commission on Atomic Weights 2007

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Contents

Preface

This study guide is intended for use by students preparing for entry to upper school chemistry courses. It covers fundamental chemistry concepts as well as calculations.

The book is designed so that it can be used as part of a whole classes learning program or by individual students. Chemistry concepts are clearly explained and well illustrated. All questions have detailed answers in order to provide students with immediate feedback and help improve understanding.

Checkpoint questions are used frequently to help students clarify their understanding of new concepts. These are ideal as in class exercises and discussion items.

Review questions at the end of each chapter are graded in difficulty. The early questions in each set (there are thirty two sets in all) will help to reinforce essential concepts while the remainder present students with a greater challenge.

The trial tests will provide students with a convenient means of self assessment to monitor their progress.

Michael Lucarelli, David Proctor
October 2002.

Chemistry Fundamentals

1. The Structure of the Atom
2. Electrons
3. Bonding
4. Writing Correct Formulae
5. Chemical Reactions
6. Writing Equations
7. Reactions Involving Metals

Chemistry Fundamentals

1. The Structure of the Atom

Elements

Some substances cannot be made into simpler substances. These simplest substances are called **ELEMENTS**. Chemistry is the study of these simplest substances and of how they combine/react with each other to form more complex substances (**COMPOUNDS**). One of the first tasks of a chemistry student is to learn the names and symbols of commonly used elements. You should learn the names and symbols for the following elements:

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Helium	He	Nitrogen	N
Barium	Ba	Hydrogen	H	Oxygen	O
Bromine	Br	Iodine	I	Phosphorus	P
Calcium	Ca	Iron	Fe	Potassium	K
Carbon	C	Lead	Pb	Silicon	Si
Chlorine	Cl	Lithium	Li	Silver	Ag
Chromium	Cr	Magnesium	Mg	Sodium	Na
Cobalt	Co	Manganese	Mn	Sulfur	S
Copper	Cu	Mercury	Hg	Tin	Sn
Fluorine	F	Neon	Ne	Uranium	U
Gold	Au	Nickel	Ni	Zinc	Zn

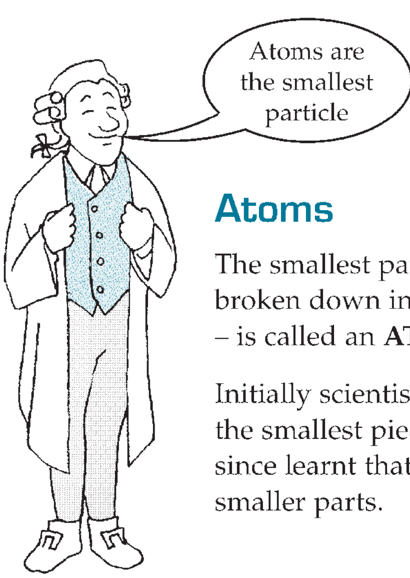
Elements: *are the simplest substances. They cannot be broken down to simpler substance by checmical means.*

Compounds: *are composed of two or more elements chemically joined in a fixed ratio.*

Atoms: *are the smallest parts of an element that can take part in a chemical reaction.*

Writing the symbols for the elements

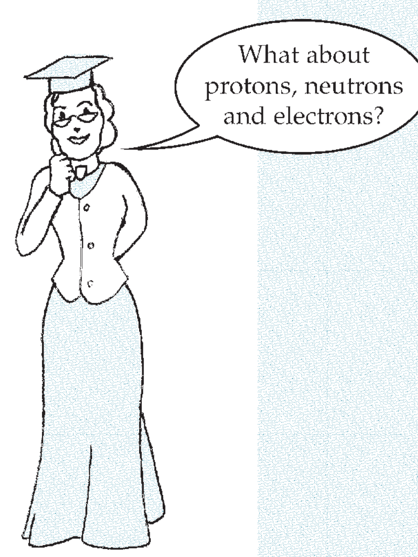
1. The symbol is always printed e.g. Al not *Al*.
2. If an element's symbol has more than one letter, the first letter must be in **CAPITALS** and the others in lower case.



Atoms

The smallest part that an element can be broken down into – without changing it – is called an **ATOM**.

Initially scientists thought that atoms were the smallest pieces of matter but they have since learnt that atoms could be split into smaller parts.

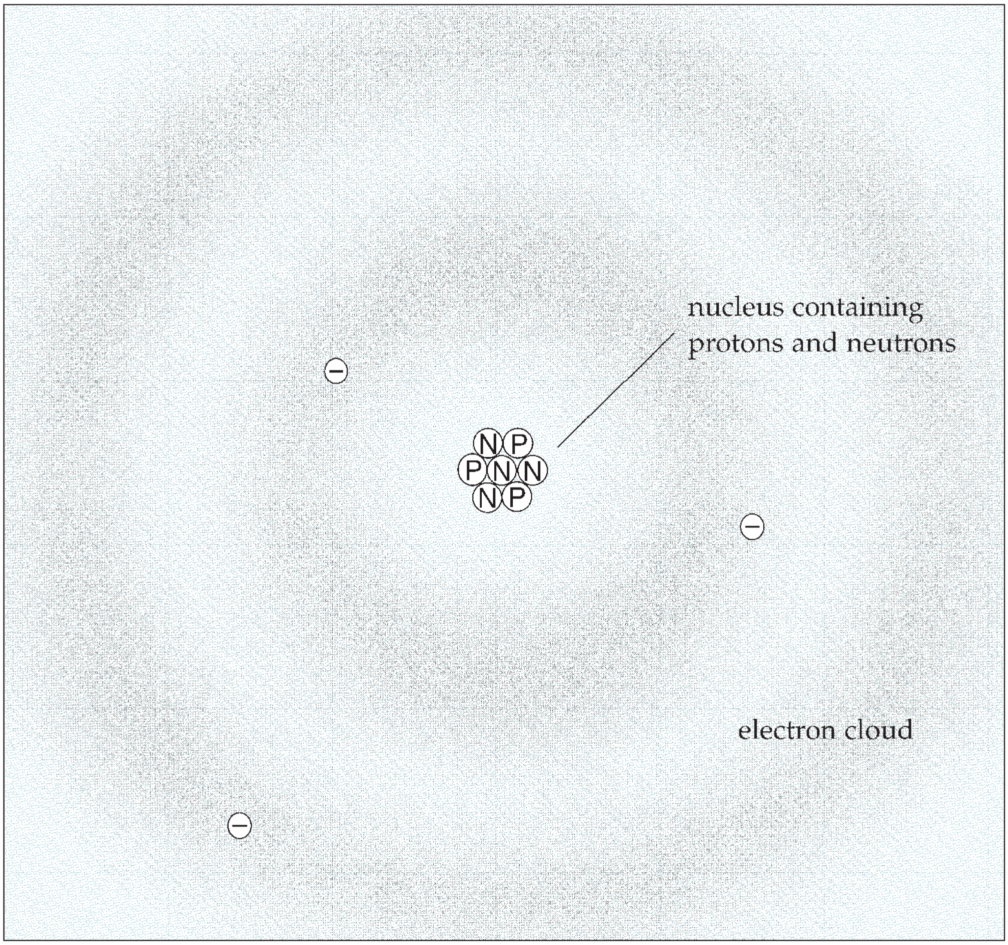


Structure of the atom

Atoms consist of 3 basic particles – **PROTONS, NEUTRONS** and **ELECTRONS**.

Atoms are mostly empty space through which the light and negatively charged electrons move.

The heavy nucleus typically makes up more than 99.9% of the atoms mass.



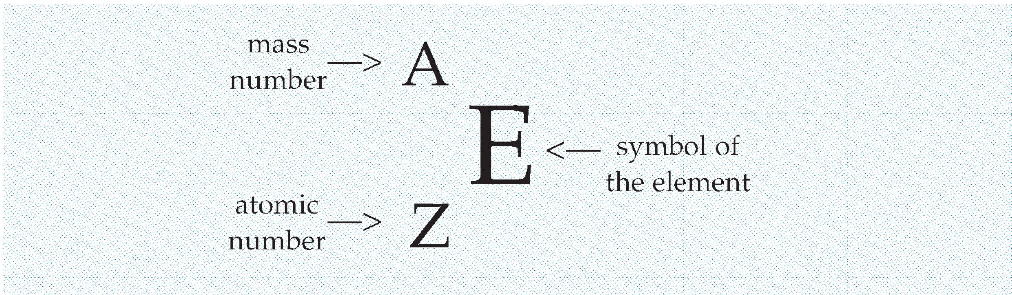
Protons and neutrons are extremely tightly packed in the centre or **NUCLEUS** of an atom. They are so tightly held they can only vibrate about fixed positions.

Electrons are moving in the region of space around the nucleus. Because of their extremely small size and wave like properties it is not possible to say exactly where an electron is and how fast it is moving. Instead we describe a region of space where the electron is likely to be – this is called an **ELECTRON CLOUD**.

The properties of the particles that make up atoms are summarised in the table below.

Particle	Position in the atom	Relative mass	Mass	Relative charge
PROTONS	nucleus	1	1.67×10^{-27} kg	+1
NEUTRONS	nucleus	1	1.67×10^{-27} kg	0
ELECTRONS	electron cloud	$^{1}/_{1836}$	9.11×10^{-31} kg	-1

The structure of a particular atom is often summarised using:



A = mass number = number of protons and neutrons in the nucleus.

Z = atomic number = number of protons in the nucleus.

Example 1.1 : Determine the number and type of particles in the nucleus of $^{23}_{11}Na$.

Number of protons = Z = 11

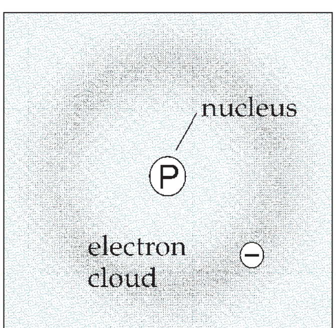
Number of neutrons = A - Z = 23 - 11 = 12

Isotopes

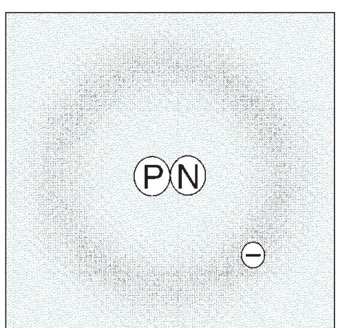
These are atoms of the same element that contain different numbers of neutrons in the nucleus.

The identity of each element is determined by its Atomic Number. Each element has its own, unique atomic number.

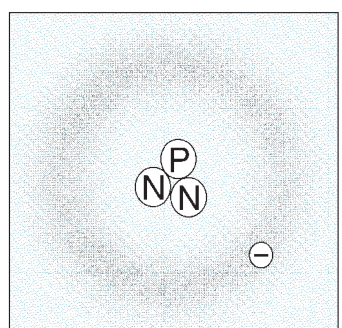
i.e. 3 different atoms of hydrogen.



Isotope 1



Isotope 2



Isotope 3

The following table summarises the nuclear structure of hydrogen's three isotopes.

	No. of protons	No. of neutrons	Atomic number	Mass number	Symbol
Isotope 1	1	0	1	1	$^{1}_{1}H$
Isotope 2	1	1	1	2	$^{2}_{1}H$
Isotope 3	1	2	1	3	$^{3}_{1}H$

Note: The 3 isotopes have the same chemical properties as they are the same element. They differ in mass only.

CHECKPOINT!

Question 1.1 - Complete the following table.

	Element	Z (Atomic number)	A (Mass number)	No. of protons	No. of neutrons
$^{12}_{6}C$	carbon	6	12	6	6
$^{35}_{17}Cl$					
$^{40}_{20}Ca$					
	chromium	24	52		
Cs	caesium			55	78
	copper		64	29	
Cm	curium	96			151
Ce	cerium		140		82
Cd	cadmium	48	112		
Cf	californium	98	251		

Question 1.2 - Give the number of protons and the number of neutrons in each of the following.

a) $^{66}_{30}Zn$: ________ protons , ________ neutrons

b) $^{101}_{44}Ru$: ________ protons , ________ neutrons

c) $^{207}_{82}Pb$: ________ protons , ________ neutrons

d) $^{226}_{88}Ra$: ________ protons , ________ neutrons

e) $^{39}_{19}K$: ________ protons , ________ neutrons

f) $^{55}_{25}Mn$: ________ protons , ________ neutrons

g) $^{35}_{17}Cl$: ________ protons , ________ neutrons

h) $^{238}_{92}U$: ________ protons , ________ neutrons

1. Review Questions

Set 1 – The structure of the atom

1. Name the following elements.

a) He	**b)** Mg	**c)** Ba	**d)** P	**e)** Si
f) Co	**g)** Li	**h)** N	**i)** Fe	**j)** Hg

2. Give the symbol for the following elements.

a) Lead	**b)** Carbon	**c)** Chlorine	**d)** Copper	**e)** Potassium
f) Gold	**g)** Sodium	**h)** Tin	**i)** Iodine	**j)** Chromium

3. State if each of the following statements are true or false.
If they are false, alter the statement so that it becomes true.

a) Protons and neutrons have approximately the same mass.

b) In a neutral atom the number of protons equals the number of neutrons.

c) The mass of an electron is one hundredth the mass of a proton.

d) The nucleus consists of protons and neutrons.

e) The atom is mainly empty space.

f) Most of the mass of an atom exists in the electron cloud.

g) An element is the simplest substance. It cannot be broken down to simpler substances by chemical reactions.

h) A compound contains 2 or more elements mixed together.

4. Give the number of protons, neutrons and electrons in each of the following neutral atoms.

a) $^{4}_{2}He$ **b)** $^{64}_{29}Cu$ **c)** $^{40}_{18}Ar$ **d)** $^{127}_{53}I$

e) $^{197}_{79}Au$ **f)** $^{236}_{92}U$

5. Use Co and CO to explain the differences between elements and compounds.

For the experts

6. Deuterium and tritium are isotopes of hydrogen. How are these isotopes similar? How are they different?

Review Questions

2. Electrons

Number of electrons

Normally an atom will contain the same number of electrons and protons. This makes the atom neutral in charge.

The chemical properties of an atom are controlled by its electrons. The nucleus (protons and neutrons) does not affect and is not changed in chemical reactions.

CHECKPOINT!

Question 2.1 - How many electrons are there in a neutral atom of each of the following?

a) $^{3}_{1}H$ ________ b) $^{4}_{2}He$ ________ c) $^{127}_{53}I$ ________

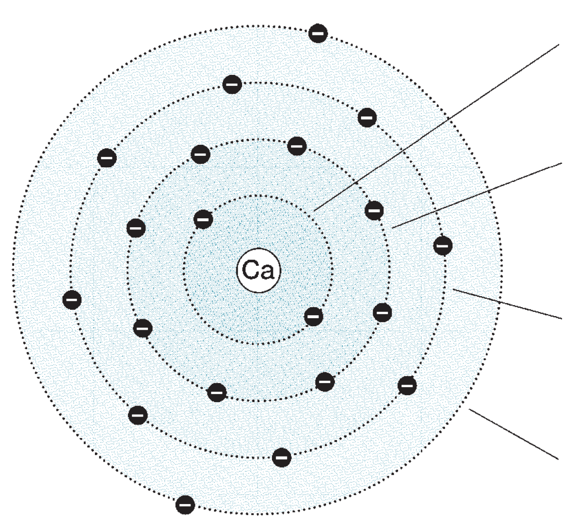
Where are they?

Although they cannot say exactly where an electron is and how fast it is travelling, scientists can determine the arrangement of electrons around the nucleus.

A simple model that shows how electrons exist around the atom is shown below for an atom of calcium. The electrons occupy **ENERGY LEVELS**.

Electrons can only be in an energy level if they have exactly the correct amount of energy.

Energy levels can contain sub-levels called ORBITALS. Any one orbital can contain a maximum of two electrons.



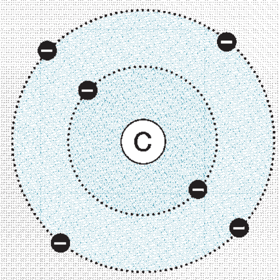
An abbreviated way of writing this electron structure for calcium would be:

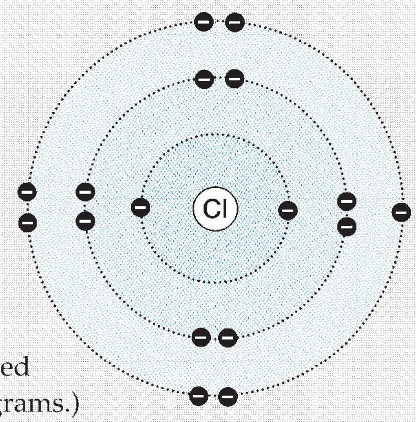
Ca 2 , 8 , 8 , 2

This is called its **ELECTRON CONFIGURATION.**

Example 2.1 : Show the arrangement of electrons around:

a) carbon ($^{12}_{6}C$) **b)** chlorine ($^{35}_{17}Cl$)





(These are sometimes called electron energy level diagrams.)

Energy level diagrams are sometimes drawn with electrons in pairs, showing they occupy the same orbital. This is only done if an energy level contains more than 4 electrons.

Example 2.2 : Write the electron configurations for the two atoms from Example 2.1.

a) carbon: 2 , 4 **b)** chlorine: 2 , 8 , 7

CHECKPOINT!

Question 2.2 - Write the electron configuration for each of the following elements:

a) $^{4}_{2}He$ ______________________ b) $^{10}_{4}Be$ ______________________

c) $^{40}_{20}Ca$ ______________________ d) $^{14}_{7}N$ ______________________

e) $^{27}_{13}Al$ ______________________ f) $^{20}_{10}Ne$ ______________________

g) $^{32}_{16}S$ ______________________ h) $^{23}_{11}Na$ ______________________

i) $^{31}_{15}P$ ______________________ j) $^{16}_{8}O$ ______________________

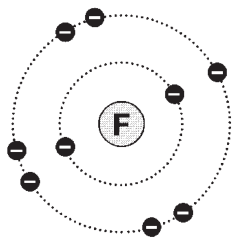
k) $^{9}_{4}Be$ ______________________ l) $^{28}_{14}Si$ ______________________

m) $^{40}_{18}Ar$ ______________________ n) $^{39}_{19}K$ ______________________

CHECKPOINT!

Question 2.3 - Draw the electron energy level diagrams and state the electron configuration for each of the following elements.
a) is completed for you

a) $^{19}_{9}F$



2, 7

b) $^{39}_{19}K$

c) $^{1}_{1}H$

d) $^{28}_{14}Si$

e) $^{24}_{12}Mg$

f) $^{40}_{18}Ar$

Example 2.3 : How many electrons in the outermost energy level of calcium?

Electron configuration of Ca = 2 , 8 , 8 , 2 Answer = 2

CHECKPOINT!

Question 2.4 - How many electrons in the outermost energy level of:

a) $^{16}_{8}O$ ____________________

b) $^{32}_{16}S$ ____________________

c) $^{9}_{4}Be$ ____________________

d) $^{7}_{3}Li$ ____________________

e) $^{40}_{18}Ar$ ____________________

Electron configurations and the periodic table

The position of an element in the Periodic Table can tell us the number of electrons it has in its outermost energy level. This is important because an element's chemical properties are controlled by how many electrons are in its outermost energy level.

GROUP NUMBERS

TRANSITION ELEMENTS

I	II											III	IV	V	VI	VII	VIII
1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorous	16 S Sulphur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium	57 La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89 Ac Actinium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium						

6 C Carbon — Atomic Number, Symbol, Element Name

RARE EARTHS (LANTHANIDES)

58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

ACTINIDES

Group numbers *(I to VIII) give the number of electrons in the outermost energy level for all elements in that group.*

The column number (from left to right) is often referred to as the Group Number. This Group Number tells us the number of electrons in the outermost energy level of each element in that column (group).

Because they have the same number of electrons in their outermost energy level, elements in the same group have similar chemical properties.

CHECKPOINT!

Question 2.5 - How many electrons in the outermost energy level of:

a) nitrogen ______________________ b) aluminium ______________________

c) helium ______________________ d) potassium ______________________

e) phosphorus ______________________ f) Li ______________________

g) B ______________________ h) Kr ______________________

i) As ______________________ j) Rb ______________________

Noble Gas configuration - *atoms have a tendency to get the same configuration as the nearest noble gas.*

Nearest means noble gas with the most similar atomic number

Noble Gases: Chemistry's role models

The Noble Gases are very unreactive, they are inert gases.
The reason why noble gases are inert is found in their electron configuration.

He	2					
Ne	2	8				
Ar	2	8	8			
Kr	2	8	18	8		
Xe	2	8	18	18	8	
Rn	2	8	18	18	32	8

Pattern

All noble gases have 8 electrons in their outer energy level. The exception is helium which has only 2 electrons.

When elements react the atoms involved must collide. This collision causes the outermost electrons to interact. Where elements react, they try and get the same electron configuration as the nearest noble gas. For most elements, this means they try to get 8 electrons in their outermost energy level.

Example 2.4 : When oxygen atoms react, how would the number of electrons in their outermost energy levels change?

electron configuration of oxygen : 2 6

electron configuration of nearest noble gas (neon) : 2 8

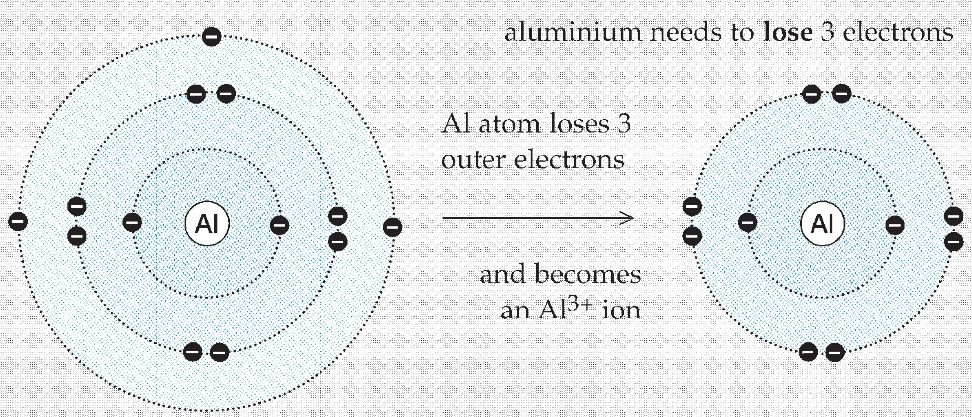
oxygen's electron change : it would need to **gain** 2 electrons from another element

Example 2.5: How could an atom of Al get a full outer energy level?

electron configuration of Al : 2 8 3

nearest noble gas : 2 8 (NOT 2 8 8)

aluminium needs to **lose** 3 electrons



CHECKPOINT!

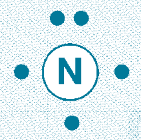
Question 2.6 - **Complete the following table to decide how each element could get the same configuration as the nearest noble gas. Hint: refer to the periodic table to check Atomic Numbers.**

Element	Electron configuration	Configuration of nearest noble gas	Change to element's configuration
Potassium	2 8 8 1	2 8 8	lose 1 electron
Magnesium		2 8	
Boron		2	
Fluorine			
Phosphorous			
Chlorine			
Calcium			
Sulfur			
Carbon		2 8	

Electron dot diagrams

A simple way to show the outermost electron energy level is to draw an **'electron dot diagram'**.

Electron dot diagram for Nitrogen



Nitrogen is from group 5 of the periodic table, and hence has 5 electrons in its outer energy level.

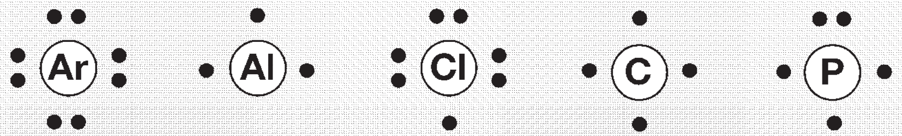
Two electrons occupy one orbital (maximum allowed) while the other 3 electrons are in partially filled orbitals.

Rules for electron dot diagrams

1. Maximum number of 8 electrons in the outermost energy level.
2. Electrons are represented by a dot (or a cross).
3. Electrons are placed in 4 regions (orbitals) around the symbol for the element. A maximum of 2 electrons in each orbital.

Example 2.6: Draw the electron dot diagrams for Ar , Al , Cl , C and P.

The electron dot diagram for an element is easy to work out – the number of electrons to draw equals the group number from the periodic table. These diagrams only show the electrons in the outermost level.



CHECKPOINT!

Question 2.7 - Draw the electron dot diagrams for each of the following elements

a) Li

b) Ca

c) B

d) Kr

e) Cs

f) Mg

g) Rb

h) Si

i) F

j) Ra

k) I

l) Rn

2. Review Questions

Set 2 – Electrons

1. Draw electron energy level diagrams for each of the following atoms.

a) $^{9}_{4}\text{Be}$ **b)** $^{12}_{6}\text{C}$ **c)** $^{32}_{16}\text{S}$ **d)** $^{3}_{2}\text{He}$

e) $^{1}_{1}\text{H}$ **f)** $^{20}_{10}\text{Ne}$

2. Write the electron configuration for each of the following atoms.

a) $^{7}_{3}\text{Li}$ **b)** $^{10}_{5}\text{B}$ **c)** $^{23}_{11}\text{Na}$ **d)** $^{19}_{9}\text{F}$

e) $^{36}_{17}\text{Cl}$ **f)** $^{40}_{20}\text{Ca}$

3. Give the number of electrons in the outermost energy level of each of the following atoms (periodic table will help).

a) $^{40}_{19}\text{K}$ **b)** $^{28}_{14}\text{Si}$ **c)** $^{14}_{7}\text{N}$ **d)** $^{84}_{36}\text{Kr}$

e) $^{133}_{55}\text{Cs}$ **f)** $^{131}_{54}\text{Xe}$

4. Say what change would happen for each atom below to get the same electron configuration as the nearest noble gas.

a) $^{6}_{3}\text{Li}$ **b)** $^{19}_{9}\text{F}$ **c)** $^{28}_{14}\text{Si}$ **d)** $^{9}_{4}\text{Be}$

e) $^{16}_{8}\text{O}$ **f)** $^{127}_{53}\text{I}$

5. Draw the electron dot diagram for each of the following elements.

a) Potassium **b)** Nitrogen

c) Strontium **d)** Aluminium

e) Helium **f)** Hydrogen

g) Oxygen **h)** Bromine

For the experts

6. Water is a very common and important compound. How do hydrogen and oxygen atoms combine to give all atoms involved the same electron configuration as their nearest noble gas?

3. Bonding

A bond is a force that holds atoms together.

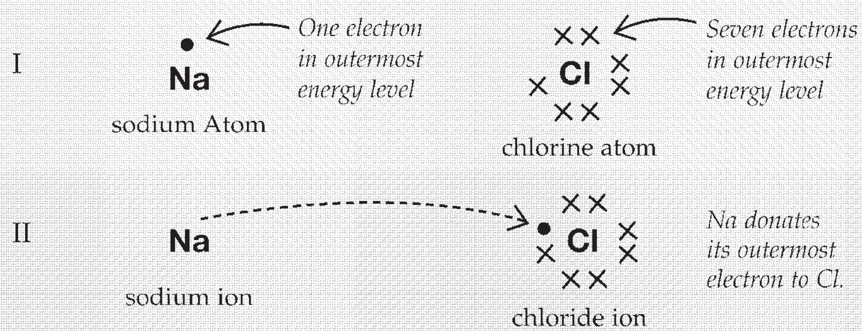
The three main types of bonds are IONIC, COVALENT and METALLIC.

Elements react with each other to become more stable and to have less energy. Reactions involve the interaction between the outermost electrons of the elements involved. When the outermost electrons of atoms interact and cause atoms to join together a new **CHEMICAL BOND** is formed.

Ionic bonds

These form when a metal with a nearly empty outer shell (energy level) reacts with a non-metal with a nearly full outer shell.

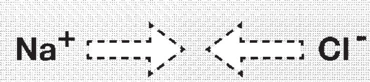
Example 3.1: Sodium reacts with chlorine to form sodium chloride.



Both atoms now have full outer shells. But because they have gained or lost electrons they are called ions not atoms.

III Na has lost an electron – it has a +1 charge.
Cl has gained an electron – it has a –1 charge.

IV An ionic bond forms because the oppositely charged atoms (now called ions) attract each other.

i.e.


Ions

Ions form when atoms gain or lose electrons.

Positive Ions – form when atoms lose electrons.
The number of electrons the atom loses gives the amount of positive charge.

i.e. Al^{3+} : aluminium ion. It forms when an aluminium atom loses 3 electrons.
Au^{+} : gold ion. It forms when a gold atom loses one electron.

Negative Ions – form when atoms gain electrons.

i.e. F^{-} : fluoride ion. It forms when a fluorine atom gains one electron.
O^{2-} : oxide ion. It forms when an oxygen atom gains two electrons.

Important points about ions

i) Metal ions keep the name of the metal atom.

ii) When non-metal atoms form negative ions, the name changes to end in "ide".

iii) Ions never occur alone in a substance. In any substance containing ions, the total positive charge always equals the total negative charge so that the substance is neutral.

iv) Ions have a charge because the number of electrons no longer equals the number of protons.

v) The charge on an ion is called its valency.

Valency table

The valency of some common ions are shown below. You should memorise these.

Positive ions		Negative ions	
Name	**Symbol**	**Name**	**Symbol**
Hydrogen	H^+	Fluoride	F^-
Sodium	Na^+	Chloride	Cl^-
Potassium	K^+	Bromide	Br^-
Silver	Ag^+	Iodide	I^-
Lithium	Li^+	Hydrogencarbonate	HCO_3^-
Copper (I)	Cu^+	Hydrogensulfate	HSO_4^-
Ammonium	NH_4^+	Hydroxide	OH^-
Magnesium	Mg^{2+}	Ethanoate	CH_3COO^-
Calcium	Ca^{2+}	Nitrate	NO_3^-
Barium	Ba^{2+}	Oxide	O^{2-}
Iron (II)	Fe^{2+}	Sulfide	S^{2-}
Cobalt	Co^{2+}	Sulfate	SO_4^{2-}
Zinc	Zn^{2+}	Sulfite	SO_3^{2-}
Lead (II)	Pb^{2+}	Carbonate	CO_3^{2-}
Tin (II)	Sn^{2+}	Nitride	N^{3-}
Copper (II)	Cu^{2+}	Phosphide	P^{3-}
Aluminium	Al^{3+}	Phosphate	PO_4^{3-}
Chromium (III)	Cr^{3+}		
Iron (III)	Fe^{3+}		
Tin (IV)	Sn^{4+}		
Lead (IV)	Pb^{4+}		

Multiple valencies

Some metals have more than one valency and this is indicated by roman numerals. eg. Iron(II), Iron(III)

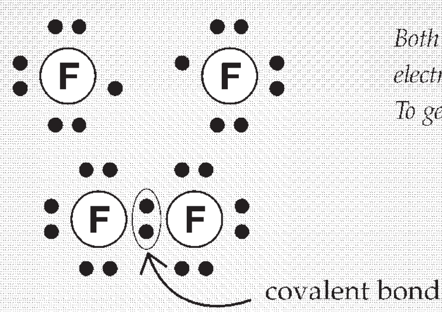
For monovalent elements this is not necessary and hence not shown.

Covalent bonds

These form when two non-metal atoms with nearly full outer shells **share** electrons so that both atoms end up with full outer shells.

Electron dot diagrams are a very good way to show how non-metal atoms form covalent bonds.

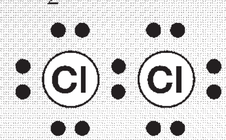
Example 3.2: Use electron dot diagrams to show how two fluorine atoms get full outer shells by forming a covalent bond.



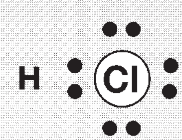
Both fluorine atoms have seven electrons in their outermost shell. To get 8 they share a pair of electrons.

Example 2: Draw the electron dot diagrams to show the covalent bonding in:

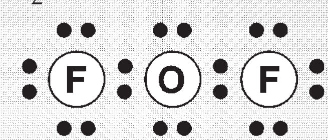
a) Cl_2



b) HCl



c) OF_2



Metallic bonds

Metal atoms have nearly empty outer shells. To get full outer shells, metal atoms lose these electrons. The metal atoms become positive ions. The valence electrons are distributed throughout the lattice of positive metal ions. They are not held to any one ion but move randomly throughout the lattice. They are often described as forming a **sea of mobile electrons.**

Summary - Bonding types

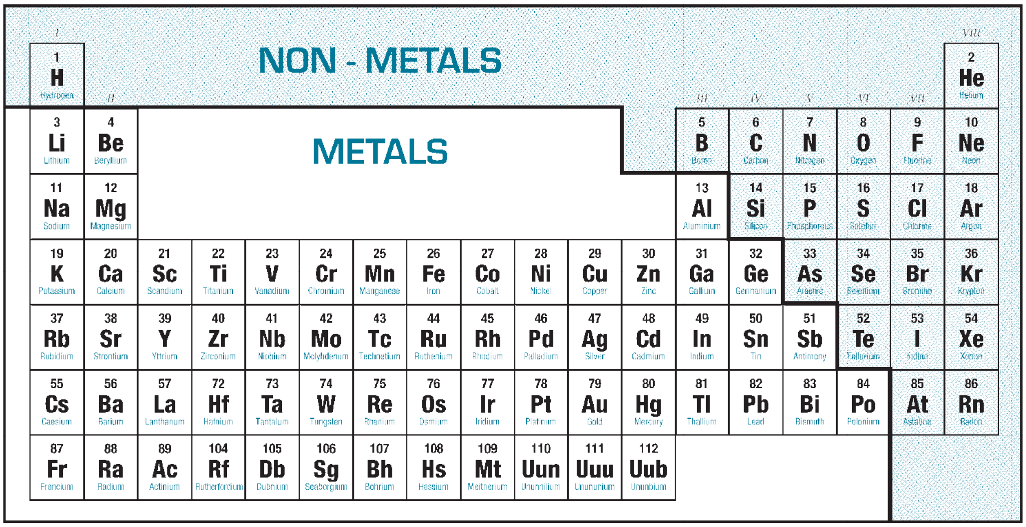
General guide for deciding how to identify the bonding type in an element or compound is as follows:

Substance composed of metals only – **METALLIC BONDING**

Substance composed of metals and non-metals – **IONIC BONDING**

Substance composed of non-metals only – **COVALENT BONDING**

The periodic table is often used to classify elements as metals or non-metals.



CHECKPOINT!

Question 3.1 - Use a periodic table to classify the following elements as metals or non-metals.

a) Na ____________________ b) Xe ____________________

c) Fe ____________________ d) F ____________________

e) O ____________________ f) Mg ____________________

g) H ____________________ h) Ca ____________________

Question 3.2 - For each of the following compounds name the type of bonding involved.

a) NaCl ____________________ b) SO_2 ____________________

c) Pb ____________________ d) $PbCl_2$ ____________________

e) C_3H_8 ____________________ f) HNO_3 ____________________

g) $ZnBr_2$ ____________________ h) N_2O_4 ____________________

3. Review Questions

Set 3 – Valencies

1. Name the following positive ions.

a) H^+ **b)** Mg^{2+} **c)** Cu^{2+} **d)** Fe^{2+}

e) Al^{3+} **f)** Fe^{3+} **g)** Ba^{2+} **h)** Zn^{2+}

2. Name the following negative ions.

a) O^{2-} **b)** F^- **c)** N^{3-} **d)** S^{2-}

e) Cl^- **f)** C^{4-} **g)** P^{3-} **h)** I^-

3. Write the formula showing the valency of the following ions.

a) silver **b)** copper (I) **c)** fluoride **d)** ammonium

e) sulfate **f)** zinc **g)** barium **h)** phosphate

i) nitrate **j)** nitride **k)** oxide **l)** iron (III)

4. Give the valencies of the positive and negative ions in each of the following compounds.

a) $CuCl_2$ **b)** ZnO **c)** Fe_2S_3 **d)** FeS

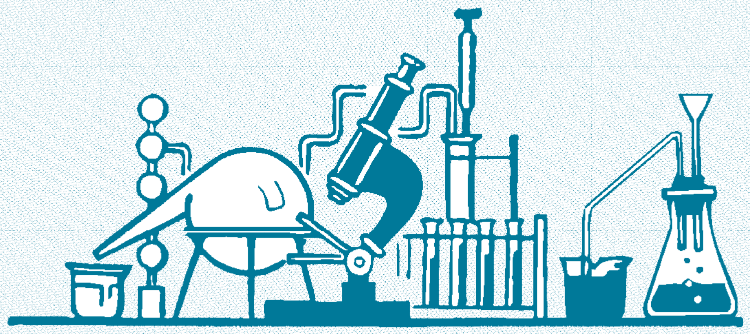
e) Mg_3N_2 **f)** $AlBr_3$

5. Give the valencies of the positive and negative ions in each of the following compounds.

a) $AlPO_4$ **b)** $Zn(NO_3)_2$ **c)** $Fe_2(SO_4)_3$

For the experts

6. Dichromate (Cr_2O_7) is an ion containing oxygen and chromium. If potassium dichromate has the formula $K_2Cr_2O_7$, what is the valency of the dichromate ion?



Set 4 – Bonding

1. Classify the following elements as metals or non-metals.

a) Zn **b)** Se **c)** I **d)** W

e) N **f)** K **g)** Kr **h)** Ti

2. Complete the following table to determine the type of bonding between the atoms (or ions).

Formula	Element type (metals or non-metals)	Bonding type
O_2	non-metals only	covalent
NaCl	metal with non-metal	ionic
Fe		
MgO		
Al_2S_3		
NH_3		
OCl_2		
BaI_2		

3. State the type of bonding that would exist in the following substances.

a) CO_2 **b)** Al **c)** K_2S **d)** Rb_3N

e) HCl **f)** CH_4 **g)** $FeBr_3$ **h)** P_2O_5

4. State the number of electrons that the element has gained or lost in forming the following ions.

a) Fe^{3+} **b)** S^{2-} **c)** F^- **d)** Co^{2+} **e)** Pb^{+4}

f) O^{2-} **g)** Cr^{3+} **h)** N^{3-} **i)** Li^+ **j)** P^{3-}

5. Draw the electron dot diagrams to show how the following non-metal atoms combine to form covalent bonds.

a) PCl_3 **b)** I_2 **c)** I_2CH_2 **d)** CF_4

For the experts

6. Draw the electron dot diagrams for the following.

a) O_2 **b)** C_2H_2 **c)** CO_2 **d)** N_2

4. Writing Correct Formula

Writing the correct formula and giving the correct name to compounds is an essential skill learnt by all chemistry students. The rules for writing the correct formula or name depend on the type of bonding holding the substance together.

Metallic substances

Metallic elements: name - that of the element

formula - single symbol that does not indicate the number of atoms present i.e. Na, Al, Fe

Mixtures of metals: These are alloys, they are given names by the inventor. They do not have a particular formula.

e.g. solder - a mixture of tin and lead

brass - a mixture of zinc and copper

sterling silver - a mixture of silver and copper

Covalent molecular substances

These are composed of non-metal atoms covalently bonded to other non-metal atoms. The formula and name indicates the number and type of atoms present in a molecule of that substance.

Rules for naming

i) The element that is closer to the left side of the periodic table is named first and it keeps its normal name. (If two elements are in the same group – the element further towards the bottom is named first.)

ii) The element closer to the right hand side of the periodic table is named second and has the end of its name changed to end in - ide.

iii) Prefixes are used to indicate if more than one atom of that element is present in the molecule.

Prefixes used: mono - 1, di - 2, tri - 3, tetra - 4, penta - 5

iv) If there is only one atom of the first element, the prefix mono is not used.

v) Molecules composed of one element only, get the name of that element.

e.g.

2 nitrogen atoms

N_2O_4 **di**nitrogen **tetra**oxide

4 oxygen atoms

1 phosphorous atoms

PCl_3 . . phosphorus **tri**chloride

3 chlorine atoms

CHECKPOINT!

Question 4.1 - Name the following molecules that are made of non-metal atoms only.

a) CO_2 ______________________ b) Br_2 ______________________

c) P_2O_5 ______________________ d) SO_2 ______________________

e) HCl ______________________ f) SO_3 ______________________

Question 4.2 - Use the name of the following covalent molecules to write their correct formula.

a) Chlorine ______________________ b) Oxygen dichloride ______________________

c) Nitrogen trifluoride ______________________ d) Nitrogen dioxide ______________________

e) Sulfur trioxide ______________________ f) Carbon tetrachloride ______________________

Question 4.3 - What is unusual about the names given to:

a) H_2O ______________________ b) CO ______________________

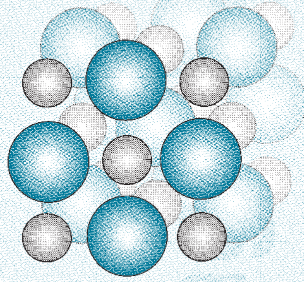
______________________ ______________________

______________________ ______________________

Ionic substances

These are composed of metal ions bonded to non-metal ions. These substances form immense lattices with countless numbers of ions. The formula of ionic substances provides the ratio of ions present NOT the actual number of ions present.

To write ionic formulae or to name ionic compounds you must memorise the valency table on page 15.



A crystal lattice of sodium chloride

Rules for writing formulae for ionic substances

i) The positive ion (usually a metal ion) is written first.

ii) The negative ion (non-metal ion) is written second.

iii) The number of each ion is adjusted so that total positive charge equals the total negative charge. Subscripts are used to indicate the number of each ion present.

Example 4.1: Write the correct formula for calcium bromide.

Step 1 Write the formula for each ion, including valency. : Ca^{2+} Br^-

Step 2 Determine how many of each ion is needed to get the total positive charge to balance the total negative charge. : 1 Ca^{2+} balances 2 Br^-

Step 3 Re-write this information so that the numbers of each ion needed are written as subscripts. (Note: the number 1 is not written.) : $CaBr_2$

Example 4.2: Write the correct formula for aluminium bromide.

Step 1 Al^{3+} Br^-

Step 2 1 Al^{3+} balances 3 Br^-

Step 3 Correct formula is $AlBr_3$

Example 4.3 : Write the correct formula for aluminium oxide.

Step 1 Al^{3+} O^{2-}

Step 2 Common factor for 2 and 3 is 6.
2 Al^{3+} balances 3 O^{2-}

Step 3 Correct formula is Al_2O_3

CHECKPOINT!

Question 4.4 - Complete the following table to produce the correct formula for each of the named ionic substances.

Name	Step 1	Step 2	Step 3
sodium bromide	Na^+, Br^-	1 Na^+ balances 1 Br^-	NaBr
barium chloride	Ba^{2+}, Cl^-	1 Ba^{2+} balances ____ Cl^-	
zinc nitride			
zinc oxide			
aluminium sulfide			
aluminium nitride			

Note: Some metals can have more than one valency. This is indicated in the name by using roman numerals to state the valency.

i.e. iron (III) oxide Fe^{3+} combines with O^{2-} to give Fe_2O_3
tin (IV) sulfide Sn^{4+} combines with S^{2-} to give SnS_2

CHECKPOINT!

Question 4.5 - Combine the following ions to give the correct formula (Step 2 still needs to be done – but mentally).

	F^-	Cl^-	O^{2-}	S^{2-}	N^{3-}
Na^+					
Li^+					
Ag^+					
K^+					
Cu^+					
Mg^{2+}					
Ba^{2+}					
Fe^{2+}					
Cu^{2+}					
Al^{3+}					
Cr^{3+}					
Fe^{3+}					
Sn^{4+}					
Pb^{4+}					

Question 4.6 - Complete the following table by writing the correct formula for each combination of ions.

	bromide	iodide	oxide	sulfide	nitride
potassium					
copper (I)					
calcium					
iron (III)					
cobalt					
chromium (III)					
tin (II)					

For NO_3^- NO_3 is the formula and this must never be altered. The negative sign gives the valency of the whole ion, which is used to work out correct formula.

Polyatomic ions

These are a combination of several atoms to form an ion. The formula for a polyatomic ion indicates the number of atoms of each element present in the ion.

eg. nitrate ion

1 nitrogen atom —> NO_3^- <— valency of -1 (for whole ion)

3 oxygen atoms

When writing the formula for an ionic compound containing a polyatomic ion you MUST NOT change the formula of the ion. This includes the subscript used to indicate the number of atoms of a particular element present. If **more than one** of that polyatomic ion is needed to balance the charge, **brackets** must be used to indicate that the number affects all parts of the polyatomic ion.

*Al^{3+} → +3 ; OH^- → 3(-1) → **$Al(OH)_3$***

brackets needed to show 3 OH^- groups needed

Example 4.4: Write the correct formula for:

a) aluminium hydroxide; b) magnesium phosphate;
c) copper (II) nitrate; and d) sodium carbonate.

Step 1	Step 2	Step 3
a) Al^{3+}, OH^-	1 Al^{3+} balances 3 OH^-	$Al(OH)_3$
b) Mg^{2+}, PO_4^{3-}	3 Mg^{2+} balance 2 PO_4^{3-}	$Mg_3(PO_4)_2$
c) Cu^{2+}, NO_3^-	1 Cu^{2+} balances 2 NO_3^-	$Cu(NO_3)_2$
d) Na^+, CO_3^{2-}	2 Na^+ balance 1 CO_3^{2-}	Na_2CO_3

Remember:

Do not change the formula of the polyatomic ion.

Brackets are only used when more than one polyatomic ion is needed.

CHECKPOINT!

Question 4.7 - Complete the following table to give the correct formula for each combination of ions.

	NO_3^-	OH^-	CH_3COO^-	SO_4^{2-}	CO_3^{2-}	PO_4^{3-}
Na^+						
Cu^+						
Cu^{2+}						
Fe^{2+}						
Fe^{3+}						
Sn^{4+}						
Zn^{2+}						
Al^{3+}						
NH_4^+						

CHECKPOINT!

Question 4.8 - Write the correct formula for each of the following compounds.

copper (II) chloride		ammonium carbonate	
aluminium oxide		magnesium iodide	
iron (II) phosphate		aluminium nitride	
gold (I) sulfide		barium ethanoate	
potassium sulfate		potassium hydrogencarbonate	
copper (I) carbonate		copper (II) sulfite	
calcium hydroxide		lead (II) nitride	
tin (II) chloride		tin (IV) nitride	
chromium (III) oxide		cobalt sulfate	
lead (IV) oxide		copper (II) hydroxide	
ammonium chloride		zinc phosphate	
iron (III) chloride		ammonium hydrogensulfate	

Rules for naming ionic compounds

1. The metal, or positive ion is named first and it keeps its normal name.
2. The non-metal, or negative ion is named second and has the end of its name written as ......ide, ...ate or ......ite (refer to valency table of ions pg 15).
3. If the metal ion has several valencies possible, indicate its valency using roman numerals.

Note: *The prefixes di, tri, tetra etc. are only used for covalent compounds. They are not used for ionic compounds*

Example 4.5: Name the following ionic compounds:

a) $AlCl_3$ - aluminium chloride

b) $Mg_3(PO_4)_2$ - magnesium phosphate

c) Cu_2O - copper (I) oxide
(copper has valencies of +1 and +2; this compound is Cu^+)

d) CuO - copper (II) oxide

e) Fe_2O_3 - iron (III) oxide
iron has valencies of +2 and +3; this compound is Fe^{3+}

CHECKPOINT!

Question 4.9 - Name the following ionic compounds.

a) NaCl ______________________

b) NH_4NO_3 ______________________

c) Ag_2O ______________________

d) $FeSO_4$ ______________________

e) $Fe_2(SO_4)_3$ ______________________

f) SnO_2 ______________________

g) $CuCO_3$ ______________________

h) K_3PO_4 ______________________

i) PbO_2 ______________________

j) Zn_3N_2 ______________________

Summary - Types of bonding

Use the periodic table to identify what the substance is composed of.

METALS ONLY

metallic substance

Formula is the symbol of the element.

Name is that of element present.

eg. Na, Al, K, Fe, Cu, Ag.

NON-METALS ONLY

covalent substance

Formula gives the number and type of atoms present in the molecule.

Name provides prefix indicating number of each atom present, first element keeps normal name, second element has name altered to end in ..... ide.

eg. H_2, CO_2, H_2O, P_2O_5, N_2O_4

METALS & NON-METALS

ionic substance

Formula gives the ratio of ions present in the substance, metal ions written first.

Name simply states names of ions present, metal ion written first. Roman numerals used if metal ion may have more than one valency.

eg. NaCl, MgO, $Ca(OH)_2$, $Zn(NO_3)_2$, $(NH_4)_2SO_4$

4. Review Questions

Set 5 – Writing formulae (I)

1. Name the following compounds (composed of non-metals only).

a) CO_2 **b)** HBr **c)** OCl_2 **d)** SO_2

e) CCl_4 **f)** HI **g)** P_2O_5 **h)** NI_3

2. Write the correct formula for the following covalent substances.

a) carbon tetrafluoride **b)** hydrogen chloride

c) sulfur trioxide **d)** dinitrogen tetraoxide

e) nitrogen triiodide **f)** ammonia

3. State the valency of the following ions.

a) hydrogen **b)** hydrogencarbonate

c) ammonium **d)** phosphate

e) ethanoate **f)** iron (III)

g) nitrate **h)** copper (I)

i) nitride **j)** aluminium

4. State the name of the following ions.

a) Zn^{2+} **b)** Cl^- **c)** HSO_4^- **d)** Ag^+ **e)** SO_4^{2-}

f) Fe^{3+} **g)** NO_2^- **h)** Sn^{4+} **i)** Pb^{2+} **j)** S^{2-}

5. Write the correct formula for the following ionic compounds.

a) copper (II) oxide **b)** iron (II) carbonate

c) magnesium nitrate **d)** zinc hydroxide

e) ammonium sulfate **f)** tin (IV) chloride

g) silver chloride **h)** aluminium sulfide

For the experts

6. Write the correct formula for the following

a) tetraphosphorus decaoxide **b)** oxygen difluoride

c) calcium hydrogencarbonate **d)** iron (III) sulfide

e) aluminium carbonate **f)** barium phosphate

Set 6 – Writing Formulae (II)

1. Name the following ionic compounds.

a) ZnS **b)** $Ca(HSO_4)_2$

c) $Fe(NO_3)_3$ **d)** $Mg(OH)_2$

e) NH_4NO_3 **f)** Al_2O_3

g) $CuCO_3$ **h)** $CrCl_3$

i) $Al_2(SO_4)_3$ **j)** $Ca(CH_3COO)_2$

2. Name the following compounds.

a) CO **b)** NH_3

c) MgS **d)** H_2O

e) Fe_2O_3 **f)** $Cu(NO_3)_2$

g) P_2O_5 **h)** $AlCl_3$

i) $BaSO_3$ **j)** NO_2

3. Write the correct formula for each of the following.

a) potassium hydroxide **b)** aluminium hydroxide

c) tin (IV) nitrate **d)** sulfur dioxide

e) carbon tetrabromide **f)** lead (II) nitride

4. Which of the following have been written incorrectly? For those that are incorrect, write the correct name or formula.

a) aluminium trichloride **b)** $ZnNO_{32}$ **c)** $FeOH_3$

d) CuI_2 **e)** $Mg(Br)_2$ **f)** $AlSO_4$

5. Write the correct formula for the following compounds.

a) aluminium sulfite **b)** chromium carbonate

c) lead (IV) sulfate **d)** cobalt nitride

For the experts

6. Write the correct formula for the following compounds.

a) nitrogen trioxide **b)** silicon dioxide

c) barium hydrogensulfate **d)** iron (III) sulfide

e) iron (III) ethanoate **f)** ammonium phosphate

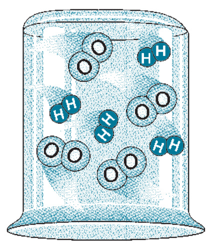
5. Chemical Reactions

Collision theory

When substances are mixed together a chemical reaction sometimes occurs. Chemical reactions always involve the collision of particles.

Beaker 1

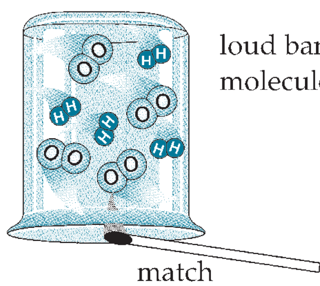
mixture of H_2 and O_2 gases



O_2 and H_2 molecules are mixed together but no reaction occurs

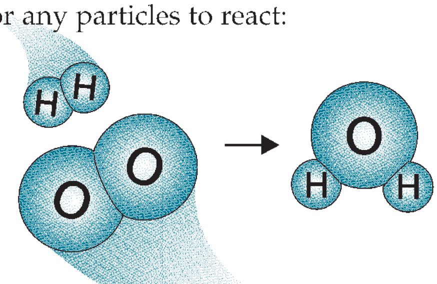
Beaker 2

mixture of H_2 and O_2 gases and a spark



loud bang heard as O_2 and H_2 molecules mix and then react

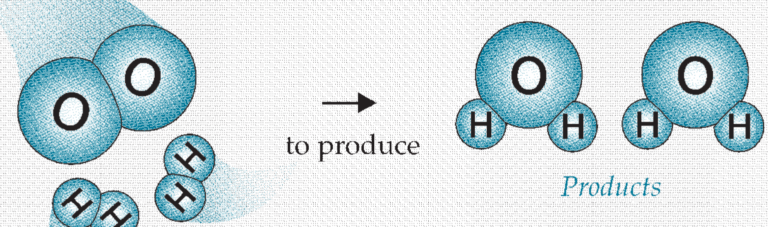
For any particles to react:



1. Particles must collide with sufficient energy to break old bonds and form new ones.
2. Particles must collide with correct orientation to allow particles to rearrange and make new compounds.

The way in which particles collide to produce a reaction and then new substances is summarised in a chemical equation.

For example the reaction between hydrogen gas and oxygen gas needs two molecules of hydrogen to collide with one molecule of oxygen to produce two molecules of water.



Reactants

Equation: $2\,H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\,H_2O_{\,(g)}$

Law of conservation of mass

Law of conservation of mass: In all chemical reactions, the number of atoms of each element involved must remain constant.

TOTAL MASS OF REACTANTS = TOTAL MASS OF PRODUCTS

For the reaction between hydrogen and oxygen: $2H_{2\,(g)} + O_{2\,(g)} \longrightarrow H_2O_{(g)}$

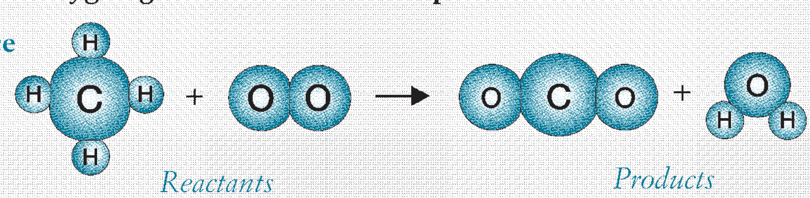
Reactants		Products
$2\,H_2$ = 4 atoms of H $1\,O_2$ = 2 atoms of O	=	$2\,H_2O$ = 4 atoms of H = 2 atoms of O

To write correct chemical equations:

1. Write correct formula for each substance involved. Once the correct formula is written it must not be changed.
2. BALANCE the equation to make sure it obeys the Law of conservation of mass. To balance an equation a COEFFICIENT (number) is written in front of each formula to make the number of atoms of each element on the reactants side is the same as the number of atoms of that element on the product side. REMEMBER: Do not change the formula – only change the coefficient. If the coefficient is one, no number is written.

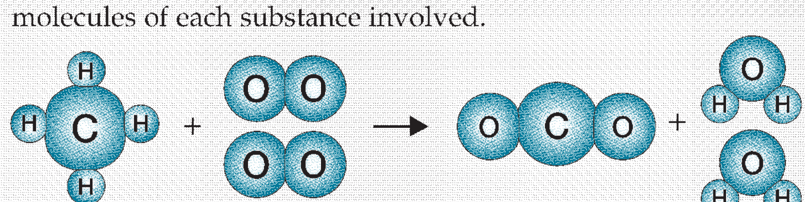
Example 5.1: Methane reacts with oxygen to give carbon dioxide and oxygen gas. Give a balanced equation.

Trial balance
(showing substances involved)



We can see that this is not balanced as on the reactant side there are less atoms of O than on the product side. Similarly there are more atoms of H on the reactant side than there is on the product side. We balance the equation by adjusting the number of molecules of each substance involved.

Balanced equation
(showing correct amount of substances involved)



$$CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{(g)}$$

Now the numbers of all atoms are equal, the equation is balanced.

Example 5.2: Balance the equation representing the reaction between Al_2O_3 and H_2S.

a) Write correct formula of each substance involved.
Do initial check to see if atoms are balanced.

$$Al_2O_{3\,(s)} + H_2S_{(g)} \longrightarrow Al_2S_{3\,(s)} + H_2O_{(l)}$$

2Al 3O   2H 1S   =   2Al 3S   2H 1O

S and O are not balanced.

b) Balance the equation by changing the coefficients in front of H_2S and H_2O (the formulae may not be changed).

$$Al_2O_{3\,(s)} + 3H_2S_{(g)} \longrightarrow Al_2S_{3\,(s)} + 3H_2O_{(l)}$$

2Al 3O   6H 3S   =   2Al 3S   6H 3O

ALL ATOMS NOW BALANCED.

NOTE:	6 Na_2O	=	(6 x 2) Na and (6 x 1) O
		OR	12 Na and 6 O
	4 $K_2Cr_2O_7$	=	(4 x 2) K ; (4 x 2) Cr and (4 x 7) O
		OR	8 K ; 8 Cr and 28 O
	3 $Fe(NO_3)_3$	=	(3 x 1) Fe ; (3 x 3) N and (3 x 3 x 3) O
		OR	3 Fe ; 9 N and 27 O

CHECKPOINT!

Question 5.1 - Use the coefficient to determine the number of atoms of each element in the following compounds.

a) 3 H_2SO_4 : ______ H , ______ S and ______ O

b) 4 $KMnO_4$: ______ K , ______ Mn and ______ O

c) 2 PbO_2 : ______ Pb and ______ O

d) 5 $KClO_4$: ______ K , ______ Cl and ______ O

e) 6 $NaHCO_3$: ______ Na , ______ H ; ______ C and ______ O

CHECKPOINT!

Question 5.2 - Use the coefficient to determine the number of atoms of each element in the following compounds.

a) 2 $Cu(OH)_2$: ______ Cu , ______ O and ______ H

b) 3 $Al_2(SO_4)_3$: ______ Al , ______ S and ______ O

c) 4 $Fe_2(CO_3)_3$: ______ Fe , ______ C and ______ O

d) 3 $Mg(NO_3)_2$: ______ Mg , ______ N and ______ O

e) 4 $Ca(HSO_4)_2$: ______ Ca , ______ H , ______ S and ______ O

TIP: When balancing equations, leave O and H until last.

NOTE: Formulae for acids:

H_2SO_4	-	sulfuric acid
HNO_3	-	nitric acid
HCl	-	hydrochloric acid
CH_3COOH	-	ethanoic acid
H_3PO_4	-	phosphoric acid
H_2CO_3	-	carbonic acid

CHECKPOINT!

Question 5.3 - Balance the following equations

a) $Fe_2O_{3\,(s)} + C_{(s)} \rightarrow Fe_{(s)} + CO_{2\,(g)}$

b) $Fe_2(CO_3)_{3\,(s)} + H_3PO_{4\,(aq)} \rightarrow FePO_{4\,(s)} + CO_{2\,(g)} + H_2O_{(l)}$

c) $Na_{(s)} + O_{2\,(g)} \rightarrow Na_2O_{(s)}$

d) $Sn(NO_3)_{2\,(aq)} + KOH_{(aq)} \rightarrow Sn(OH)_{2\,(s)} + KNO_{3\,(aq)}$

e) $NaHCO_{3\,(aq)} + H_3PO_{4\,(aq)} \rightarrow Na_3PO_{4\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

5. Review Questions

Set 7 - Balancing equations (I)

1. Balance the following equations.

a) $Na_{(s)} + H_2O_{(l)} \longrightarrow NaOH_{(aq)} + H_{2(g)}$

b) $Cu(NO_3)_{2(aq)} + NaOH_{(aq)} \longrightarrow Cu(OH)_{2(aq)} + NaNO_{3(aq)}$

c) $CaCO_{3(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

2. a) $Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$

b) $NaOH_{(aq)} + H_3PO_{4(aq)} \longrightarrow Na_3PO_{4(aq)} + H_2O_{(l)}$

c) $Cu(OH)_{2(aq)} + HCl_{(aq)} \longrightarrow CuCl_{2(aq)} + H_2O_{(l)}$

3. a) $CaCO_{3(s)} + H_3PO_{4(aq)} \longrightarrow Ca_3(PO_4)_{2(s)} + H_2O_{(l)} + CO_{2(g)}$

b) $ZnO_{(s)} + H_2S_{(g)} \longrightarrow ZnS_{(s)} + H_2O_{(l)}$

c) $H_2O_{2(aq)} \longrightarrow O_{2(g)} + H_2O_{(l)}$

4. a) $KHCO_{3(aq)} \longrightarrow K_2CO_{3(aq)} + H_2O_{(l)} + CO_{2(g)}$

b) $Na_2O_{2(aq)} + H_2O_{(l)} \longrightarrow NaOH_{(aq)} + O_{2(g)}$

c) $Cr(OH)_{3(s)} + H_2SO_{4(aq)} \longrightarrow Cr_2(SO_4)_{3(aq)} + H_2O_{(l)}$

5. a) $Mg_{(s)} + HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$

b) $Al_{(s)} + HCl_{(aq)} \longrightarrow AlCl_{3(aq)} + H_{2(g)}$

c) $NaOH_{(aq)} + H_3PO_{4(aq)} \longrightarrow Na_3PO_{4(aq)} + H_2O_{(l)}$

For the experts

6. a) $MgO_{(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + H_2O_{(l)}$

b) $Al(OH)_{3(s)} + H_2SO_{4(aq)} \longrightarrow Al_2(SO_4)_{3(aq)} + H_2O_{(l)}$

c) $Fe_2O_{3(s)} + HNO_{3(aq)} \longrightarrow Fe(NO_3)_{3(aq)} + H_2O_{(l)}$

Set 8 - Balancing equations (II)

1. Convert the following word equations to symbol form and then balance.

a) sodium carbonate + calcium nitrate → sodium nitrate + calcium carbonate

b) sodium hydrogencarbonate → sodium carbonate + water + carbon dioxide

c) zinc sulfate + aluminium → aluminium sulfate + zinc

2. a) potassium hydroxide + sulfuric acid → potassium sulfate + water

b) aluminium + oxygen gas → aluminium oxide

c) magnesium oxide + phosphoric acid → magnesium phosphate + water

3. a) potassium hydrogencarbonate + phosphoric acid → potassium phosphate + water + carbon dioxide

b) sodium hydroxide + phosphoric acid → sodium phosphate + water

c) lead (II) nitrate + sodium iodide → sodium nitrate + lead (II) iodide

4. a) chromium (III) carbonate + sulfuric acid → chromium sulfate + water + carbon dioxide

b) sodium ethanoate + hydrochloric acid → sodium chloride + ethanoic acid

c) calcium hydroxide + ethanoic acid → calcium ethanoate + water

5. a) ammonium hydrogencarbonate + nitric acid → ammonium nitrate + water + carbon dioxide

b) potassium hydroxide + hydrochloric acid → potassium chloride + water

c) hydrogen gas + oxygen gas → water

For the experts

6. a) iron + sulfuric acid → iron (III) sulfate + hydrogen gas

b) iron (III) oxide + nitric acid → iron (III) nitrate + water

c) copper (II) hydroxide + hydrochloric acid → copper (II) chloride + water

6. Writing Equations

Predicting the outcome of a reaction

The outcome of many chemical reactions can be predicted if the general nature of the reactants is known. This section looks at some of these general reactions.

Reactions between acidic and basic substances (neutralisation)

Acids:

These can be classified as substances that produce hydrogen ions (H^+) when dissolved in water.

Common acids: Hydrochloric Acid . . HCl
Nitric Acid . . . . HNO_3
Sulfuric Acid . . . . . . H_2SO_4
Phosphoric Acid . . . H_3PO_4
Carbonic Acid . . . . . H_2CO_3
Ethanoic Acid . . . . . . CH_3COOH

Most non-metal oxides are acidic. (H_2O and CO are two exceptions.)

Most non-metal oxides are acidic, for example: SO_2, SO_3, CO_2, NO_2 and P_2O_5.

Most metal oxides are basic, for example: Na_2O, K_2O, CaO, MgO, BaO and Fe_2O_3

Bases:

Bases are classified as substances that produce hydroxide ions (OH^-) when dissolved in water. Metal oxides, metal hydroxides, metal carbonates, metal hydrogencarbonates and ammonia are basic substances.

Salts:

When acids react with bases, salts are produced. A salt is formed when the negative ion from the acid combines with the positive ion from the base.

CHECKPOINT!

Question 6.1 - Classify the following substances as acidic or basic substances by placing them into the table below.

List of substances: HCl, NaOH, NH_3, $NaHCO_3$, $Mg(OH)_2$, K_2O, HNO_3, Fe_2O_3, SO_3, CH_3COOH, Na_2CO_3, H_3PO_4

Acidic substances		Basic substances	

CHECKPOINT!

Question 6.2 - Give the formula and name of the salt produced when the following acids and bases react.

a) $HCl_{(aq)} + NaOH_{(aq)}$ NaCl ______ Sodium Chloride ______

b) $H_2SO_{4\,(aq)} + K_2O_{(aq)}$ ______ ______

c) $CaCO_{3\,(s)} + HNO_{3\,(aq)}$ ______ ______

d) $NaOH_{(aq)} + HNO_{3\,(aq)}$ ______ ______

e) $H_3PO_{4\,(aq)} + NaOH_{(aq)}$ ______ ______

f) $SO_{3\,(g)} + KOH_{(aq)}$ ______ ______

There are 5 main reaction types involving acidic substances.

Reaction 1: Acid & Metal Hydroxide

Acid + Metal Hydroxide → Salt + Water

Example 6.1:

forms water

$$HNO_{3\,(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3\,(aq)} + H_2O_{(l)}$$

forms salt

$$2HCl_{(aq)} + Ca(OH)_{2\,(aq)} \rightarrow CaCl_{2\,(aq)} + 2H_2O_{(l)}$$

CHECKPOINT!

Question 6.3 - Complete and balance the following reactions between acids and metal hydroxides.

a) ___ $H_3PO_{4\,(aq)}$ + ___ $Mg(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

b) ___ $CH_3COOH_{(aq)}$ + ___ $Ba(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

c) ___ $H_2SO_{4\,(aq)}$ + ___ $Cr(OH)_{3\,(aq)}$ → ___ ________ + ___ ________

d) ___ $H_2CO_{3\,(aq)}$ + ___ $KOH_{(aq)}$ → ___ ________ + ___ ________

e) ___ $HCl_{(aq)}$ + ___ $Fe(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

Reaction 2: Non-metal Oxide & Metal Hydroxide

Non Metal Oxide + Metal Hydroxide → Salt + Water

Example 6.2: $SO_{3\,(g)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4\,(aq)} + H_2O_{(l)}$

$CO_{2\,(g)} + 2KOH_{(aq)} \rightarrow K_2CO_{3\,(aq)} + H_2O_{(l)}$

CHECKPOINT!

Question 6.4 - Complete and balance the following reactions between non-metal oxides and metal hydroxides.

a) ___ $SO_{2\,(g)}$ + ___ $Ca(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

b) ___ $P_2O_{5\,(g)}$ + ___ $Mg(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

c) ___ $SO_{3\,(g)}$ + ___ $Cu(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

d) ___ $CO_{2\,(g)}$ + ___ $Ba(OH)_{2\,(aq)}$ → ___ ________ + ___ ________

e) ___ $SO_{2\,(g)}$ + ___ $Al(OH)_{3\,(aq)}$ → ___ ________ + ___ ________

Reaction 3: Acid & Metal Oxide

Acid + Metal Oxide → Salt + Water

Example 6.3: $2HCl_{(aq)} + Na_2O_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)}$

$3H_2SO_{4\,(aq)} + Fe_2O_{3\,(s)} \rightarrow Fe_2(SO_4)_{3\,(aq)} + 3H_2O_{(l)}$

CHECKPOINT!

Question 6.5 - Complete and balance the following reactions between acids and metal oxides.

a) ___ $CH_3COOH_{(aq)}$ + ___ $BaO_{(s)}$ → ___ ________ + ___ ________

b) ___ $H_3PO_{4\,(aq)}$ + ___ $CuO_{(s)}$ → ___ ________ + ___ ________

c) ___ $H_2CO_{3\,(aq)}$ + ___ $K_2O_{(aq)}$ → ___ ________ + ___ ________

d) ___ $HNO_{3\,(aq)}$ + ___ $Al_2O_{3\,(s)}$ → ___ ________ + ___ ________

e) ___ $H_2SO_{4\,(aq)}$ + ___ $Cr(OH)_{3\,(s)}$ → ___ ________ + ___ ________

Reaction 4: Acid & Carbonate

Acid + Metal Carbonate → Salt + Water + Carbon Dioxide

Reaction 5: Acid & Hydrogencarbonate

Acid + Hydrogencarbonate → Salt + Water + Carbon Dioxide

Example 6.4: $2HCl_{(aq)} + CaCO_{3\,(s)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

$H_2SO_{4\,(aq)} + 2KHCO_{3\,(aq)} \rightarrow K_2SO_{4\,(aq)} + 2H_2O_{(l)} + 2CO_{2\,(g)}$

CHECKPOINT!

Question 6.6 - Complete and balance the following reactions between acids and metal carbonates or metal hydrogencarbonates.

a) ___ $H_3PO_{4\,(aq)}$ + ___ $(NH_4)_2CO_{3\,(aq)}$ → ___ ________ + ___ ________

b) ___ $HCl_{(aq)}$ + ___ $KHCO_{3\,(aq)}$ → ___ ________ + ___ ________

c) ___ $CH_3COOH_{(aq)}$ + ___ $ZnCO_{3\,(s)}$ → ___ ________ + ___ ________

d) ___ $HNO_{3\,(aq)}$ + ___ $Fe_2(CO_3)_{3\,(s)}$ → ___ ________ + ___ ________

e) ___ $H_2SO_{4\,(aq)}$ + ___ $Mg(HCO_3)_{2\,(aq)}$ → ___ ________ + ___ ________

Summary of Reactions

Acid + Metal Hydroxide → Salt + Water

Non-Metal Oxide + Metal Hydroxide → Salt + Water

Acid + Metal Oxide → Salt + Water

Acid + Carbonate → Salt + Water + Carbon Dioxide

Acid + Hydrogencarbonate → Salt + Water + Carbon Dioxide

6. Review Questions

Set 9 - Writing equations

1. Complete the following general equations.

a) acid + metal hydroxide →

b) acid + metal carbonate →

c) acid + metal oxide →

d) acid + metal hydrogencarbonate →

e) non-metal oxide + metal hydroxide →

2. Complete and balance the following equations.

a) $H_2SO_{4\,(aq)}$ + $Al(OH)_{3\,(s)}$ →

b) $HNO_{3\,(aq)}$ + $Ba(OH)_{2\,(s)}$ →

c) $CH_3OOH_{\,(aq)}$ + $Mg(HCO_3)_{2\,(aq)}$ →

d) $SO_{3\,(g)}$ + $NaOH_{\,(aq)}$ →

3. a) $Fe(OH)_{3\,(s)}$ + $H_2SO_{4\,(aq)}$ →

b) $HCl_{\,(aq)}$ + $CaO_{\,(s)}$ →

c) $Ca(OH)_{2\,(aq)}$ + $CO_{2\,(g)}$ →

4. a) $HCl_{\,(aq)}$ + $FeCO_{3\,(s)}$ →

b) $HNO_{3\,(aq)}$ + $Na_2O_{\,(s)}$ →

c) $H_2SO_{4\,(aq)}$ + $Cr(OH)_{3\,(s)}$ →

5. a) hydrochloric acid + iron (III) hydroxide →

b) nitric acid + barium carbonate →

c) ethanoic acid + calcium hydroxide →

d) sulfuric acid + lithium hydroxide →

e) carbonic acid + magnesium hydroxide →

For the experts

6. a) phosphoric acid + iron (III) oxide →

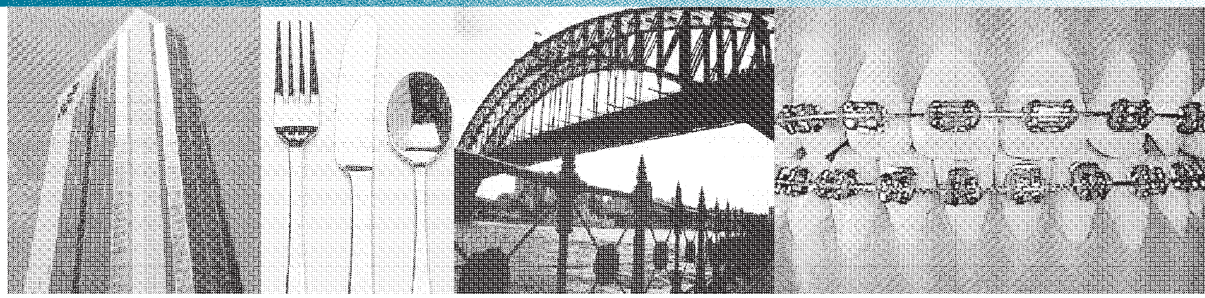
b) sulfur trioxide + barium hydroxide →

c) diphosphorus pentaoxide + sodium hydroxide →

d) sulfuric acid + iron (III) carbonate →

e) hydrochloric acid + chromium hydrogencarbonate →

7. Reactions Involving Metals



Activity Series
ranking ability to form H_2 with substance mentioned

- K, Na, Ca ↑ *cold water*
- Al, Zn, Fe, Ni, Sn, Pb ↑ *super heated steam or diluted acids*
- Cu, Hg, Ag, Pt, Au ↑ *Do not react with acids or water to form H_2*

Metals have a wide range of uses. Understanding and predicting the ways metals react is very important to reasons why metals have so many uses. The extent and speed with which metals react with metal ions, acids, oxygen and water is summarised by the metal activity series.

Reactions of metals with acids

Most metals react with dilute acids to produce a salt and hydrogen gas. Nitric acid, HNO_3, and concentrated H_2SO_4 do not react in this way.

Reactive Metal + Acid ⟶ Salt + Hydrogen Gas

From the activity series; metals below (and including) Cu do not react with dilute acids to produce hydrogen gas. As you proceed up the activity series the metals react more vigorously with dilute acids. Ca, Na and K react explosively. It should be noted that some metals have oxide layers that limit the reaction with acids. This oxide layer needs to be removed before the metal can react with the dilute acid.

Example 7.1: Write the balanced equations for the following reactions

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$$

CHECKPOINT!

Question 7.1 - Write balanced equations for the following. Where no reaction occurs write "no reaction"

a) ______ $Al_{(s)}$ + ______ $HCl_{(aq)}$ → ___ ________ + ___ ________

b) ______ $Sn_{(s)}$ + ______ $H_2SO_{4\,(aq)}$ → ___ ________ + ___ ________

c) ______ $Zn_{(s)}$ + ______ $HCl_{(aq)}$ → ___ ________ + ___ ________

d) iron + phosphoric acid

___ ________ + ___ ________ → ___ ________ + ___ ________

e) copper + hydrochloric acid

___ ________ + ___ ________ → ___ ________ + ___ ________

Reaction of metals with water

Reactive metals, those above Cu, can react with water to form hydrogen gas.

[K, Na, Ca] + H_2O ⟶ metal hydroxide + hydrogen gas

[Mg, Al, Zn, Fe, Ni, Sn, Pb] + superheated steam ⟶ metal oxide + hydrogen gas

[Cu, Hg, Ag, Pt, Au] - DO NOT REACT WITH WATER OR STEAM

Example 7.2: Write the balanced equations for the following reactions.

a) calcium and cold water

$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2\,(aq)} + H_{2\,(g)}$

b) iron and superheated steam

$2Fe_{(s)} + 3H_2O_{(g)} \rightarrow Fe_2O_{3\,(s)} + 3H_{2\,(g)}$

CHECKPOINT!

Question 7.2 - Write balanced equations for the following reactions.

a) aluminium + superheated steam

___ _______ + ___ _______ ⟶ ___ _______ + ___ _______

b) sodium + water

___ _______ + ___ _______ ⟶ ___ _______ + ___ _______

c) copper + superheated steam

___ _______ + ___ _______ ⟶ ___ _______ + ___ _______

d) nickel + superheated steam

___ _______ + ___ _______ ⟶ ___ _______ + ___ _______

e) lead + superheated steam

___ _______ + ___ _______ ⟶ ___ _______ + ___ _______

Reaction of metals with oxygen

Most metals react with oxygen gas to form an oxide. The higher up the activity series, the more rapid the reaction. Ag, Pt and Au do not react with oxygen, even if heated.

Metal + Oxygen Gas → Metal Oxide

Example 7.3: Write the equation for the reaction between zinc and oxygen gas.

$$2Zn_{(s)} + O_{2\,(g)} \rightarrow 2ZnO_{(s)}$$

CHECKPOINT!

Question 7.3 - Write balanced equations for the following reactions.

a) aluminium + oxygen gas

___ _______ + ___ _______ → ___ _______

b) sodium + oxygen gas

___ _______ + ___ _______ → ___ _______

c) copper + oxygen gas

___ _______ + ___ _______ → ___ _______

d) nickel + oxygen gas

___ _______ + ___ _______ → ___ _______

e) gold + oxygen gas

___ _______ + ___ _______ → ___ _______

Summary of Reactions

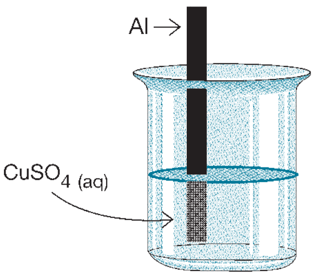
1. Reactive metal + Dilute Acid → Salt + Hydrogen Gas
2. [K,Na, Ca] + Cold water → Metal Hydroxide + Hydrogen Gas
3. [Mg, Al, Zn, Fe, Ni, Sn, Pb] + Super heated steam → Metal Oxide + Hydrogen Gas
4. Metal + Oxygen Gas → Metal Oxide [Exceptions: Ag, Pt, Au]
5. K Na Ca | Al Zn Fe Ni Sn Pb | Cu Hg | Ag Pt Au

← *reacts with oxygen* → (K to Hg)

← *reacts with dilute acid or super heated steam* → (K to Pb)

← *reacts with cold water* → (K, Na, Ca)

Reactions between metals and metal ions



A copper (II) sulfate solution contains Cu^{2+} ions and SO_4^{2-} ions. When a strip of Al is placed into the solution, the Al displaces the Cu^{2+} ions to form Al^{3+} ions and Cu solid. The sulfate ion takes no place in the reaction and so is not included in the equation.

Unbalanced equation:

$$Al_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Al^{3+}_{(aq)} + Cu_{(s)}$$

This equation IS NOT balanced. Atoms are balanced but charges are not.
To balance an ionic equation: i) balance atoms

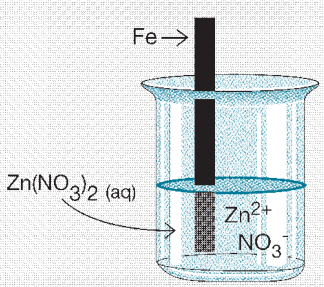
ii) balance charges by increasing the number of ions

iii) repeat (i) and (ii) until atoms and charges are balanced.

i.e. $2\,Al_{(s)} + 3Cu^{2+}_{(aq)} \longrightarrow 2Al^{3+}_{(aq)} + 3Cu_{(s)}$

The activity series provides a predictive tool to determine if the metal will displace the metal ion from solution.

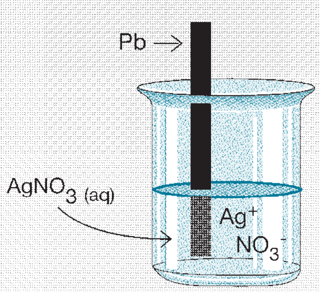
The metal will displace the metal ion from solution if the metal is higher up the activity series than the metal the ion comes from.



Example 7.4 :

Will the $Fe_{(s)}$ displace the $Zn^{2+}_{(aq)}$ ions from the solution?

* Check the activity series: Fe is lower in the series than Zn. Fe(s) WILL NOT displace $Zn^{2+}_{(aq)}$ from the solution.
* No reaction will be observed.



Example 7.5:

Will the $Pb_{(s)}$ displace the $Ag^{+}_{(aq)}$ ions from the solution?

* Check the activity series:
  Pb is higher in the series than Ag. $Pb_{(s)}$ WILL displace $Ag^{+}_{(aq)}$ from the solution.

* Write the equation: $Pb_{(s)} + Ag^{+}_{(aq)} \longrightarrow Pb^{2+}_{(aq)} + Ag_{(s)}$
* Charges are not balanced: follow 3 steps to balance.

$$Pb_{(s)} + 2Ag^{+}_{(aq)} \longrightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)}$$

Activity Series:

K
Na
Ca
Al
Zn
Fe
Ni
Sn
Pb
Cu
Hg
Ag
Pt
Au

↑ *atoms more reactive*

↓ *ions more reactive*

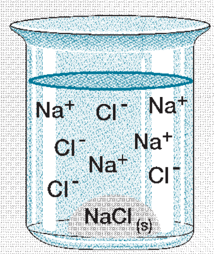
Note: *Pb^{2+} forms in preference to Pb^{4+}*

Reactions producing precipitates

Many substances form ions when they dissolve in water.

Dissociation occurs when an ionic substance is dissolved in water. The ions are already there, the water simply causes the ions to separate.

DISSOCIATION: occurs when ionic substances (metal ions bonded to non-metal ions) dissolve in water.



eg: when NaCl(s) dissolves in water, the ionic bond is weakened and the Na^+ ions and the Cl^- ions separate.

This is often represented using an **ionic equation.**

$$NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

The (aq) subscript indicates that the ions are dissolved in water and an aqueous solution has formed.

Not all ionic solids dissolve in water. A set of **solubility rules** as shown below can be used to determine if an ionic solid is soluble, slightly soluble or insoluble in water.

Ionic solids that are soluble in water:

Soluble	Exceptions	
	Insoluble	Slightly soluble
Most chlorides	AgCl, Hg_2Cl_2	$PbCl_2$
Most bromides	AgBr, Hg_2Br_2, $HgBr_2$	$PbBr_2$
Most iodides	AgI, Hg_2I_2, HgI_2, PbI_2	
All nitrates	Nil	
Most sulfates	$SrSO_4$, $BaSO_4$, $HgSO_4$, $PbSO_4$	$CaSO_4$, Ag_2SO_4

Ionic solids that are insoluble in water:

Insoluble	Exceptions	
	Soluble	Slightly soluble
Most hydroxides	NaOH, KOH, $Ba(OH)_2$ (NH_4OH does not exist)	$Ca(OH)_2$, $Sr(OH)_2$
Most carbonates	Na_2CO_3, K_2CO_3, $(NH_4)_2CO_3$	
Most phosphates	Na_3PO_4, K_3PO_4, $(NH_4)_3PO_4$	
Most sulfides	Na_2S, K_2S, $(NH_4)_2S$	

Soluble = more than 0.1 mol dissolves per litre

Slightly soluble = between 0.01 mol and 0.1 mol dissolves per litre

Insoluble = less than 0.01 mol dissolves per litre

Example 7.6: Use the solubility rules to determine if the following substances are soluble or not. For those that are soluble write ionic equations to show what ions are produced when the substance dissolves.

K_2SO_4 $MgCl_2$ $CaCO_3$

From the solubility rules $CaCO_3$ is insoluble while K_2SO_4 and $MgCl_2$ are both soluble:

$$K_2SO_{4(s)} \rightarrow 2\,K^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

$$MgCl_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2\,Cl^-_{(aq)}$$

NOTE: When balancing ionic equations, first check that atoms are balanced and then check that charges are balanced. Charges are balanced by adjusting the numbers of the ions present.

CHECKPOINT!

Question 7.4 - Use the solubility rules to determine if the following ionic solids are soluble in water.

a) $CuCO_3$ ______________ b) $MgCl_2$ ______________

c) $Zn(OH)_2$ ______________ d) $Ca_3(PO_4)_2$ ______________

e) $Ca(NO_3)_2$ ______________ f) $Al(OH)_3$ ______________

g) K_2SO_4 ______________ h) $FeCl_3$ ______________

Question 7.5 - Use the solubility rules to determine if the following ionic solids are soluble in water. For those that are write equations to show the ions produced. Assume that 0.15 mole of the solid is being dissolved in one litre of water.

a) Na_2S ______________

b) $BaSO_4$ ______________

c) $Cu(NO_3)_2$ ______________

d) $Al_2(CO_3)_3$ ______________

e) $Fe(OH)_3$ ______________

f) $Ca(OH)_2$ ______________

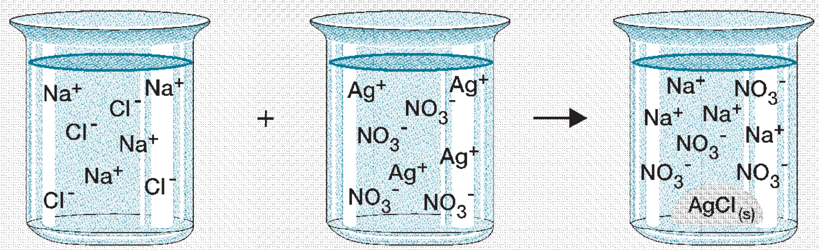
Note: Nearly all substances will dissolve to some extent eg. AgCl is listed as insoluble (less than 0.01 mole per litre dissolves) yet one litre of saturated AgCl solution contains in excess of 10^{20} ions of Ag^+ and Cl^-.

Reactions between ionic solutions

On some occasions when two ionic solutions are mixed, the combination of ions present will produce a pairing of two ions that are not soluble. When this occurs, the large numbers of ions available combine to form an insoluble ionic solid.

Example 7.7: When a solution of NaCl is combined with a solution of $AgNO_3$ a white precipitate forms. Determine what that precipitate is and write an ionic equation to show its formation.

Step 1: Determine which ions are present when the solutions are to be mixed; the solubility rules are an essential tool at this stage:



$NaCl_{(aq)}$ consists of separated $Na^+_{(aq)}$ ions and Cl^- ions;
$AgNO_{3(aq)}$ consists of separated $Ag^+_{(aq)}$ ions and $NO_3^-{}_{(aq)}$ ions.

Step 2: Identify those ions that have altered their state, ie have gone from being in the aqueous state to being a solid (or a liquid or a gas).

ie. $Ag^+_{(aq)}$ and $Cl^-_{(aq)}$ have combined to form $AgCl_{(s)}$. In the solid form the ions cannot be separated. The $Na^+_{(aq)}$ and $NO_3^-{}_{(aq)}$ ions do not take part in the reaction and are not included in the equation. (They are called spectator ions.)

Step 3: Write the ionic equation to show just those substances that have changed (reacted). $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

Step 4: Check that the atoms and charges in the equation are balanced. (In this case they are.)

CHECKPOINT!

Question 7.6 - Use the solubility rules to determine which of the following combinations of solutions will result in a precipitate forming. Write an ionic equation to show the reaction that produced any precipitate. If no precipitate forms write "no reaction".

a) $CuSO_{4\ (aq)}$ + $NaOH_{\ (aq)}$ (List the ions present: ________________________)

Ionic Equation: ____________________________________

b) $Na_2S_{\ (aq)}$ + $Ca(NO_3)_{2\ (aq)}$ (List the ions present: ________________________)

Ionic Equation ____________________________________

7. Review Questions

Set 10 - Reactions involving metals

1. List each of the following group of metals in order of reactivity (most reactive first)

a) Zinc, gold, potassium, aluminium

b) Lead, iron, mercury, silver

c) Copper, sodium, nickel, calcium

2. Name a metal which

a) Reacts with oxygen but not with dilute acids

b) Does not react with any acid even if concentrated

c) reacts with cold water

d) reacts with steam but not with water

3. Write a balanced equation for the following reactions of metals with dilute acids. If no reaction occurs write 'no reaction'.

a) calcium + hydrochloric acid **b)** iron + hydrochloric acid

c) silver + sulfuric acid **d)** sodium + carbonic acid

4. Write a balanced equation for the following reactions of metals with dilute acids. If no reaction occurs write 'no reaction'.

a) sodium + cold water **b)** zinc + steam

c) platinum + steam **d)** magnesium + cold water

5. Write a balanced equation for the following reactions of metals with dilute acids. If no reaction occurs write 'no reaction'.

a) potassium + oxygen **b)** gold + oxygen

c) aluminum + oxygen **d)** copper + oxygen

For the experts

6. Jenny was given a small rod made of shiny silver metal and asked to determine the identity of the metal. She decided to test it by placing it in different solutions to see if it would react. She found that it reacted with copper (II) sulfate solution but not with zinc nitrate solution.

a) which metal (or metals) could the rod be made of?

b) what other test could Jenny undertake to determine the identity of the metal?

Set 11 - Ionic solutions

1. For each ionic compound named, give the cations (positve ions) and anions (negative ions) it is a composed of:

a) $Ca(OH)_2$ **b)** $Fe_2(CO_3)_3$ **c)** $AlPO_4$

d) $Cr_2(SO_4)_3$ **e)** $Ba(NO_3)_2$ **f)** Rb_2CO_3

2. Give the cations and anions for each of the following compounds:

a) Calcium phosphate **b)** Cobalt nitrate **c)** Nickel bromide

3. Complete the table below to indicate the formula of any precipitate formed when the solutions listed are mixed

	$AgNO_3$	$Cu(NO_3)_2$	$Fe(NO_3)_2$	$Ba(NO_3)_2$
K_2SO_4				
NaCl				
$(NH_4)_2CO_3$				
NaOH				

4. Write ionic equations for each of the following precipitate forming reactions. If no precipitate forms, write No Reaction.

a) $NaOH_{(aq)} + Ni(NO_3)_{2\,(aq)}$ **b)** $Pb(NO_3)_{2\,(aq)} + NH_4I_{(aq)}$

c) $CaSO_{4\,(aq)} + BaCl_{2\,(aq)}$ **d)** $Hg(NO_3)_{2\,(aq)} + ZnI_{2\,(aq)}$

5. Write ionic equations for each of the following precipitate forming reactions. If no precipitate forms, write No Reaction.

a) $NiCl_{2\,(aq)} + Na_2S\ (aq)$ **b)** $Al_2(SO_4)_{3\,(aq)} + Ba(OH)_{2\,(aq)}$

c) $Ag_2SO_{4\,(aq)} + FeBr_{3\,(aq)}$ **d)** $AlCl_{3\,(aq)} + Ba(OH)_{2\,(aq)}$

For the experts

6. A laboratory assistant had prepared 0.20 mol L^{-1} solutions of barium nitrate, iron (III) chloride and sodium nitrate. However, when left over night the labels fell from the bottles onto the floor. Use your knowledge of solubility rules to suggest a series of tests that could be used to identify and correctly label each bottle. Your answer needs to explain what test you would use on each solution and what result you would expect.

Chemistry Calculations

8. Relative Masses
9. The Mole
10. Calculations from Equations - Moles/Mass
11. Calculations from Equations - Moles/Volume
12. Gases

Chemistry Calculations

8. Relative Masses

Relative atomic mass (A_r)

The mass of individual atoms is very small and hence it is more convenient to use relative masses. This means that the mass of each atom is compared to a standard which is an isotope of carbon, carbon-12.

The **relative atomic mass (A_r)** of an element is the average mass of one atom of it compared to $^1/_{12}$ of the mass of an atom of carbon-12.

Comparing atomic masses

Note: The mass of 1 carbon atom is taken as being exactly 12.

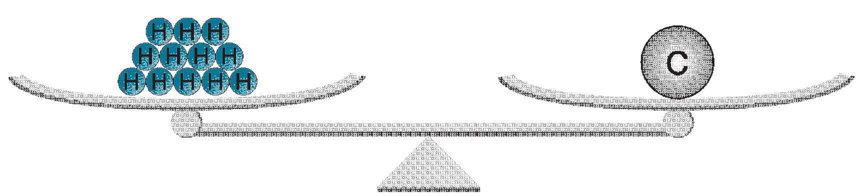
The carbon-12 atom is used for the comparison of all atomic masses

A_r (H) ≈ 1

mass of 12 H atoms ≈ mass of 1 carbon atom

∴ mass of 1H atom ≈ 1

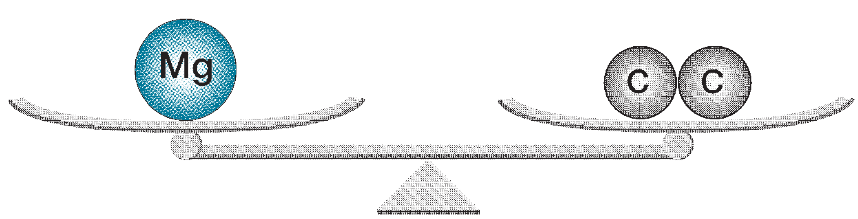
∴ A_r (H) ≈ 1



A_r (Mg) ≈ 24

mass of 1 Mg atom ≈ mass of 2 carbon atoms

∴ A_r (Mg) ≈ 24

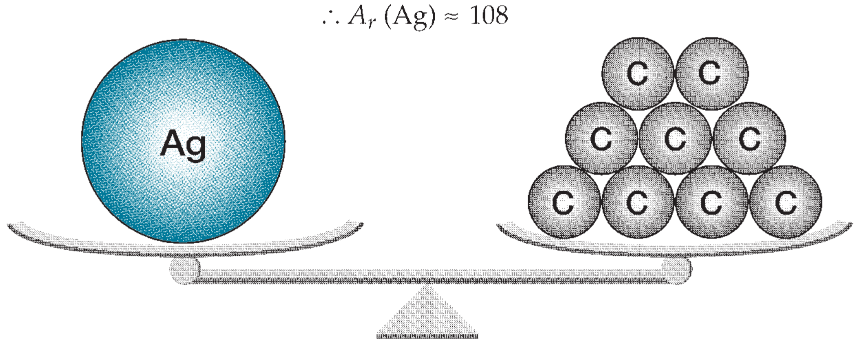


The relative atomic mass (A_r) of magnesium is 24.0. This means that an atom of magnesium is exactly twice the mass of an atom of carbon-12.

A_r (Ag) ≈ 108

mass of 1 Ag atom ≈ mass of 9 carbon atoms

∴ A_r (Ag) ≈ 108



Relative atomic masses have no units because they are ratios

Table 1: Relative atomic masses (A_r) of some elements

METALS			NON METALS		
Element	**Symbol**	**A_r**	**Element**	**Symbol**	**A_r**
Aluminium	Al	27.0	Argon	Ar	40.0
Barium	Ba	137.3	Boron	B	10.8
Calcium	Ca	40.1	Bromine	Br	79.9
Chromium	Cr	52.0	Carbon	C	12.0
Copper	Cu	63.5	Chlorine	Cl	35.5
Gold	Au	197.0	Fluorine	F	19.0
Iron	Fe	55.8	Helium	He	4.0
Lead	Pb	207.2	Hydrogen	H	1.0
Magnesium	Mg	24.3	Krypton	Kr	83.8
Mercury	Hg	200.6	Iodine	I	126.9
Potassium	K	39.1	Neon	Ne	20.2
Silver	Ag	107.9	Nitrogen	N	14.0
Sodium	Na	23.0	Oxygen	O	16.0
Tin	Sn	118.7	Phosphorus	P	31.0
Titanium	Ti	47.9	Silicon	Si	28.1
Zinc	Zn	65.4	Sulfur	S	32.1

CHECKPOINT!

Question 8.1 - Use Table 1 to determine the following.

a) Approximately how many times heavier than a carbon-12 atom is an atom of:

i) Chlorine ____________ iii) Titanium ____________

ii) Silver ____________ iv) Krypton ____________

b) Approximately how many times heavier than a hydrogen atom is an atom of:

i) Helium ____________ iii) Carbon ____________

ii) Oxygen ____________ iv) Iron ____________

c) Approximately how many atoms of aluminium have the same mass as 1 atom of Silver?

____

d) List in order of size, the three lightest:

i) metal atoms ____________ ii) non-metal atoms ____________

e) Which metal atom is approximately 40 times heavier than hydrogen?

____

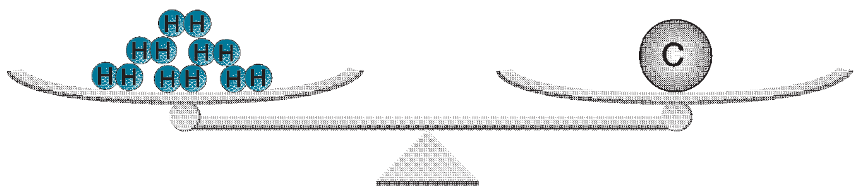
Relative molecular mass (M_r)

The atoms of non-metals, such as those listed in Table 1, are able to combine to form molecules. The mass of these molecules can also be compared to the mass of carbon-12 atoms to find their relative molecular mass.

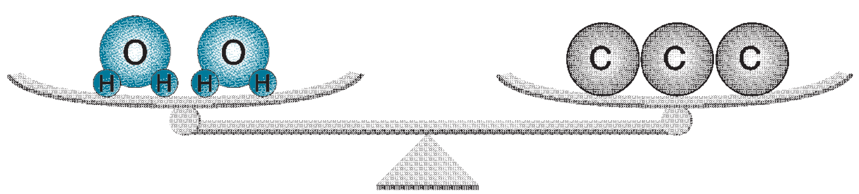
The **relative molecular mass (M_r)** of an element or a compound is the mass of one of its molecules compared to $^1/_{12}$ of the mass of an atom of carbon-12.

Molecular masses are also compared to the carbon-12 atom.

M_r (H_2) ≈ 2 mass of 6 molecules of hydrogen ≈ mass of 1 carbon atom



M_r (H_2O) ≈ 18 mass of 2 water molecules ≈ mass of 3 carbon atoms



Relative formula mass (M_r)

Ionic compounds such as sodium chloride (table salt) are not made up of discrete molecules and hence it would be incorrect to refer to their relative molecular mass. Instead, for ionic substances, we refer to their **relative formula mass (M_r)**. You will notice the same symbol, M_r, is used and it is defined in the same way as relative molecular mass.

Calculating relative masses

The relative molecular mass (or relative formula mass) can be calculated by simply adding the relative masses of all the atoms shown in the formula.

The following two examples show the main steps involved in calculating relative formula mass for compounds.

Example 8.1: Simple formula - Find M_r for sulfuric acid.

Formula → H_2SO_4			
Elements in formula	H	S	O
Mass of each element	2 x 1.0	32.1	4 x 16.0
M_r (H_2SO_4) = 2.0 + 32.1 + 64.0 = 98.1			

Example 8.2: Formula with brackets - Find M_r for zinc nitrate.

Formula → $Zn(NO_3)_2$			
Elements in formula	**Zn**	**N**	**O**
Mass of each element	65.4	2 x 14.0	6 x 16.0
$M_r\ (Zn(NO_3)_2) = 65.4 + 28.0 + 96.0 = 189.4$			

The calculation of M_r would normally be set out in a single line as shown below. The most important thing is to make sure you have the correct formula.

Example – (normal set out)

$$M_r\ (H_2SO_4) = (2 \times 1.0) + (1 \times 32.1) + (4 \times 16.0) = 98.1$$

$$M_r\ (Zn(NO_3)_2) = (1 \times 65.4) + (2 \times 14.0) + (6 \times 16.0) = 189.4$$

CHECKPOINT!

Question 8.2 - Complete the following:

a) $M_r\ (CO_2)$ = (1 x ______) + (2 x ______) =

b) $M_r\ (Cl_2)$ = (2 x ______) = ______

c) $M_r\ (CuSO_4)$ = (1 x ______) + (1 x ______) + (4 x ______) = ______

d) $M_r\ (Pb(NO_3)_2)$ = (1 x ______) + (2 x ______) + (6 x ______) = ______

e) $M_r\ (Mg(OH)_2)$ = (______) + (______) + (______) = ______

Question 8.3 - Write down the formulae for the following and determine their relative molecular mass.

a) sulfur dioxide ______ ______

b) aluminium chloride ______ ______

c) chlorine gas ______ ______

d) ammonia gas ______ ______

e) barium chloride ______ ______

f) ammonium sulfate ______ ______

g) iron (II) hydroxide ______ ______

h) zinc carbonate ______ ______

Percentage composition

The proportion (or percentage) by mass of each of the elements in a compound can be determined from the formula by comparing relative masses.

$$\text{Percentage (\%) by mass (of an element)} = \frac{\text{total } A_r \text{ for that element}}{M_r \text{ for the compound}} \times 100$$

Example 8.3: Determine percentage by mass of carbon in ethanol.

Step 1 - Find M_r for ethanol

Formula → C_2H_5OH			
Elements in formula	**C**	**H**	**O**
Mass of each element	2 x 12.0	6 x 1.0	1 x 16.0
M_r (C_2H_5OH) = 24.0 + 6.0 + 16.0 = 46.0			

Step 2 - % by mass of carbon $= \frac{24.0}{46.0} \times 100 = 52.2\%$

Example 8.4: Determine the percentage by mass of the water of crystallisation contained in copper (II) sulfate - 5 - water.

Step 1 - Find M_r for copper (II) sulfate – 5 – water

Formula → $CuSO_4.5H_2O$				
Elements in formula & H_2O	**Cu**	**S**	**O**	**H_2O**
Masses	63.5	32.1	4 x 16.0	5 x 18.0
M_r ($CuSO_4 . 5H_2O$) = 63.5 + 32.1 + 64.0 + 90.0 = 249.6				

Step 2 - % by mass of water $= \frac{90.0}{249.6} \times 100 = 36.1\%$

CHECKPOINT!

Question 8.4 - Use the data in example 3 above to determine the percentage of hydrogen and oxygen in ethanol.

i) % (by mass) of hydrogen = ________ x 100 = ________

ii) % (by mass) of oxygen = ________ x 100 = ________

CHECKPOINT!

Question 8.5 - Determine the M_r of the following compounds and their percentage composition.

a) carbon dioxide (CO_2) M_r (CO_2) = (1 x ______) + (2 x ______) = ________

∴ % carbon = ________ x 100 = ________

∴ % oxygen = ________ x 100 = ________

b) lead sulfate ($PbSO_4$)

M_r ($PbSO_4$) = (1 x ______) + (1 x ______) + (4 x ______) = ________

∴ % lead = ________ x 100 = ________

% sulfur = ________ x 100 = ________

% oxygen = ________ x 100 = ________

Total % = ________

Question 8.6 - Determine M_r for the following compounds and their percentage composition.

a) silver nitrate ($AgNO_3$)

M_r ($AgNO_3$) = ________________________________

% silver = ________________________________

% nitrogen = ________________________________

% oxygen = ________________________________

b) sodium sulfate (________)

____

____

____

c) ammonium sulfate (________)

____

____

____

7. Review Questions

Set 12 – Relative atomic mass

1. List the following elements in order of relative atomic mass (from lowest to highest).

a) oxygen , nitrogen , neon

b) aluminium , carbon , chlorine

c) iron , zinc , chromium

2. For each of the following sets of elements select the one with the heaviest atoms.

a) phosphorus , potassium , titanium

b) neon , argon , krypton

c) iodine , chlorine , fluorine

3. Determine approximately:

a) how many atoms of helium would weigh as much as one atom of oxygen;

b) how many atoms of boron would weigh as much as one atom of silver;

c) how many atoms of hydrogen would weigh as much as one atom of carbon.

4. Which two elements have atoms with (almost) identical masses?

5. The relative atomic masses of some elements are whole numbers while for many others they are not.

e.g. A_r (H) = 1.0 , Ar (O) = 16.0 , A_r (Na) = 23.0, while

A_r (B) = 10.8 , Ar (Cl) = 35.5 , A_r (Ca) = 40.1

Explain how it is possible to have fractional masses.
(Hint: you may need to refer to the section on atomic structure.)

For the experts

6. A group of chemists decided that it might be better to use oxygen-16 as a standard instead of carbon-12. They would define the relative atomic mass of an element as *"the average mass of one atom of that element compared to $^1/_{16}$ of the mass of an oxygen-16 atom"*.

Comment on their idea and discuss how this would affect the relative masses of the elements listed in Table 1.

Set 13 – Relative molecular mass

1. Determine the relative molecular mass (M_r) for each of the following molecular compounds.

a) nitrogen gas N_2 **b)** chlorine gas Cl_2

c) carbon dioxide CO_2 **d)** sulfur dioxide SO_2

e) sulfur trioxide SO_3 **f)** methane CH_4

2. Write the correct formula and determine the relative formula mass (M_r) for the following.

a) sodium chloride **b)** calcium oxide

c) aluminium chloride **d)** zinc sulfide

e) magnesium oxide **f)** potassium hydroxide

3. Write the correct formula and determine the relative formula mass (M_r) for the following.

a) zinc nitrate **b)** aluminium sulfate

c) ammonium carbonate **d)** magnesium hydroxide

e) copper (II) carbonate **f)** iron (II) oxide

4. For each of the following sets of molecules determine which is the heaviest.

a) H_2 , N_2 , O_2 **b)** SO_2 , CO_2 , NO_2

c) Cl_2 , Br_2 , I_2 **d)** SO_3 , C_4H_{10} , C_2H_5OH

5. Determine which of the following molecules
H_2O , CO , CH_3COOH , C_2H_5OH , NH_3 , C_3H_8

a) has the same mass as 5 carbon atoms;

b) has the same mass as 17 hydrogen atoms.

For the experts

6. For compounds such as those in question (1) above we refer to their relative molecular mass whereas for those listed in question (2) we refer to their relative formula mass. Explain the difference between relative molecular mass and relative formula mass.

Set 14 – Percentage composition

1. Determine the percentage by mass of each element within the following compounds.

a) sulfur dioxide **b)** carbon monoxide

c) sodium chloride **d)** magnesium hydroxide

e) silver nitrate

2. Determine the percentage by mass of:

a) hydrogen in water **b)** carbon in propane (C_3H_8)

c) sodium in sodium sulfate **d)** lead in lead (II) nitrate

e) carbon in ammonium carbonate

3. Determine the percentage by mass of water in the following hydrated compounds.

a) barium chloride - 2 - water **b)** calcium sulfate - 2 - water

c) magnesium sulfate - 7 - water **d)** sodium carbonate - 10 - water

e) iron (III) chloride - 6 - water

4. An essential element for plant growth is nitrogen. Calculate the percentage by mass of nitrogen in the following commonly used fertilisers.

a) liquid ammonia **b)** ammonium nitrate

c) ammonium sulfate **d)** urea ($CO(NH_2)_2$)

5. Most metals are recovered from minerals which are found in ores. The minerals are actually compounds of the desired metal.

For each of the following minerals calculate the percentage by mass of the metallic element.

a) iron in haematite (iron (III) oxide)

b) aluminium in alumina (aluminium oxide)

c) copper in chalcopyrite ($CuFeS_2$)

d) calcium in pure limestone (calcium carbonate)

e) lead in galena (lead (II) sulfide)

For the experts

6. Aluminium metal is recovered from a bauxite ore which contains 10% alumina (aluminium oxide).

Calculate the percentage by mass of aluminium in a typical sample of bauxite ore.

9. The Mole

Moles

Chemical reactions involve very large numbers of extremely small particles. These particles, such as atoms, molecules and ions are simply too small to count or weigh individually.

The mole *(n)* is a number that chemists use to count large numbers of particles. Just as we can refer to a dozen eggs (12), or a ream of paper (500 sheets), chemists speak of a mole of atoms (6.02×10^{23} atoms).

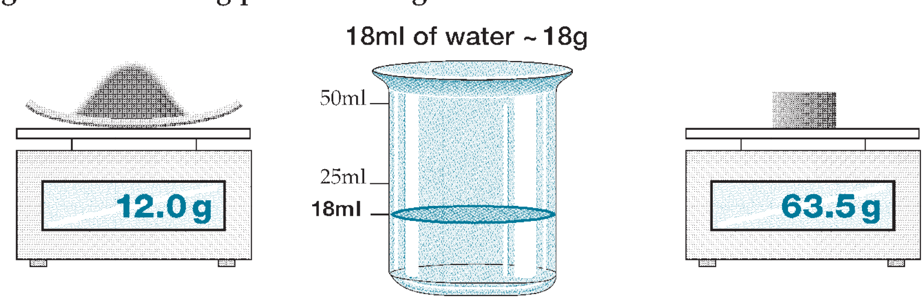
The mole is the amount of substance containing Avogadro's number (N_A) of particles. This number, named after the Italian scientist Amadeo Avogadro is approximately 602,000,000,000,000,000,000,000 or more simply 6.02×10^{23}.

Chemists don't actually count out a mole of atoms but instead do so by weighing. Just as a bank teller would weigh out $100 of 5¢ coins, a chemist can weigh out a mole of, say, aluminium atoms by weighing out its relative atomic mass in grams (27g).

Important terms

Avogradro's Number (N_A)	=	6.02×10^{23}
1 mole of substance	=	6.02×10^{23} particles of that substance
Molar mass *(M)*	=	mass of one mole of a substance
Atomic mass *(M)*	=	mass of one mole of atoms of an element
Molecular mass *(M)*	=	mass of one mole of molecules of an element or compound
Formula mass *(M)*	=	mass of one mole of formula units of an ionic compound

Figure 1 – Counting particles using mass



12g of carbon powder	18g of water	63.5g of copper metal
contains	*contains*	*contains*
6.02×10^{23} carbon atoms (1 mole)	6.02×10^{23} water molecules (1 mole)	6.02×10^{23} copper atoms (1 mole)

Counting very tiny particles is impractical but we can achieve the same thing by weighing substances. The relative atomic mass (A_r) or relative molecular mass (M_r), measured in grams, always contains 1 mole of particles.

Calculations – moles and particles

The number of particles that make up one mole of a substance is 6.02×10^{23}. Hence if we wish to convert the number of particles to moles we use the following relationship.

$$n = \frac{N}{6.02 \times 10^{23}}$$

n = moles of particles
N = number of particles

Example 9.1: How many moles of carbon dioxide molecules are there in 3.60×10^{24} molecules of this substance?

$$n(CO_2) = \frac{N}{6.02 \times 10^{23}}$$

$$= \frac{3.60 \times 10^{24}}{6.02 \times 10^{23}}$$

$= 5.98$ mol of CO_2 molecules

Example 9.2: How many atoms of sodium are there in 4.0 moles of this substance?

$$n = \frac{N}{6.02 \times 10^{23}}$$

$$4.0 = \frac{N}{6.02 \times 10^{23}}$$

$$\therefore N = (4.0)(6.02 \times 10^{23})$$

$= 2.41 \times 10^{24}$ atoms of sodium

Example 9.3: How many atoms of a) nitrogen and b) hydrogen are there in 3.0 moles of ammonia molecules (NH_3)?

3.0 mol of NH_3 molecules contain:
-> 3.0 mol of N atoms
and -> 9.0 mol of H atoms

$\therefore$ a) N (N atoms) $= (3.0)(6.02 \times 10^{23})$
$= 1.81 \times 10^{24}$ atoms of Nitrogen

b) N (H atoms) $= (9.0)(6.02 \times 10^{23})$
$= 5.42 \times 10^{24}$ atoms of Hydrogen

Example 9.4: Calculate the number of a) Mg^{2+} ions; b)NO_3^- ions and c) oxygen atoms contained in 5.0 mol of magnesium nitrate $Mg(NO_3)_2$.

5.0 mol of $Mg(NO_3)_2$ formula units contain:

–> 5.0 mol of Mg^{2+} ions

–> 10.0 mol of NO_3^- ions

–> 30.0 mol of O atoms

∴ a) $N (Mg^{2+} \text{ ions}) = (5.0)(6.02 \times 10^{23}) = 3.01 \times 10^{24}$ Mg^{2+} ions

b) $N (NO_3^- \text{ ions}) = (10.0)(6.02 \times 10^{23}) = 6.02 \times 10^{24}$ NO_3 ions

c) $N (\text{O atoms}) = (30.0)(6.02 \times 10^{23}) = 1.81 \times 10^{25}$ O atoms

CHECKPOINT!

Question 9.1 - In Figure 1 you can see that 12 g of carbon contains the same number of atoms as 63.5 g of copper. What does this tell us about the mass of copper atoms compared to the mass of carbon atoms?

Question 9.2 - If you were given 1 mole of 5¢ coins would you be a millionaire? Calculate how many dollars you would have.

Question 9.3 - How many atoms of oxygen are there in:

a) 1 mol of oxygen atoms

b) 1 mol of oxygen molecules (O_2)

c) 2 mol of water molecules (H_2O)

d) 5 mol of carbon dioxide molecules (CO_2)

e) 5 mol of glucose molecules ($C_6H_{12}O_6$)

Molar mass (*M*)

The mass of one mole of a substance is called its molar mass. This mass is simply the relative atomic mass (A_r), or relative molecular mass (M_r), expressed in grams.

e.g. A_r (Na) = 23 ∴ M (Na) = 23 g mol^{-1}

M_r (CO_2) = 44 ∴ M (CO_2) = 44 g mol^{-1}

Calculating molar mass

Molar mass can be calculated in the same way that we calculated relative molecular mass. Simply add the individual masses of the atoms in the formula.

Example 9.5: Find the molar mass (M) for calcium carbonate ($CaCO_3$).

Formula → $CaCO_3$			
Elements in formula	**Ca**	**C**	**O**
Mass of each element	40.1	12.0	16.0
Molar mass (*M*) = 40.1 + 12.0 + (3 x16.0) = 100.1 g mol^{-1}			

or more simply *M* ($CaCO_3$) = (40.1) + (12.0) + (3 x 16.0) = 100.1 g mol^{-1}

CHECKPOINT!

Question 9.4 - Complete the following ((a) is completed for you).

a) M (SO_2) = (32.1) + (2 x 16.0) = 64.1 g mol^{-1}

b) M (NaCl) = __________ = __________

c) M (H_2O) = __________ = __________

d) M ($ZnCl_2$) = __________ = __________

e) M (Al_2O_3) = __________ = __________

Question 9.5 - Write the correct formula and calculate molar mass for the following compounds ((a) is completed for you).

a) calcium chloride M ($CaCl_2$) = 40.1 + (2 x 35.5) = 111.1 g mol^{-1}

b) zinc sulfate ____________________

c) lead (IV) oxide ____________________

d) iron (III) chloride ____________________

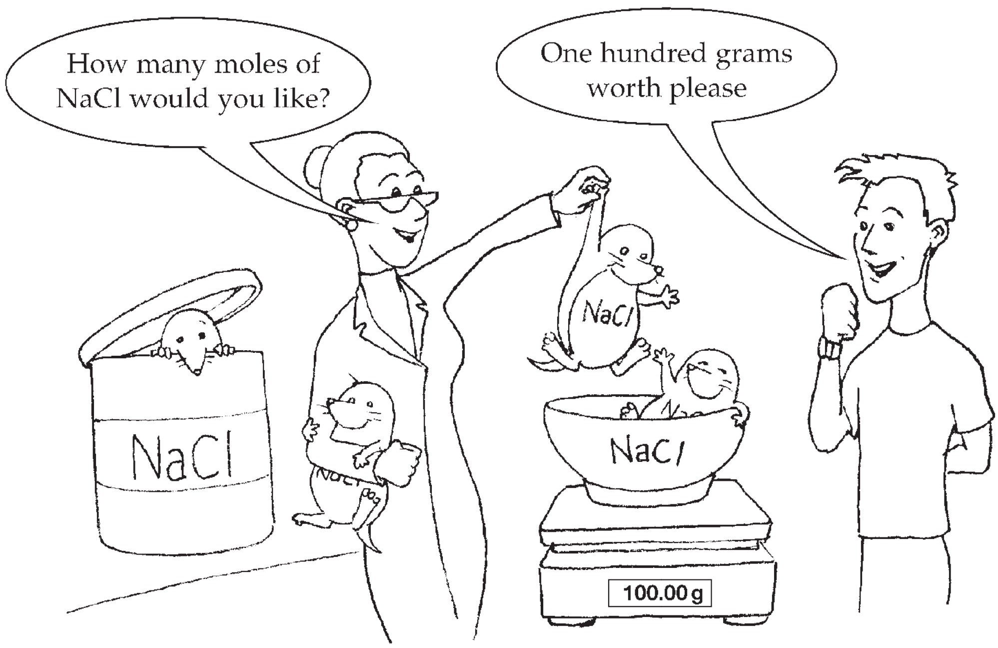
e) tetraphosphorous decaoxide ____________________

Calculations – mass to moles

The number of moles of a substance in a given mass of that substance can be calculated using the following relationship.

$$n = \frac{m}{M}$$

n = number of moles
m = mass of substance
M = molar mass of substance



Example 9.6: Calculate the number of moles of sodium chloride contained in 100.0 g of this substance.

$$M\,(NaCl) = 23.0 + 35.5 = 58.5\ g\ mol^{-1}$$

$$n\,(NaCl) = \frac{m}{M} = \frac{100.0}{58.5} = 1.71\ mol$$

Example 9.7: Calculate the number of moles of sulfuric acid in 240g of this substance.

$$M\,(H_2SO_4) = (1.0 \times 2) + 32.1 + (16.0 \times 4) = 98.1\ g\ mol^{-1}$$

$$n\,(H_2SO_4) = \frac{m}{M} = \frac{240}{98.1} = 2.45\ mol$$

CHECKPOINT!

Question 9.6 - Calculate the number of moles in 135 g of each of the following substances ((a) is completed for you).

a) $n\ (Fe_2O_3) = \frac{m}{M} = \frac{135}{(55.8 \times 2) + (16.0 \times 3.0)} = 0.846$ mol of Fe_2O_3

b) $n\ (CuSO_4) =$ ______________________

c) $n\ (CuSO_4\ .\ 5H_2O) =$ ______________________

d) $n\ (H_3PO_4) =$ ______________________

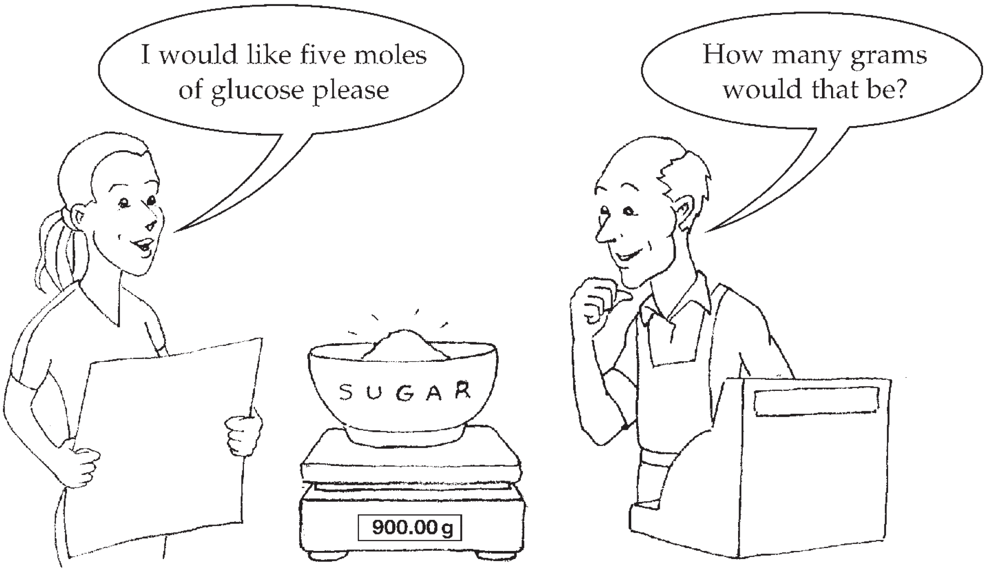
e) $n\ (BaCl_2) =$ ______________________

Calculations – moles to mass

We can rearrange the moles / mass formula in order to convert moles to mass.

$n = \frac{m}{M}$ *becomes –>* $m = n\ .\ M$

n = number of moles
m = mass of substance
M = molar mass of substance



The Mole

Example 9.8: Calculate the mass of 5.0 moles of glucose ($C_6H_{12}O_6$).

M ($C_6H_{12}O_6$) = (12.0 x 6) + (1.0 x 12) + (16.0 x 6) = 180 g mol^{-1}

$\therefore m$ ($C_6H_{12}O_6$) = n . M = (5.0) (180) = 900 g of sucrose

Example 9.9: Calculate the mass of 0.435 moles of ammonium carbonate.

M $(NH_4)_2CO_3$ = [14.0 + (1.0 x 4)] 2 + 12.0 + (16.0 x 3) = 96.0 g mol^{-1}

$\therefore m$ $(NH_4)_2CO_3$ = n . M = (0.435) (96.0)
= 41.8 g of ammonium carbonate

CHECKPOINT!

Question 9.7 - Calculate the mass of each of the following ((a) is completed for you).

a) 2.45 moles of aluminium nitrate

M ($Al(NO_3)_3$) = 27.0 + [14.0 + (16.0 x 3)] x 3 = 213 g mol^{-1}

m ($Al(NO_3)_3$) = n . M = (2.45) (213) = 522 g of aluminium nitrate

b) 4.62 moles of calcium oxide (lime)

M (CaO) = ________________

m (CaO) = ________________

c) 3.70 moles of calcium carbonate (limestone)

M ($CaCO_3$) = ________________

m ($CaCO_3$) = ________________

d) 0.015 moles of iron (II) sulfate

M (________) = ________________

m (________) = ________________

e) 3.70 moles of aluminium phosphate

M (________) = ________________

m (________) = ________________

f) 1.15 moles of sodium sulfate

M (________) = ________________

m (________) = ________________

Moles/mass – constituents

The formula of any given substance indicates the number of atoms (or ions) present in a molecule (or formula unit) of that substance.

e.g. 1 molecule of H_2SO_4 contains:

–> 2 atoms of hydrogen

–> 1 atom of sulfur

–> 4 atoms of oxygen

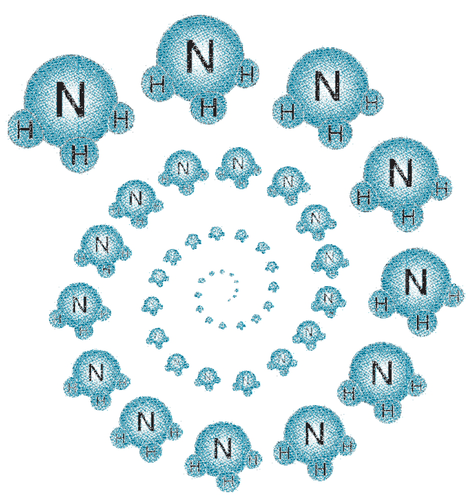
We can use the same logic when considering moles of a substance.

e.g. 5 moles of $Al_2(SO_4)_3$ contains:

–> 10 moles of Al^{3+} ions, –> 15 moles of SO_4^{2-} ions

–> 15 moles of S atoms, –> 60 moles of O atoms

1 mole of NH_3



contains:

- 6.02×10^{23} molecules of NH_3 (1 mol)
- 6.02×10^{23} atoms of N (1 mol)
- 18.06×10^{23} atom of H (3 mol)

has a mass of:

17.0g of NH_3

14.0g of N

3.0g of H

CHECKPOINT!

Question 9.8 - Complete the following:
10 molecules of phosphoric acid (H_3PO_4) contains:

__________ atoms of hydrogen __________ atoms of phosphorus and

__________ atoms of oxygen

Question 9.9 - 2.0 moles of ethanol molecules (CH_3CH_2OH) contains:

__________ mol of C atoms __________ mol of H atoms and

__________ mol of O atoms

CHECKPOINT!

Question 9.10 - A sample of $Mg(NO_3)_2$ has a mass of 296.6 g. Determine for this sample the number of:

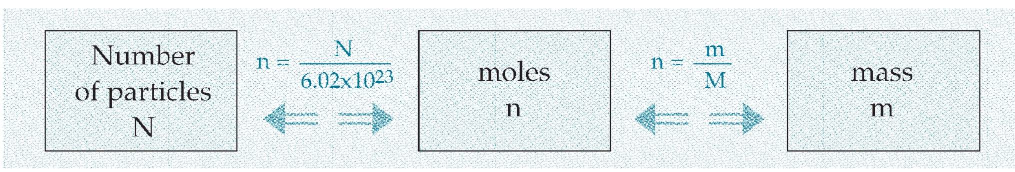
a) moles of $Mg(NO_3)_2$ ____________________

b) moles of NO_3^- ions ____________________

c) mass of Mg atoms ____________________

Calculations – No. particles/moles/mass

The following overview of mole relationships is useful in dealing with calculations such as those shown below.



Example 9.10: A balloon is filled with 10.0 g of hydrogen gas (H_2). Calculate:

a) moles of hydrogen molecules;

b) number of hydrogen molecules present in this amount of hydrogen gas.

Using the summary diagram above we can see that we firstly convert the mass to moles and then calculate the number of particles.

a) $$n\,(H_2) = \frac{m}{M} = \frac{10\text{g}}{2\text{g mol}^{-1}} = 5 \text{ mol of } H_2 \text{ gas}$$

b) $$N = n \times 6.02 \times 10^{23} = 5.0 \times 6.02 \times 10^{23}$$
$$= 3.01 \times 10^{24} \text{ molecules of hydrogen}$$

Example 9.11: How many lead atoms are there in 10.0 grams of lead?

$$n\,(Pb) = \frac{m}{M} = \frac{10}{207.2} = 0.0483 \text{ mol}$$

$$\therefore N = n \times 6.02 \times 10^{23} = 0.0483 \times 6.02 \times 10^{23}$$
$$= 2.91 \times 10^{22} \text{ atoms of lead}$$

Example 9.12: A drop of water contains 3.30×10^{21} molecules of water. Calculate the mass of this drop of water.

$$n\,(H_2O) = \frac{N}{6.02 \times 10^{23}} = \frac{3.30 \times 10^{21}}{6.02 \times 10^{23}} = 0.00548 \text{ mol}$$

$$m\,(H_2O) = n\,.\,M = (0.00548)\,(18.0) = 0.098 \text{ g of water}$$

9. Review Questions

Set 15 – Moles/particles

1. Calculate the number of moles of:

a) calcium atoms in 6.02×10^{23} atoms of calcium

b) zinc atoms in 2.41×10^{24} atoms of zinc

c) water molecules in 3.01×10^{24} molecules of water

d) hydrogen molecules in 1.20×10^{25} molecules of hydrogen.

2. Calculate the number of:

a) silver atoms in 0.25 moles of silver

b) lead atoms in 2.0 moles of lead

c) carbon monoxide molecules in 0.05 moles of carbon monoxide

d) ammonia molecules in 20 moles of ammonia gas.

3. Calculate the number of:

a) nitrogen molecules in 2.5 moles of nitrogen gas (N_2)

b) nitrogen atoms in 2.5 moles of nitrogen gas (N_2)

c) hydrogen atoms in 0.40 moles of ethanoic acid (CH_3COOH)

d) all atoms in 6.25 moles of sulfuric acid (H_2SO_4).

4. It is found that 24.0 g of carbon contains exactly the same number of atoms as 46.0 g of sodium. From this information determine:

a) which atoms (carbon or sodium) are heavier

b) by what factor.

5. Which of the following contains the greatest number of atoms?

a) 2 moles of hydrogen gas (H_2)

b) 6 moles of zinc metal (Zn)

c) 2 moles of ammonia gas (NH_3)

d) 1 mole of ammonium chloride (NH_4OH).

For the experts

6. Samantha wants enough one dollar coins to become a billionaire. How many moles of dollar coins will she need?

Set 16 – Molar mass

1. Determine the molar mass of:

a) sodium
b) sodium chloride
c) nitrogen gas
d) sulfur dioxide.

2. Determine the molar mass of:

a) sodium hydroxide
b) zinc carbonate
c) lead (II) oxide
d) magnesium chloride.

3. Determine the molar mass of:

a) aluminium sulfate
b) magnesium hydrogencarbonate
c) tetraphosphorus decaoxide
d) sodium carbonate–10–water.

4. Explain the difference between:

a) relative atomic mass (A_r) and relative molecular mass (M_r)

b) relative molecular mass (M_r) and molar mass (M).

5. Determine each of the following:

a) relative atomic mass (A_r) for oxygen atoms

b) relative molecular mass (M_r) for oxygen gas

c) molar mass (M) for oxygen gas.

Be sure to include the correct units with your answers.

For the experts

6. In researching two elements (X and Y), John found that the A_r for X was 14.0 and the A_r for Y was 19.0. Use this information to determine:

a) molar mass (M) for diatomic molecules of X

b) molar mass (M) for diatomic molecules of Y

c) molar mass (M) for a compound made up of one atom of X and 3 atoms of Y.

Set 17 – Mass to moles

1. Calculate the number of moles of:

a) calcium in 80.2 g of calcium

b) carbon dioxide in 8.8 g of carbon dioxide

c) hydrochloric acid in 10.0 g of hydrochloric acid

d) ethanol in 25.0 g of ethanol (C_2H_5OH).

2. Calculate the number of moles of:

a) hydrogen molecules in 20.0 g of hydrogen gas (H_2)

b) hydrogen atoms in 20.0 g of hydrogen gas (H_2)

c) hydrogen atoms in 20.0 g of ammonia gas (NH_3)

d) hydrogen atoms in 20.0 g of ethyne gas (C_2H_2).

3. Calculate the number of moles of:

a) silver chloride in 125 g of silver chloride

b) aluminium nitrate in 4.5 g of aluminium nitrate

c) ammonium carbonate in 25.0 g of ammonium carbonate

d) potassium hydroxide in 240 g of potassium hydroxide.

4. A sample of carbon dioxide gas has a mass of 2.20 g. For this sample calculate the moles of each of the following:

a) carbon dioxide molecules

b) carbon atoms

c) oxygen atoms.

5. A sample of copper II nitrate has a mass of 20.0 g. For this sample calculate the moles of:

a) copper (II) nitrate

b) copper (II) ions

c) nitrate ions

d) oxygen atoms.

For the experts

6. Louise dissolved a tablespoon (30.0 g) of sugar (sucrose – $C_{12}H_{22}O_{11}$) into 100.0 g of water (H_2O).

Which substance contained the greatest number of oxygen atoms, the sugar or the water?

Set 18 – Moles to mass

1. Calculate the mass of 1.0 mol of:

a) water molecules

b) oxygen atoms

c) carbon dioxide molecules

d) phosphorus atoms.

2. Calculate the mass of each of the following:

a) 1.25 mol of sodium hydroxide ($NaOH$)

b) 0.25 mol of zinc metal (Zn)

c) 20.0 mol of lead (II) nitrate ($Pb(NO_3)_2$)

d) 3.5 mol of octane (C_8H_{18}).

3. Calculate the mass of each of the following:

a) 0.025 mol of copper (II) sulfate

b) 0.025 mol of silver nitrate

c) 15.0 mol of ammonium chloride

d) 15.0 mol of ammonium sulfate.

4. Calculate in each case which has the greatest mass.

a) 1.0 mol of sulfur dioxide gas (SO_2) or 1.0 mol of chlorine gas (Cl_2)

b) 2.0 mol of ammonia gas (NH_3) or 1.0 mol of hydrogen chloride gas (HCl)

c) 1.5 mol of zinc carbonate ($ZnCO_3$) or 1.0 mol of lead (II) oxide (PbO)

d) 3.0 mol of sodium hydrogencarbonate ($NaHCO_3$) or 1.0 mol of magnesium hydrogen sulfate ($Mg(HSO_4)_2$)

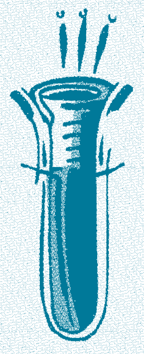
5. Calculate the mass of each of the following:

a) 0.60 mol of aluminium sulfate

b) 1.25 mol of ammonium carbonate

c) 0.55 mol of potassium hydrogencarbonate

d) 3.20 mol of sodium carbonate-10-water.



For the experts

6. Jason made up an alphabetical list of all the common gases he had heard of. His list is as follows: ammonia, carbon dioxide, carbon monoxide, chlorine, hydrogen, nitrogen, oxygen, sulfur dioxide

a) Calculate the molar mass (mass of one mole) of each of these gases and relist them from lightest to heaviest.

b) Which two gases have exactly the same molar mass?

c) Which gas has exactly twice the molar mass of another?

Set 19 – Moles – general

1. Determine the number of moles of hydrogen atoms in 1.0 mol of each of the following.

a) hydrogen gas

b) sulfuric acid

c) ethanoic acid

d) glucose ($C_6H_{12}O_6$)

2. Determine the number of moles of oxygen atoms in each of the following.

a) 5.0 mol of SO_2

b) 15.0 mol of $C_{12}H_{22}O_{11}$

c) 1.25 mol of $Ba(NO_3)_2$

d) 0.02 mol of $MgSO_4 . 7H_2O$

3. Determine the number of moles of each element in each of the following.

a) 2.25 mol of carbon dioxide

b) 3.40 mol of nitric acid

c) 0.50 mol of sodium sulfate

d) 4.0 mol of calcium hydrogencarbonate

4. Determine the number of moles of oxygen atoms in each of the following.

a) 50.0 g of water

b) 2.50 g of sulfuric acid

c) 1 tonne (1000 kg) of alumina (aluminium oxide)

d) 100 g of ammonium carbonate

5. Determine the number of moles of each of the ions in the following ionic compounds.

a) 60.0 g of sodium chloride

b) 2.25 g of ammonium sulfate

c) 200.0 g of lead (II) nitrate

d) 10.0 g of iron (III) oxide

For the experts

6. Paula noted that the balsamic vinegar she was using listed its ethanoic acid (CH_3COOH) content as 6.0% (by mass).

If she used 50.0 g of this vinegar on her salad, calculate:

a) the moles of ethanoic acid used

b) the mass of carbon atoms used (Hint: find moles of C first).

Set 20 – Moles – particles/mass

1. Determine how many atoms in total are contained in:

a) 10.0 g of silver

b) 10.0 g of aluminium

c) 20.0 g of water

d) 20.0 g of ethanoic (acetic) acid (CH_3COOH)

2. Determine the number of molecules in each of the following.

a) 71.0 g of chlorine gas

b) 30.0 g of ammonia gas

c) 6.0 g of hydrogen gas

d) 40.0 g of carbon monoxide gas

3. Determine the total number of atoms in each of the following.

a) 125.0 g of $CaCO_3$

b) 10.6 g of $CuSO_4$

c) 22.5 g of NH_4NO_3

d) 84.0 g of NaOH

4. Determine the number of atoms of:

a) chlorine in 17.6 g of hydrochloric acid

b) lead in 155.0 g of lead (II) sulfate

c) oxygen in 22.2 g of magnesium carbonate

d) nitrogen in 6.8 g of copper (II) nitrate.

5. Determine the mass of each of the following.

a) 6.02×10^{23} molecules of sulfur dioxide

b) 3.01×10^{24} atoms of zinc

c) 2.60×10^{22} molecules of octane (C_8H_{18})

d) an ionic compound containing 4.5×10^{24} Ca^{2+} ions and 9.0×10^{24} OH^- ions.

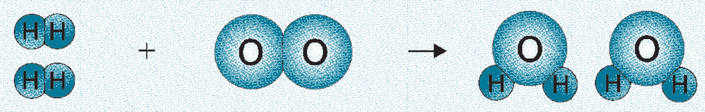
For the experts

6. A sample of sulfuric acid contains 2.0×10^{24} atoms of sulfur.
What is the mass of this sample of sulfuric acid?

10. Calculations from Equations - *Moles/Mass*

Chemical reactions can be represented by chemical equations if all the substances involved are known. The equation will tell us in what proportion (mole ratio) the reactants and products are involved.

e.g. We can represent the combustion of hydrogen with oxygen as follows.

word equation	hydrogen gas +	oxygen gas	→	water vapour
molecular equation	$2H_2\,(g)$ +	$O_2\,(g)$	→	$2H_2O(g)$
visual				
equation tells us	2 molecules of hydrogen gas *react with* 1 molecule of oxygen gas		*to give* ⇒	2 molecules of water vapour
OR				
equation tells us	2 moles of hydrogen gas *react with* 1 mole of oxygen gas		*to give* ⇒	2 moles of water vapour
mole ratio	$n\,(H_2)$: $n\,(O_2)$: $n\,(H_2O)$		=	2 : 1 : 2

The mole relationship (ratio) for a particular chemical reaction is always the same no matter what actual amounts are involved. This allows us to calculate how many moles of one substance are involved if we know the molar amount of another substance in the reaction.

Mole – mole calculations

Example 10.1: Nitrogen and hydrogen gases combine to form ammonia gas. If 6.0 mol of hydrogen gas are used in the reaction, calculate the moles of ammonia gas produced.

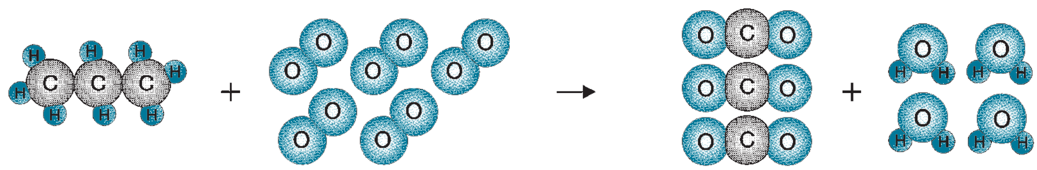
STEPS

Write a balanced equation.	$N_2\,(g)$ +	$3H_2\,(g)$	→	$2NH_3\,(g)$
Indicate known and unknown quantities.		6.0 mol *(known)*		x mol *(unknown)*
Determine mole ratio (unknown/known).	$\frac{n\,(NH_3)}{n\,(H_2)}$		=	$\frac{2}{3}$
Determine moles of unknown.	$n\,(NH_3) = \frac{2}{3}(6.0)$		=	4.0 mol

ie. 4.0 mol of NH_3 gas are produced

CHECKPOINT!

Question 10.1 - The reaction between propane gas and oxygen gas to produce carbon dioxide gas and water vapour is illustrated diagrammatically below. Complete each line as indicated.



word equation:

____________ + ____________ → ____________ + ____________

balanced equation:

____________ + ____________ → ____________ + ____________

mole ratio: n (C_3H_8) : $n(O_2)$: $n(CO_2)$: $n(H_2O)$ = ______ : ______ : ______ : ______

Question 10.2 - Complete the following statements which are based on the reaction shown above (question 1).

a) One mole of propane gas reacts with __________ moles of __________ to produce __________ moles of carbon dioxide gas and __________ moles of water vapour.

b) 4.5 mol of propane gas requires __________ moles of oxygen gas for complete combustion.

c) 15.0 mol of carbon dioxide gas are produced from the combustion of __________ mol of propane gas.

d) When 9.0 mol of carbon dioxide gas are produced, __________ mol of water vapour are also produced.

Question 10.3 - Sodium metal reacts with water as follows.

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2\,(g)}$$

a) If 0.15 mol of sodium is reacted, determine the moles of sodium hydroxide produced.

____

____

b) If 25.0 mol of hydrogen gas is required, determine the moles of sodium that are required.

____

Mole – mass calculations

Example 10.2: Zinc reacts with hydrochloric acid to produce zinc chloride and hydrogen gas. What mass of hydrogen gas would be produced by consuming 0.60 mol of hydrochloric acid?

STEPS

Write a balanced equation.	$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$
Indicate known and unknown quantities.	0.60 mol *(known)* … x mol *(unknown)*
Determine mole ratio (unknown/known).	$\frac{n\,(H_2)}{n\,(HCl)} = \frac{1}{2}$
Determine moles of unknown.	$n\,(H_2) = \frac{1}{2}\,(0.60) = 0.30$ mol of H_2
(Extra step) Determine mass of unknown	$m(H_2) = (n)(M) = (0.30)\,(2.0)$ $= 0.60$g of H_2 gas

When required, the masses involved in a chemical reaction can be determined by using:

$$m = n \, . \, M$$

n = number of moles
m = mass of substance
M = molar mass of substance

Mass – mole calculations

Example 10.3: Oxygen gas can be produced from potassium chlorate as shown in the equation below. Calculate the number of moles of oxygen that would be produced from 40.0 g of potassium chlorate.

STEPS

Write a balanced equation.	$2KClO_{3\,(s)} \rightarrow 2KCl_{(s)} + 3O_{2\,(g)}$
Indicate known and unknown quantities.	40.0 g *(known)* … x mol *(unknown)*
Determine mole ratio (unknown/known).	$\frac{n\,(O_2)}{n\,(KClO_3)} = \frac{3}{2}$
(Extra step) Convert known to moles	$n(KClO_3) = \frac{(m)}{(M)} = \frac{40.0}{39.1 + 35.5 + 48}$ $= 0.326$ mol
Determine moles of unknown.	$n\,(O_2) = \frac{3}{2}\,(0.326) = 0.489$ mol

ie. 0.489 mol of O_2 gas is produced.

When known quantities are given as a mass we must first convert them to moles to do our calculation. Again, this involves an extra step using:

$$n = \frac{m}{M}$$

n = number of moles
m = mass of substance
M = molar mass of substance

Mass – mass calculations

This type of calculation involves two extra steps. The known is given as a mass and must firstly be converted to moles for calculating the unknown. The mole ratio will help us find the unknown (in moles) and this must then be converted to mass.

Example 10.4: Magnesium metal burns in air to form magnesium oxide as shown in the equation below. Calculate the mass of oxygen required to burn 14.0 g of magnesium metal.

STEPS	
Write a balanced equation.	$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$
Indicate known and unknown quantities.	14.0 g *(known)* x g *(unknown)*
Determine mole ratio (unknown/known).	$\frac{n\,(O_2)}{n\,(Mg)} = \frac{1}{2}$
(Extra step) Convert known to moles.	$n(Mg) = \frac{(m)}{(M)} = \frac{14.0}{24.3} = 0.576$
Determine moles of unknown.	$n(O_2) = \frac{1}{2}(0.576) = 0.288$
Convert unknown to mass.	$m(O_2) = (n)(M) = (0.288)(32.0) = 9.22$ g

ie. 9.22g of oxygen is required.

CHECKPOINT!

Question 10.4 - Complete the following statements relating to the steps in calculations from equations.

Step 1: Write a balanced ______________

Step 2: Indicate the ______________ and ________________

Step 3: Determine the ______________ ratio (from the coefficients of the unknown and known).

Step 4: Determine ____

Step 5: ____

Extra: If masses are involved we use the relationship (n =).

CHECKPOINT!

Question 10.5 - Calcium carbonate reacts with hydrochloric acid as indicated in the balanced equation given below. Complete the steps shown below to determine the mass of HCl required to consume 2.6 mol of $CaCO_3$.

STEPS

1. *Write a balanced equation.* $CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

2. *Indicate known and unknown quantities.*

3. *Determine mole ratio (unknown/known).*

4. *Determine moles of unknown.*

5. *Convert unknown to mass.*

Question 10.6 - Complete the steps shown below to determine how many moles of carbon dioxide gas are produced when 120.0 g of sodium hydrogen carbonate react as shown.

STEPS

1. *Write a balanced equation.* $2NaHCO_{3\,(s)} \rightarrow Na_2CO_{3\,(s)} + CO_{2\,(g)} + H_2O_{(g)}$

2. *Indicate known and unknown quantities.*

3. *Determine mole ratio (unknown/known).*

4. *Convert mass of known to moles*

5. *Determine moles of unknown.*

Question 10.7 - Determine the mass of silver metal produced when 10.0 g of copper are reacted as shown.

Balanced equation. $Cu_{(s)} + 2AgNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + 2Ag_{(s)}$

10. Review Questions

Set 21 – Calculations from equations – mole/mole

1. Methane (CH_4) combines with oxygen gas to form carbon dioxide gas and water vapour. Using a balanced equation for the reaction determine how many moles of carbon dioxide gas would be produced from one mole of methane gas.

2. When magnesium burns in air it forms magnesium oxide as shown in the following equation.

$2Mg_{(s)} + O_{2\,(g)} \rightarrow 2MgO_{(s)}$

Determine the number of moles of oxygen gas consumed in producing 5.0 mol of magnesium oxide.

3. Determine the number of moles of hydrochloric acid needed to consume 0.15 mol of zinc in the following reaction.

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

4. Calculate the number of moles of sodium nitrate produced when 0.05 mol of sodium carbonate is reacted with excess nitric acid as shown below.

$Na_2CO_{3\,(s)} + 2HNO_{3\,(aq)} \rightarrow 2NaNO_{3\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

5. Determine the number of moles of potassium chlorate required to produce 4.50 mol of oxygen gas using the following reaction.

$2KClO_{3\,(s)} \rightarrow 2KCl_{(s)} + 3O_{2\,(g)}$

For the experts

6. Carbon dioxide gas can be produced from calcium carbonate according to the following reaction.

$CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

If 5.0 mol of hydrochloric acid is added to 5.0 mol of calcium carbonate what is the maximum number of moles of carbon dioxide that can be produced?

(Hint: consider the reactant which is in limited supply.)

Set 22 – Calculations from equations – mole/mass

1. Determine the mass of water that would be produced by the complete combustion of 1.0 mol of hydrogen gas.

2. Determine the mass of mercury that would be produced by heating 0.55 mol of mercury (II) oxide. The reaction is as follows.

$$2HgO_{(s)} \xrightarrow{heat} 2Hg_{(l)} + O_{2\,(g)}$$

3. Determine the mass of sodium chloride required to react with 12.0 mol of silver nitrate according to the following equation.

$$AgNO_{3\,(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3\,(aq)} + AgCl_{(s)}$$

4. When copper (II) carbonate is heated it breaks down to copper (II) oxide and carbon dioxide gas as shown below.

$$CuCO_{3\,(s)} \xrightarrow{heat} CuO_{(s)} + CO_{2\,(g)}$$

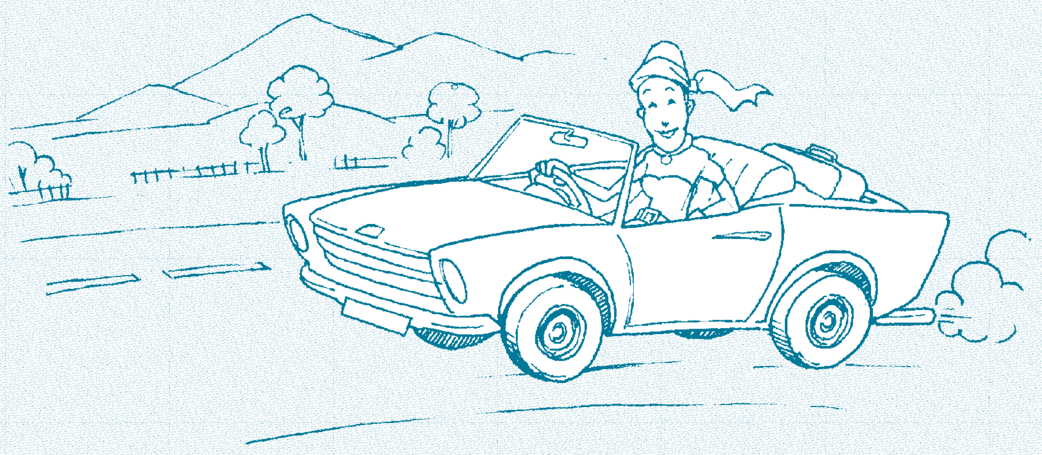
Determine the mass of copper (II) oxide and carbon dioxide gas produced by the decomposition of 0.40 mol of copper (II) carbonate.

5. Calculate the mass of carbon dioxide gas produced when 1.5 mol of propane gas (C_3H_8) are burnt in a plentiful supply of oxygen.

For the experts

6. Calculate the total mass of gases released in the atmosphere by the burning of 10.0 mol of octane (petrol) according to the following reaction.

$$2C_8H_{18\,(g)} + 25O_{2\,(g)} \rightarrow 16CO_{2\,(g)} + 18H_2O_{(g)}$$



Set 23 – Calculations from equations – mass/mole

1. Determine the number of moles of water produced by the complete combustion of 1.0 g of hydrogen gas.

2. Calculate the number of moles of hydrochloric acid necessary to completely consume 4.86 g of magnesium metal. The equation for the reaction is as follows.

$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$

3. Calculate the number of moles of sulfuric acid needed to produce 80.0 g of ammonium sulfate when it reacts with ammonia gas as follows.

$2NH_{3\,(g)} + H_2SO_{4\,(aq)} \rightarrow (NH_4)_2SO_{4\,(aq)}$

4. Calculate the number of moles of carbon dioxide gas produced when 2.4 g of copper carbonate are reacted with excess hydrochloric acid as shown below.

$CuCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CuCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

5. Calculate the number of moles of magnesium metal required to form 1.56 g of magnesium nitride by the following reaction.

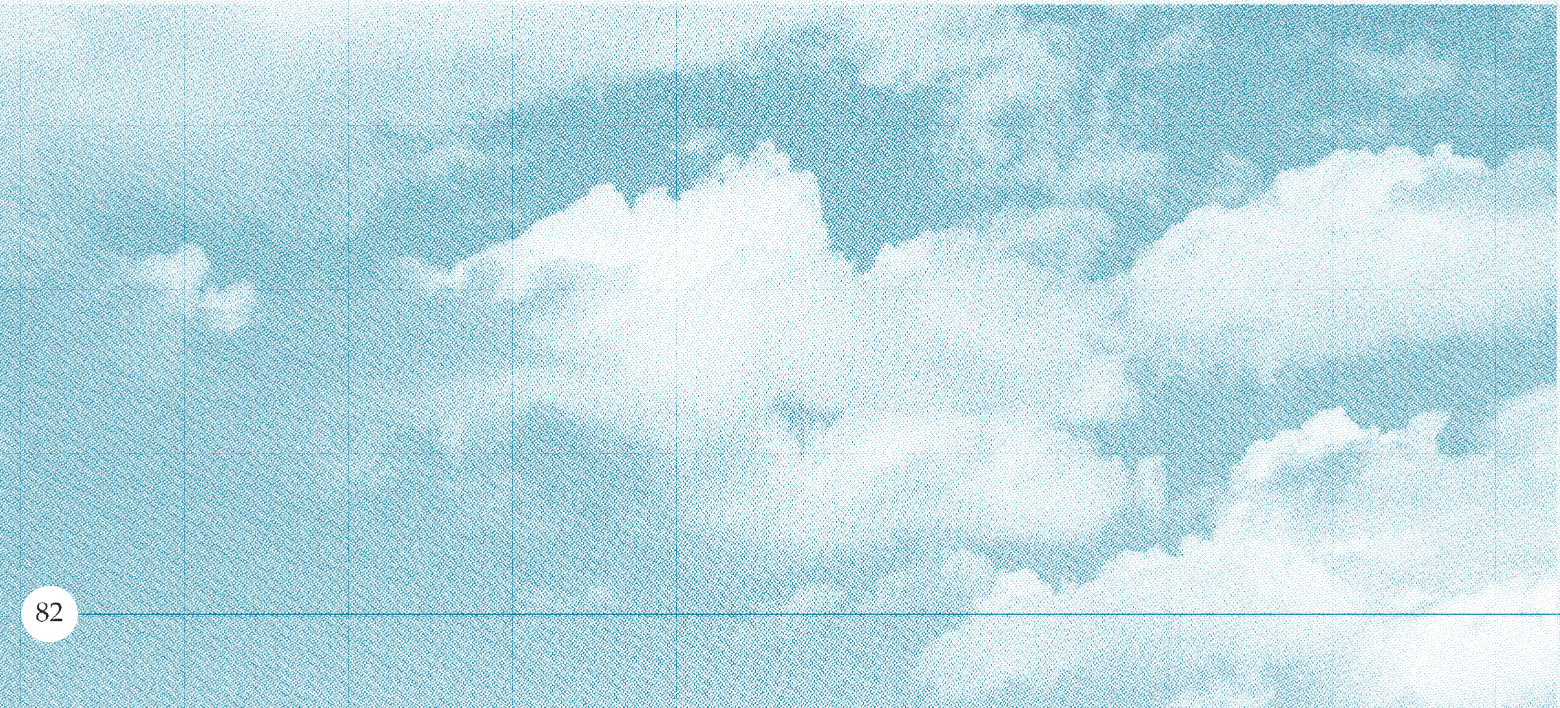
$3Mg_{(s)} + N_{2\,(g)} \rightarrow Mg_3N_{2\,(s)}$

For the experts

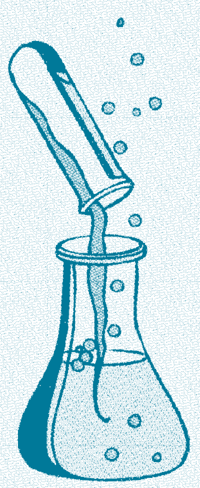
6. When butane gas (commonly used as cigarette lighter fuel) burns in air, the gases produced are carbon dioxide and water vapour as follows.

$2C_4H_{10\,(g)} + 13O_{2\,(g)} \rightarrow 8CO_{2\,(g)} + 10H_2O_{(g)}$

Calculate the total number of moles of gaseous products from the combustion of 0.50 g of butane gas.



Set 24 – Calculations from equations – mass/mass



1. Calculate the mass of water produced by the complete combustion of 1.0 g of hydrogen gas.

2. Calculate the mass of silver metal produced when 6.35 g of copper are dissolved in silver nitrate according to the following reaction.

$Cu_{(s)} + 2AgNO_3{}_{(aq)} \rightarrow Cu(NO_3)_2{}_{(aq)} + 2Ag_{(s)}$

3. Sodium peroxide reacts with water according to the following equation.

$2Na_2O_2{}_{(s)} + 2H_2O_{(l)} \rightarrow 4NaOH_{(aq)} + O_2{}_{(g)}$

If 25.0 g of Na_2O_2 are reacted calculate

a) the mass of sodium hydroxide produced

b) the mass of oxygen gas evolved.

4. Determine the mass of lead (II) iodide precipitated by adding excess potassium iodide to 7.50 g of lead (II) nitrate. The reaction is as follows.

$Pb(NO_3)_2{}_{(aq)} + 2KI_{(aq)} \rightarrow PbI_2{}_{(s)} + 2KNO_3{}_{(aq)}$

5. Nitric acid reacts with calcium hydroxide as follows.

$2HNO_3{}_{(aq)} + Ca(OH)_2{}_{(aq)} \rightarrow Ca(NO_3)_2{}_{(aq)} + 2H_2O_{(l)}$

Determine the mass of nitric acid required to completely neutralise 50.0 g of calcium hydroxide.

For the experts

6. Calcium metal reacts with hydrochloric acid to produce calcium chloride ($CaCl_2$) and hydrogen gas (H_2).

a) Write a balanced equation for the reaction.

b) If 4.0 g of hydrochloric acid are added to 4.0 g of calcium metal

(i) which reactant will be completely used up?

(ii) what mass of hydrogen gas will be produced?

11. Calculations from Equations - *Moles/Volume*

Avogadro's hypothesis and molar volume

Avogadro's hypothesis states that *"equal volumes of gases at the same temperature and pressure contain equal numbers of particles"*.

This means, for example, that a 5 L balloon of hydrogen gas contains exactly the same number of particles as a 5 L balloon of helium gas under the same conditions.

Molar volume of a gas is simply the volume occupied by 1 mole of a gas. From Avogadro's hypothesis it follows that this is the same for all gases.

The molar volume of all gases is taken as 22.4 L at S.T.P. (standard temperature and pressure: 0°C, 101.3 kPa).

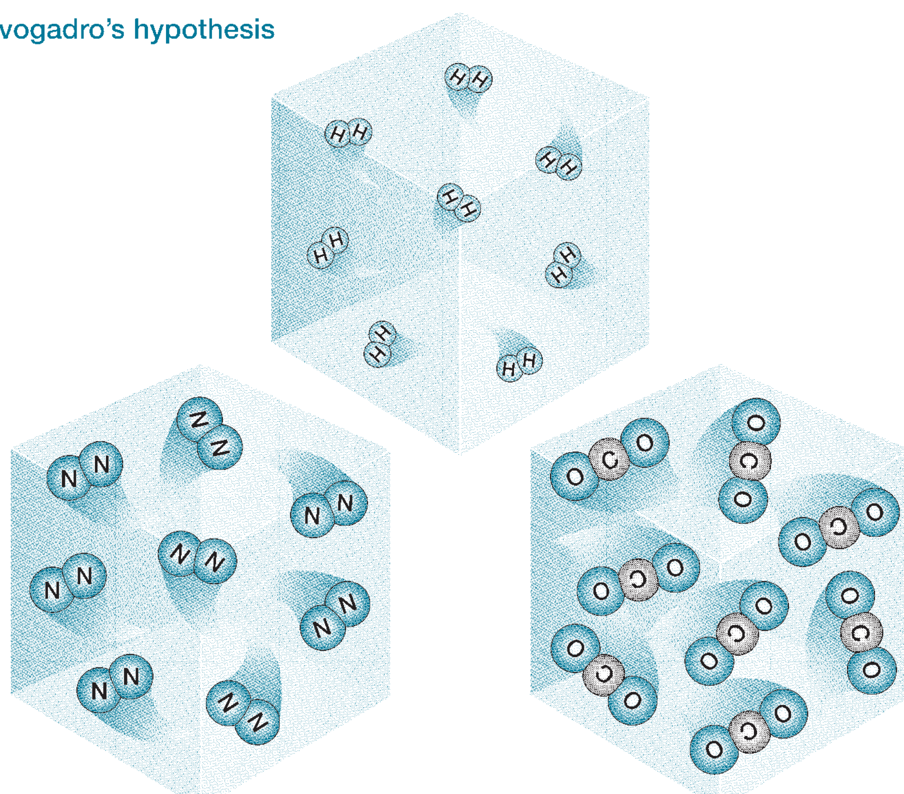
This means for example,

1 mole (2 g) of H_2 gas occupies 22.4 L at S.T.P.

1 mole (28 g) of N_2 gas occupies 22.4 L at S.T.P.

1 mole (44 g) of CO_2 gas occupies 22.4 L at S.T.P.

Avogadro's hypothesis



Avogadro's hypothesis: *"equal volumes of gases at the same temperature and pressure contain equal numbers of particles"*.

CHECKPOINT!

Question 11.1 - Complete the following table. The first row is done for you.

gas	conditions	no. of moles	no. of particles	mass
O_2	S.T.P.	1.0	6.02×10^{23}	32.0 g
O_2	S.T.P.	0.5		
NH_3	S.T.P.	2.0		
CO_2	S.T.P.		3.01×10^{23}	
Ne	S.T.P.			30.3 g
SO_2	S.T.P.	1.5		

Question 11.2 - Two similar balloons are filled at room temperature so that each holds 10.0 L of gas. Balloon A is filled with hydrogen (H_2) gas and balloon B with helium (He) gas.

Which balloon (if any):

a) has the greatest number of molecules of gas? ______________________

b) has the greatest number of moles of gas? ______________________

c) has the greatest mass? ______________________

Molar volume calculations

To calculate the number of moles of gas from a given volume we use the following relationship.

$$n = \frac{V}{22.4}$$

n = number of moles

V = volume of gas at S.T.P.

S.T.P. = standard temperature and pressure
= 0°C, 101.3kPa

The following summary relationship between mass, moles and volume of a gas is also very useful in calculations.

mass m ⇄ ($n = \frac{m}{M}$) ⇄ moles n ⇄ ($n = \frac{V}{22.4}$) ⇄ volume (S.T.P.) V

Example 11.1: A gas jar contains 250 mL of oxygen gas at S.T.P. Calculate:

a) the number of moles of oxygen gas:

$$n = \frac{V}{22.4} = \frac{0.250}{22.4} = 0.011 \text{ mol}$$

b) the mass of oxygen gas:

$$m(O_2) = n \cdot m = (0.011)(32.0) = 0.36 \text{ g}$$

Example 11.2: Calculate the volume of 2.50 mol of nitrogen gas at S.T.P.

$$n = \frac{V}{22.4}$$

$$\therefore V = (n)(22.4) = (2.50)(22.4) = 56.0 \text{ L}$$

Example 11.3: Determine the volume of 25.0 g of carbon dioxide gas at S.T.P.

This calculation involves two steps. Firstly we determine the number of moles and then the volume (see summary relationship above).

$$n(CO_2) = \frac{m}{M} = \frac{25.0}{44.0} = 0.568 \text{ mol}$$

$$\therefore V(CO_2) = (n)(22.4) = (0.568)(22.4) = 12.7 \text{ L}$$

CHECKPOINT!

Question 11.3 - Calculate the volume at S.T.P. of:

a) 2.0 mol of H_2 gas ____________________

b) 0.15 mol of CO_2 gas ____________________

Question 11.4 - Calculate the volume at S.T.P. of:

a) 8.0 g of O_2 gas ____________________

b) 550 g of NH_3 gas ____________________

Question 11.5 - Calculate the mass of:

a) 20.0 L of SO_2 gas at S.T.P. ____________________

b) 760 mL of CH_4 gas at S.T.P. ____________________

Calculations from equations – volume / volume

Since the molar volume is the same for all gases it follows that in chemical reactions involving gases the following applies:

mole ratio = volume ratio

The following example illustrates the ratios involved.

$$2SO_2\,(g) + O_2\,(g) \rightarrow 2SO_3\,(g)$$

$2SO_2$ (g)	O_2 (g)	$2SO_3$ (g)
2 mol	*1 mol*	*2 mol*
2 volumes	*1 volume*	*2 volumes*

This means, for example, that 200 L of sulfur dioxide gas combines with 100 L of oxygen gas (at the same temperature and pressure).

Example 11.4 : Determine the volume of ammonia gas produced when 500 mL of nitrogen gas are reacted as shown. Assume all volumes are measured at same temperature and pressure.

1. *Write a balanced equation.*	$N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g)$	
2. *Indicate known and unknown quantities.*	500 mL *(known)*	x mL *(unknown)*
3. *Determine mole ratio (unknown/known).*	$\frac{n\,(NH_3)}{n\,(N_2)} = \frac{2}{1}$	
4. *Hence volume ratio.*	$= \frac{2}{1}$	
5. *Determine volume of unknown.*	$\text{Vol}\,(NH_3) = \left(\frac{2}{1}\right)(500)$ $= 1000$ mL of NH_3 gas	

CHECKPOINT!

Question 11.6 - For the previous example (Eg11.4) determine the volume of hydrogen gas consumed.

Balanced Equation: $N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g)$

____

____

____

____

____

CHECKPOINT!

Question 11.7 - Determine the volume of carbon dioxide gas produced when 25.0 litres of propane gas (C_3H_8) are burnt in air as shown. All volumes are at S.T.P.

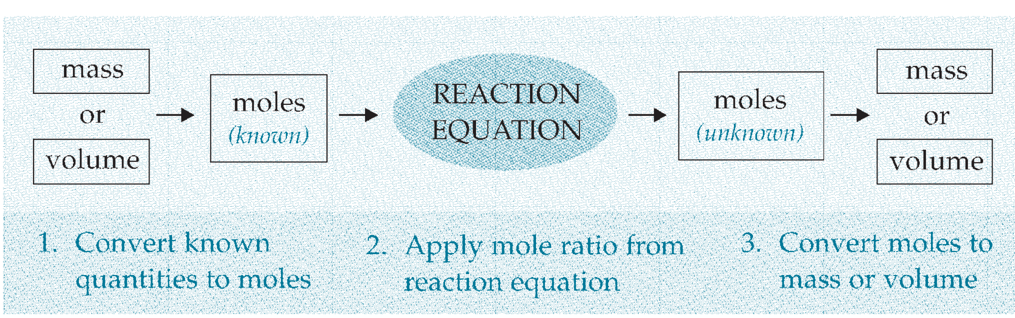
1. *Write a balanced equation.*	$C_3H_8\,(g) + 5O_2\,(g) \rightarrow 3CO_2\,(g) + 4H_2O\,(g)$
2. *Indicate known and unknown quantities.*	
3. *Determine mole ratio (unknown/known).*	
4. *Hence volume ratio.*	
5. *Determine volume of unknown.*	

Calculations from equations – mass/volume or volume/mass

Calculations from equations always require the use of the mole ratio, except of course, where only gas volumes are involved. Hence if the amounts of the substances involved in a reaction include both volume and mass it is necessary to convert these quantities to moles. The mole ratio from the equation can then be applied, moles of the unknown determined, and, if necessary, converted back to mass or volume.

Calculations flowchart

The following flowchart helps us visualise the three main steps involved.



Example 11.5: Determine the volume of carbon dioxide gas that can be produced by reacting 20.0 g of calcium carbonate with excess hydrochloric acid. Assume S.T.P. conditions.

1.	*Write a balanced equation.*	$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
2.	*Indicate known and unknown quantities.*	20.0 g *(known)* … x L *(unknown)*
3.	*Determine mole ratio (unknown/known).*	$\frac{n\ (CO_2)}{n\ (CaCO_3)} = \frac{1}{1} = 1$
4.	*Convert known to moles*	$n\ (CaCO_3) = \frac{m}{M} = \frac{20.0}{100.1} = 0.20$ mol
5.	*Determine moles of unknown.*	$n\ (CO_2) = (1)\ (0.20) = 0.20$ mol
6.	*Convert known to volume.*	$V\ (CO_2) = (n)\ (22.4) = (0.20)\ (22.4) = 4.48$L at S.T.P.

Example 11.6: Determine the mass of water produced when 50.0 L of methane are burnt in excess oxygen. Assume S.T.P. conditions.

1.	*Write a balanced equation.*	$CH_{4\ (g)} + 2O_{2\ (g)} \rightarrow CO_{2\ (g)} + 2H_2O_{\ (g)}$
2.	*Indicate known and unknown quantities.*	50 L *(known)* … x g *(unknown)*
3.	*Determine mole ratio (unknown/known).*	$\frac{n\ (H_2O)}{n\ (CH_4)} = \frac{2}{1} = 2$
4.	*Convert known to moles*	$n\ (CH_4) = \frac{V}{22.4} = \frac{50.0}{22.4} = 2.23$ mol
5.	*Determine moles of unknown.*	$n\ (H_2O) = (2)(2.23) = 4.46$ mol
6.	*Convert known to mass.*	$n\ (H_2O) = (n)\ (m) = (4.46)\ (18.0) = 80.3$ g

CHECKPOINT!

Question 11.8 - Determine the volume of hydrogen chloride gas at S.T.P. produced when 12.0 g of hydrogen gas reacts with excess chlorine gas.

1. *Write a balanced equation.*	$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$
2. *Indicate known and unknown quantities.*	
3. *Determine mole ratio (unknown/known).*	
4. *Convert known to moles.*	
5. *Determine moles of unknown.*	
6. *Convert known to volume*	

Question 11.9 - Determine the mass of sodium carbonate required to produce 400 mL of carbon dioxide gas at S.T.P. when it is reacted with excess hydrochloric acid.

1. *Write a balanced equation.*	$Na_2CO_3\,(s) + 2HCl(g) \rightarrow 2NaCl\,(aq) + H_2O\,(l) + CO_2\,(g)$
2. *Indicate known and unknown quantities.*	
3. *Determine mole ratio (unknown/known).*	
4. *Convert known to moles.*	
5. *Determine moles of unknown.*	
6. *Convert known to mass*	

11. Review Questions

Set 25 – Molar volume

1. Calculate the number of moles of each of the following gases. Volumes are at S.T.P.

a) 11.2 L of helium gas (He) **b)** 560 mL of chlorine gas (Cl_2)

c) 200 L of carbon monoxide gas (CO) **d)** 384 L of methane gas (CH_4)

2. Calculate the volume at S.T.P. of each of the following gases.

a) 2.0 mol of sulfur dioxide gas (SO_2) **b)** 0.15 mol of ammonia gas (NH_3)

c) 125 mol of oxygen gas (O_2) **d)** 0.042 mol of butane gas (C_4H_{10})

3. Calculate the volume at S.T.P. of each of the following gases.

a) 24.0 g of hydrogen gas (H_2) **b)** 200 g of oxygen gas (O_2)

c) 1.25 g of sulfur dioxide gas (SO_2) **d)** 60.0 g of carbon monoxide gas (CO)

4. What is the mass of each of the following? Volumes are at S.T.P.

a) 20.0 L of oxygen gas (O_2) **b)** 20.0 L of chlorine gas (Cl_2)

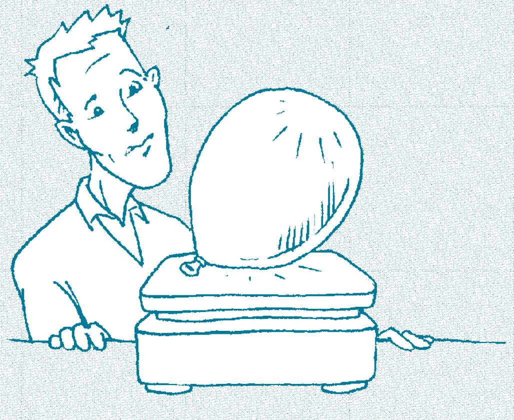
c) 560 mL of carbon dioxide gas (CO_2) **d)** 3500 L of ammonia gas (NH_3)

5. Gas jar A contains 200 mL of oxygen gas (O_2) at S.T.P. while gas gar B contains 300 mL of ammonia gas (NH_3) at S.T.P. Determine which gas jar contains the greatest:

a) number of molecules **b)** mass of gas.

For the experts

6. As an approximation, we can consider 1.0 litre of dry air to be made up of 780 mL of nitrogen gas, 210 mL of oxygen gas and 10 mL of argon gas. Determine the approximate mass of a litre of dry air at S.T.P.



Review Questions

Set 26 - Calculations from equations - volume / volume

Assume the volumes of all gases in each problem are measured under the same conditions of temperature and pressure. Assume water above 100 °C is a gas.

1. Determine the volume of carbon dioxide gas (CO_2) produced when carbon combines with 50 L of oxygen gas.

2. Carbon dioxide gas combines with oxygen gas as follows.

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)}$$

If 60 mL of CO_2 is produced, determine

a) volume of CO consumed

b) volume of O_2 required.

3. Water can be electrolysed to give hydrogen and oxygen gases.

a) Write a balanced equation.

b) Determine the volume of oxygen gas produced when 125 mL of hydrogen gas are also produced.

4. Determine the volume of hydrogen chloride gas produced when 450 mL of hydrogen gas combines with sufficient chlorine gas.

5. A mixture in a combustion chamber made up of 200 mL of methane gas (CH_4) and 200 mL oxygen gas (O_2) is sparked in a combustion chamber. The following reaction occurs.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Assuming temperature is above 100°C, determine:

a) which reactant is completely consumed

b) the total volume of gases produced

c) the total volume of gases remaining after the reaction.

For the experts

6. Two commonly used fuels are propane gas (C_3H_8) and ethyne gas, commonly called acetylene (C_2H_2).

a) Write separate balanced equations for the combustion of each of these gases. Assume a plentiful supply of oxygen.

b) Determine which gas creates the greatest increase in volume when comparing total volume of reactants with total volume of products. Assume temperature is above 100°C.

Set 27 - Calculations from equations - mass / volume

Assume the volumes of all gases in each problem are at S.T.P.

1. Determine the volume of carbon dioxide gas evolved by the decomposition of 500 g of calcium carbonate ($CaCO_3$) to its oxide.

2. Determine the mass of potassium metal required to produce 100.0 mL of hydrogen gas using the following reaction.

$2K_{(s)} + 2H_2O_{(l)} \rightarrow 2KOH_{(aq)} + H_{2\,(g)}$

3. Determine the volume of hydrogen chloride gas which can be produced by reacting 24.0 g of sodium chloride as shown.

$NaCl_{(s)} + H_2SO_{4\,(aq)} \rightarrow NaHSO_{4\,(aq)} + HCl_{(g)}$

4. Determine the volume of carbon dioxide gas produced by heating 20.0 g of potassium hydrogen carbonate. The reaction is as follows.

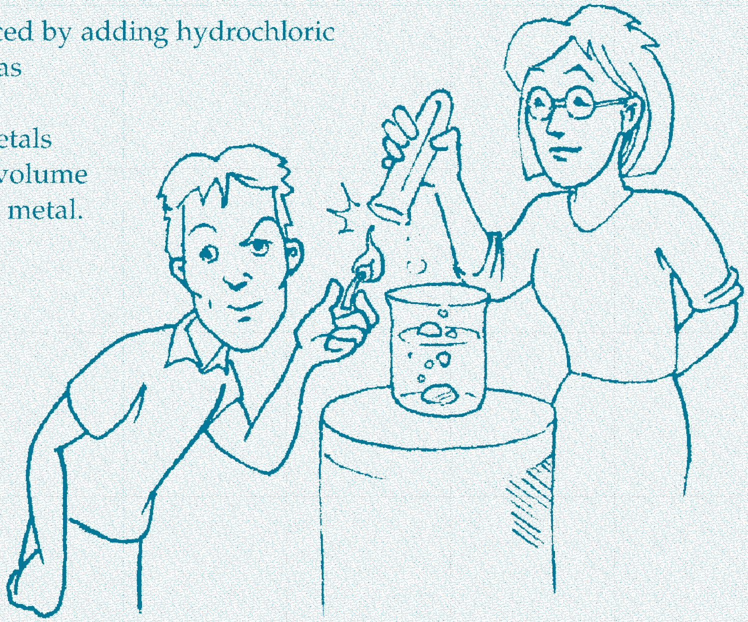
$2KHCO_{3\,(s)} \xrightarrow{heat} K_2CO_{3\,(s)} + H_2O\,(l) + CO_{2\,(g)}$

5. Determine the volume of nitrogen gas required to produce 60.0 g of magnesium nitride by the following reaction.

$3Mg_{(s)} + N_{2\,(g)} \rightarrow Mg_3N_{2\,(s)}$

For the experts

6. Hydrogen gas can be produced by adding hydrochloric acid to an active metal such as aluminium or magnesium. Determine which of these metals would produce the greatest volume of hydrogen gas per gram of metal.



Set 28 – Calculations from equations – volume/mass

Assume the volumes of all gases in each problem are at S.T.P.

1. Determine the mass of carbon required to produce 100.0 L of carbon dioxide gas from its combustion with oxygen gas.

2. Determine the mass of copper (II) oxide (CuO) produced when 500.0 mL of carbon dioxide gas is given off by the heating of copper carbonate ($CuCO_3$).

3. Determine the mass of magnesium metal necessary to produce 40.0 L of hydrogen gas by the reaction shown.

$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$

4. Determine the mass of sodium peroxide necessary to produce 2.5 L of oxygen gas by the reaction shown.

$2Na_2O_{2\,(s)} + 2H_2O_{(l)} \longrightarrow 4NaOH_{(aq)} + O_{2\,(g)}$

5. Determine the mass of nitric acid consumed to produce 5.0 L of carbon dioxide gas by the following reaction.

$CaCO_{3\,(s)} + 2HNO_{3\,(aq)} \longrightarrow Ca(NO_3)_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

For the experts

6. Two gases commonly used as fuels are methane (CH_4) and propane (C_3H_8).

a) Write separate equations for their combustion in a plentiful supply of oxygen.

b) Determine which gas creates the greatest mass of carbon dioxide gas per litre of gaseous fuel burnt.

Set 29 - Calculations from equations - miscellaneous

Assume the volumes of all gases in each problem are at S.T.P.

1. Sodium hydrogencarbonate ($NaHCO_3$) decomposes on heating to sodium carbonate (Na_2CO_3), carbon dioxide gas and water vapour.

a) Write a balanced equation for this reaction.

b) Calculate the volume of carbon dioxide gas produced from the decomposition of 5.0 kg of sodium hydrogencarbonate.

2. Ammonia gas can be produced according to the following reaction.

$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3\,(g)}$

In order to produce 40.0 L of ammonia gas, determine

a) the volume of hydrogen gas needed

b) the mass of nitrogen gas required.

3. Molten iron is produced in a blast furnace according to the following reaction.

$Fe_2O_{3\,(s)} + 3CO_{(g)} \rightarrow 2Fe_{(l)} + 3CO_{2\,(g)}$

If 1 tonne (1000 kg) of iron is produced by this reaction determine

a) the volume of carbon dioxide gas produced

b) the mass of iron (III) oxide required.

4. Aluminium metal reacts with hydrochloric acid to produce aluminium chloride and hydrogen gas. Determine the mass of aluminium required to produce 200.0 mL of hydrogen gas.

5. A mixture made up of 4.0 g of ethyne gas (C_2H_2) and 5.0 g of oxygen gas is sparked in a combustion chamber. The following reaction occurs.

$2C_2H_{2\,(g)} + 5O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 2H_2O_{(l)}$

Determine:

a) the number of moles of each of the reactant gases before the reaction

b) which of the reactant gases is completely consumed

For the experts

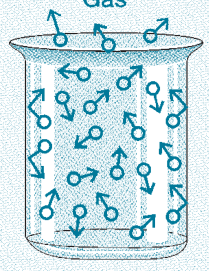
6. Ammonium sulfate and ammonium nitrate are two fertilisers which can be produced from ammonia as follows.

$2NH_{3\,(g)} + H_2SO_{4\,(aq)} \rightarrow (NH_4)_2SO_{4\,(aq)}$

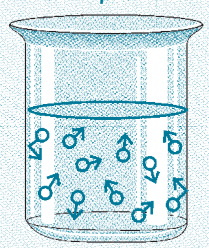
$NH_{3\,(g)} + HNO_{3\,(aq)} \rightarrow NH_4NO_{3\,(aq)}$

Determine which reaction requires the greatest volume of ammonia gas to produce 1.0 kg of fertiliser.

12. Gases



Gas particles are always in constant motion and take up all available space.



Liquids take the shape of their container, but volume is constant.

Kinetic theory of gases

The behaviour of gases is best explained by the kinetic theory as it applies to gases. Some important assumptions of this theory are as follows.

i) Gases are made up of very tiny particles (atoms or molecules).

ii) The volume of the gas particles is negligible compared to the total volume taken up by the gas.

iii) The gas molecules move rapidly in random straight-line motion. Hence molecules are constantly colliding with each other and with the walls of their container.

iv) The greater the temperature, the greater the average kinetic energy of the particles.

Gas pressure

Pressure is exerted by gas particles as they constantly collide with each other and the walls of their container. The standard unit of pressure (force per unit area) is the Pascal (Pa). However for gases we commonly use the units kilopascal (kPa) or atmospheres (atm).

Atmospheric pressure at sea level = 1.0 atm = 101.3 kPa.

CHECKPOINT!

Question 12.1 - Select one of the kinetic theory assumptions (i, ii, iii or iv) which best explains each of the following.

a) Gases are easily compressed. ______________________

b) Gases completely fill any container. ______________________

c) When you blow up a football it becomes hard and difficult to squash. __________

d) You can smell perfume from a distance. ______________________

Question 12.2 - Suggest a reason, in terms of movement of gas particles, for each of the following.

a) Pressure in a car tyre increases when we pump air into it. ______________________

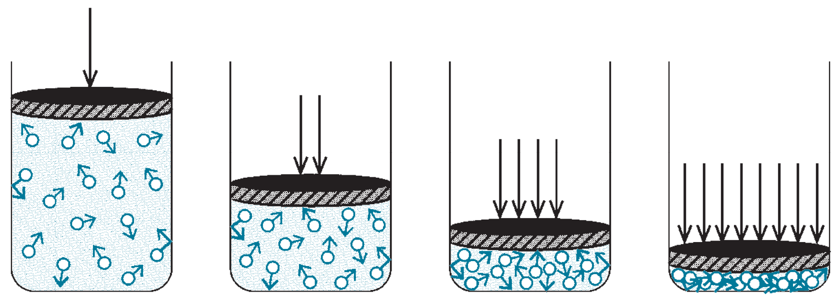
____

b) Pressure in a car tyre increases when it becomes hot. ______________________

____

Boyle's Law

" For a given mass of gas at constant temperature, the volume is inversely proportional to its pressure. "



Pressure	1.0 atm	2.0 atm	4.0 atm	8.0 atm
Volume	10 L	5.0 L	2.5 L	1.25 L

Boyle's Law calculations

Boyle's Law can be expressed as:

$$P \propto \frac{1}{V} \quad \text{or} \quad PV = k$$

where k is a constant

For calculations it is more convenient to use the following expression:

$$P_1 V_1 = P_2 V_2$$

P_1 = initial pressure
V_1 = initial volume
P_2 = final pressure
V_2 = final volume

Example 12.1 : The air inside a bicycle pump is squeezed from an original volume of 450 mL to 120 mL without any change in temperature or loss of gas from the pump. If the initial pressure was atmospheric pressure (101.3 kPa) what will be the new pressure inside the pump?

P_1 = 101.3 kPa
V_1 = 0.450 L
P_2 = ?
V_2 = 0.120 L

$$P_1 V_1 = P_2 V_2$$

$$P_2 = \frac{P_1 V_1}{V_2}$$

$$P_2 = \frac{(101.3)\ (0.450)}{(0.120)}$$

new pressure = **380 kPa**

GAS LAWS

For gases, changes in pressure, volume and temperature are all interrelated. A change in one will cause a change in one or both of the other.

The gas laws give us the mathematical relationship between these quantities.

When gas particles are squeezed into a smaller volume they hit the walls of the container more often and hence pressure is greater.

Boyle's Law is an inverse relationship. As volume is decreased, pressure increases and vice-versa.

Example 12.2 : A helium balloon is 5.0 L in volume at atmospheric pressure (101.3 kPa). It is released and rises to an altitude where the atmospheric pressure is only 25 kPa. What will be the new volume of the balloon assuming no change temperature?

$P_1 = 101.3$ kPa
$V_1 = 5.0$ L
$P_2 = 25$ kPa
$V_2 = ?$

$$P_1 V_1 = P_2 V_2$$

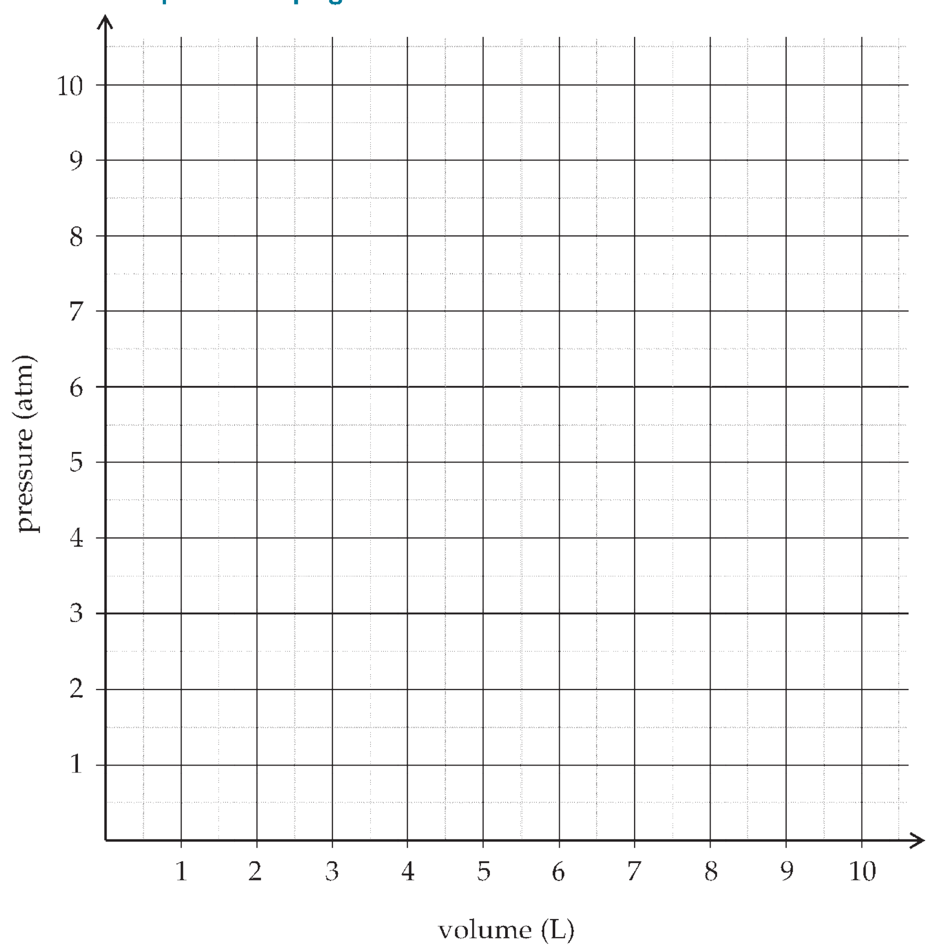
$$V_2 = \frac{P_1 V_1}{P_2}$$

$$V_2 = \frac{(101.3)\,(5.0)}{(25)}$$

new volume = **20.3 L**

CHECKPOINT!

Question 12.3 - a) Graph the pressure-volume data included in the diagram on the previous page.



CHECKPOINT!

b) What type of relationship does this graph indicate between pressure and volume?

____

____

c) Express this relationship in a mathematical way.

____

____

d) Use the graph to determine the volume at 3.0 atm.

____

Question 12.4 - A 20.0 L volume of gas has its pressure increased from 1.0 atm to 7.5 atm. Find its new volume assuming no change in temperature.

P_1	____________ =	P_1V_1 =		
V_1	____________ =	V_2 =		
P_2	____________ =	=		
V_2	____________ =	=		

Question 12.5 - A 5.0 L balloon filled with air at 100 kPa is forced under water to the bottom of a swimming pool. Its new volume is estimated to be 4.0 L. Determine the air pressure inside the balloon assuming no change in temperature.

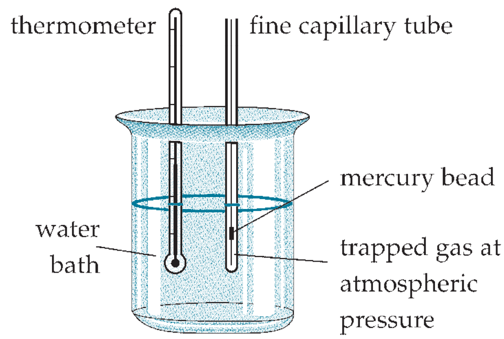
P_1	____________ =	P_1V_1 =		
V_1	____________ =	P_2 =		
P_2	____________ =	=		
V_2	____________ =	=		

Charles' Law

" For a given mass of gas at constant pressure, the volume is directly proportional to its Kelvin temperature."

As temperature rises, gas particles move faster. This causes the gas particles to collide more often and with greater force.

Charles' Law investigation



Typical results

Temp °C	Volume mL
0	3.50
20	3.76
40	4.00
60	4.27
80	4.52
100	4.76

Charles' Law calculations

Charles' Law can be expressed as

$$V \propto T\,(K) \quad \text{or} \quad \frac{V}{T} = k$$

where k is a constant

$K = {}^\circ C + 273$

For calculations it is more convenient to use the following expression:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

T_1 = initial temperature
V_1 = initial volume
T_2 = final temperature
V_2 = final volume

Important note:
Kelvin temperature (absolute temperature) must be used for all gas law calculations.

Example 12.3 : A sample of gas occupies 5.50 L at 20°C. Assuming no change in pressure what will be its volume at 40°C?

V_1 = 5.50 L
T_1 = 20°C (293 K)
V_2 = ?
T_2 = 40°C (313 K)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\therefore V_2 = \frac{V_1}{T_1} \times T_2$$

$$= \frac{5.50}{293} \times 313$$

new volume = **5.88 L**

Example 12.4 : A sample of gas occupies 4.5 L at 25°C and 1.0 atm. To what temperature must it be heated to increase its volume to 15.0 L without changing the pressure?

$V_1 = 4.5$ L

$T_1 = 25°C$ (298 K)

$V_2 = 15.0$ L

$T_2 = ?$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\therefore T_2 = \frac{V_2}{V_1} \times T_1$$

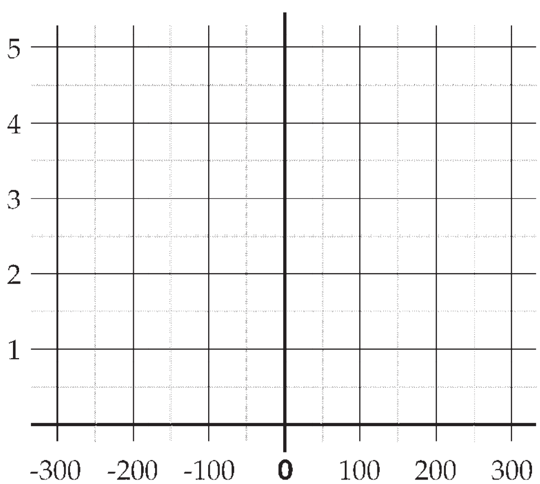
$$= \frac{15.0}{4.5} \times 298$$

$$= \mathbf{993\ K}\ (720°C)$$

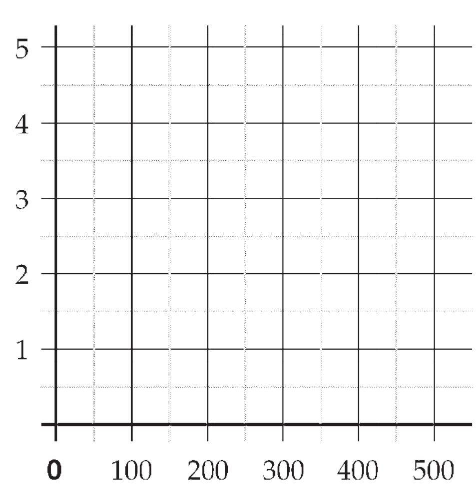
CHECKPOINT!

Question 12.6 - a) Graph the temperature-volume data included in the diagram on the previous page.

i) V versus T (°C);



ii) V versus T (K).



b) Extrapolate the first graph to a volume of zero. What temperature is indicated? ________ This temperature is referred to as absolute zero.

c) What relationship does the second graph indicate between volume and temperature?

____

____

d) Express this relationship mathematically.

____

CHECKPOINT!

Question 12.7 - A 4.0 L balloon is inflated on a warm day at a temperature of 35˚C. It is then taken into an airconditioned room where the temperature is 20˚C. Calculate the new volume of the balloon assuming no change in pressure.

V_1 = ____________

T_1 = ____________

V_2 = ____________

T_2 = ____________

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

V_2 = ____________

____

____

Question 12.8 - A sample of gas occupies 400 mL at 25˚C. To what temperature (˚C) must it be cooled in order to reduce its volume to 300 mL? Assume no change in pressure.

V_1 = ____________

T_1 = ____________

V_2 = ____________

T_2 = ____________

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

T_2 = ____________

____

____

Question 12.9 - The volume of a balloon increased in size by 10% when it was taken from a refrigerated room to a sunny area outside. If the temperature outside was 36˚C, what must have been the temperature in the refrigerated room?

V_1 = ____________

T_1 = ____________

V_2 = ____________

T_2 = ____________

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

=

=

=

Combined Gas Law

Boyle's Law and Charles' Law can be combined to give an equation which relates pressure, volume and temperature as follows.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

* *If we know the change in any two variables we can calculate the third.*
* *Note that the temperature is always in Kelvin.*

Example 12.5 : A gas occupies 6.2 L at 25˚C and 100 kPa. What volume will it occupy at 50˚C and 200 kPa?

P_1 = 100 kPa
V_1 = 6.2 L
T_1 = 25˚C (298 K)
P_2 = 200 kPa
V_2 = ?
T_2 = 50˚C (323 K)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\therefore\ V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

$$= \frac{(100)(6.2)(323)}{(298)(200)}$$

$\therefore$ new volume = **3.36L**

CHECKPOINT!

Question 12.10 - Rearrange the combined gas formula to give an expression for each of the following (the first is done for you).

a) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \therefore\ V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$

b) *similarly* P_2 =

c) *similarly* T_2 =

d) *similarly* P_1=

Gases

CHECKPOINT!

Question 12.11 - A 240 L weather balloon is filled at ground level where the pressure in the day is 102 kPa and temperature 15°C. Calculate the volume of this balloon at an altitude of 5 km where the temperature is -18°C and pressure 54.0 kPa.

P_1 = ______________

V_1 = ______________

T_1 = ______________

P_2 = ______________

V_2 = ______________

T_2 = ______________

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$\therefore\ V_2$ = ______________

____

new volume = ______________

Question 12.12 - A cylinder of compressed air has a volume of 4.5L at a temperature of 15°C and a pressure of 16,500 kPa. If all the gas is released into the atmosphere at a temperature of 25°C and pressure of 101.3 kPa, what will be the total volume of gas released?

P_1 =

V_1 =

T_1 =

P_2 =

V_2 =

T_2 =

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

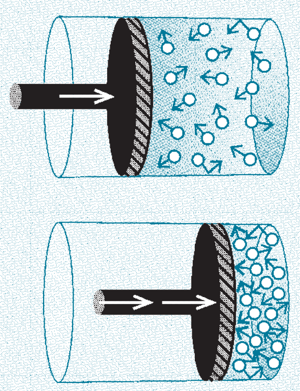
=

=

=

12. Review Questions

Set 30 – Boyle's Law



1. Air inside a metal cylinder is forced into a smaller volume as shown. Use kinetic theory to explain:

a) why it is possible to compress air;

b) why the pressure exerted by the air in the smaller volume is higher.

2. A bicycle pump has 85 mL of trapped air at 101.3 kPa. Paula compresses the air inside the pump to a volume of 30 mL. Determine the new pressure inside the pump assuming no change in temperature.

3. In an experiment designed to study the pressure-volume relationship for gases the following results were obtained. The temperature was kept constant.

Pressure (kPa)	100	200	300	400	500	600
Volume (L)	4.00	2.00	1.33	1.00	0.80	0.67

a) Graph the above data (graph paper or your graphic calculator).

b) What is the relationship between P and V?

c) Calculate the value of P x V in each case. What do you notice?

d) Determine the volume of this gas at 800 kPa.

4. Determine the new volume in each of the following cases. Assume no change in temperature.

a) 500 L of gas at 120 kPa is compressed to 12,000 kPa.

b) 4.0 L of compressed gas at 14,000 kPa is released into the atmosphere where the pressure is 101 kPa.

5. Determine the new pressure in each of the following cases. Assume no change in temperature.

a) 2500 L of air at 98 kPa is compressed into a volume of 24.0 L.

b) A helium balloon released into the atmosphere (101.3 kPa) increases in volume from 15.0 L to 16.0 L as it rises to a height of 500 m.

For the experts

6. Jason has just completed the repair of his flat tyre which now requires air. His hand pump can compress 100 mL of air each time it is used. Assuming his bike tyre has a volume of 1.60 L calculate the number of times Jason will need to use the pump in order to achieve the required pressure of 160 kPa. Assume air in the pump is initially at 101.3 kPa and there is no change in temperature.

Set 31 – Charles' Law

1. a) Convert the following to Kelvin units (K).

i) 0°C ii) 25°C iii) 100°C iv) -50°C

b) Convert the following to Celsius units (°C).

i) 100 K ii) 273 K iii) 300 K iv) 400 K

2. It is found that the pressure inside car tyres increases when they become warm after a long journey. Explain, in terms of kinetic theory, why the pressure of the air inside the tyre is greater at a higher temperature.

3. In an experiment designed to study the volume-temperature relationship for gases the following results were obtained. The pressure was kept constant.

Temp (°C)	0.0	20.0	40.0	60.0	80.0
Temp (K)					
Volume (mL)	3.60	3.87	4.13	4.40	4.65

a) Complete the table by converting temperatures to Kelvin units.

b) Graph V versus T (K) using graph paper or your graphic calculator.

c) What is the relationship between V and T (K)?

d) Use graph to determine volume of this mass of gas at 200°C.

4. Determine the new volume in each of the following cases. Assume no change in pressure.

a) 85.0 L of gas at 100°C is heated to 200°C.

b) A 20.0 L balloon is moved from an outside temperature of 35°C to a cool room at 5.0°C.

5. Determine the new temperature (°C) in each of the following cases. Assume no change in pressure.

a) A sample of gas occupies 220 mL at 80°C and is cooled until its new volume is 200 mL.

b) A 25.0 L helium filled balloon at 15.0°C is heated until its volume is 35.0 L.

c) A sample of gas at 120°C has its volume reduced from 340 mL to 200 mL.

For the experts

6. a) Assuming no change in pressure, determine the percentage (%) change in volume if a mass of gas is heated from:

i) 300°C to 600°C ii) 300 K to 600 K

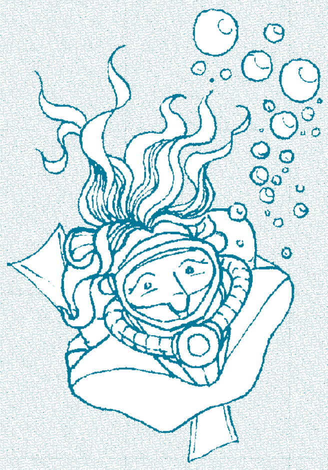
b) Explain any difference in results.

Set 32 – Combined Gas Law

1. John has an air filled balloon whose volume is 15.0 L at a temperature of 18°C and internal pressure of 112 kPa. Suggest three different ways by which John can increase the pressure inside the balloon.

2. A weather balloon is filled to 140 L at a temperature of 18°C and pressure of 1.0 atm and then released. It rises to a height of 4 km where the temperature is -11°C and pressure 0.62 atm. Determine the balloon's new volume at this height.

3. A scuba diver releases a 15 mL bubble of gas at a depth of water where the pressure is 250 kPa and temperature 10°C. Calculate the volume of the bubble just before it reaches the surface where the pressure is 105 kPa and temperature 17°C.



4. During an experiment 400 mL of gas is collected in a syringe at 21°C and 98.5 kPa. Calculate the volume of this gas at S.T.P.

5. A 5.0 L sample of gas at S.T.P. is subjected to various changes as follows. Determine:

a) its new volume if temperature is increased to 50°C and pressure doubled;

b) its new pressure if volume is doubled and temperature increased to 100°C;

c) its new temperature if volume is increased to 8.0 L and pressure reduced to 50 kPa.

For the experts

6. Michelle is using a small cylinder of compressed balloon gas (helium/air mixture) to fill some party balloons. The cylinder contains 2.4 L of gas at a pressure of 14,500 kPa and temperature of 20°C.

How many balloons will Michelle be able to fill with this gas if we assume that the average size of the balloons is 10 L at a pressure of 115 kPa and temperature of 32°C? Assume also that Michelle is going to be able to use all the gas.

Summary - formulae and flowcharts

1. Mole calculations formulae

$$n = \frac{N}{6.02 \times 10^{23}} \qquad n = \frac{m}{M} \qquad n = \frac{V}{22.4} \text{ at (S.T.P.)}$$

2. Gas Laws

Boyle's Law

$$P_1V_1 = P_2V_2$$

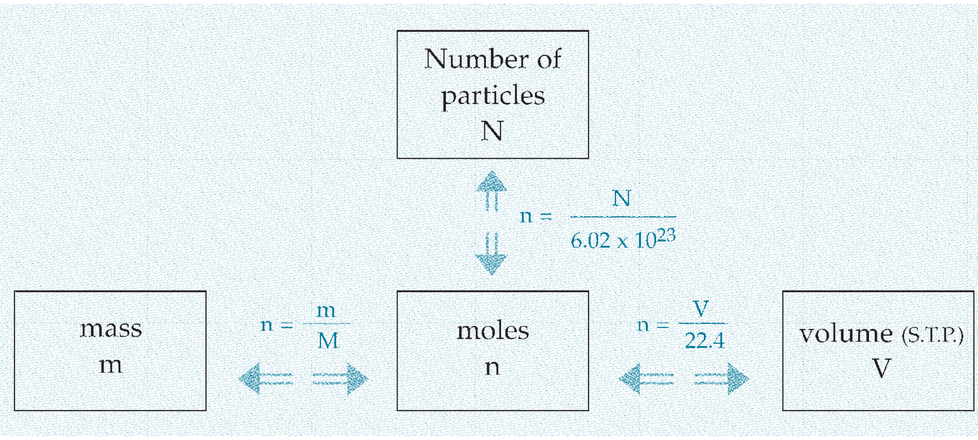
Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

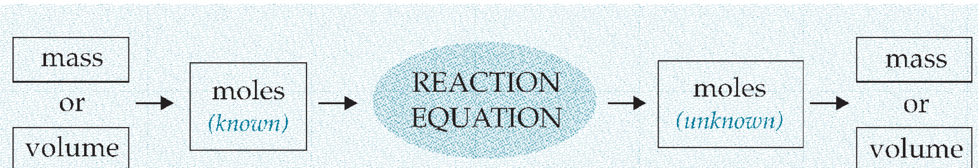
Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

3. Mole calculations flow chart



4. Calculations from equations flowchart



1. Convert known quantities to moles
2. Apply mole ratio from reaction equation
3. Convert moles to mass or volume

Test Section

Chemistry Fundamentals
- Multiple Choice
- Written Test

Chemistry Calculations
- Multiple Choice
- Written Test

The following tests are designed to extend your knowledge and find out what you have learnt from your study of introductory chemistry.

Test Section

1. Test 1 - Chemistry Fundamentals

Multiple Choice Section

1. The smallest part of an element that still has the properties of that element is called

a) an isotope **b)** an atom **c)** a molecule **d)** a nucleus

2. The formula CO represents

a) an atom of the element cobalt

b) a molecule of the element cobalt

c) an atom of the compound carbon monoxide

d) a molecule of the compound carbon monoxide

3. Which of the following are isotopes of the same element?

Atom W	36 protons	38 neutrons	37 electrons
Atom X:	37 protons,	38 neutrons,	36 electrons
Atom Y:	A = 76,	Z = 38	
Atom Z:	A = 80,	its neutral atom contains 37 electrons	

a) W and Z **b)** X and Y **c)** X and Z **d)** Y and Z

4. What element is represented by the "E" in the following formula: $^{39}_{20}E$

a) Ca **b)** Pr **c** K **d)** P

5. A neutral atom of element X has the electron configuration of 2 8 8

Which of the following statements about X is true?

a) X is an alkali metal

b) X will combine with O to form X_2O

c) X will combine with Na to form NaX

d) X is unlikely to combine with any other atoms to form a compound.

6. The element Y can be involved in chemical reactions that cause it to gain two electrons. Which of the elements listed is most likely be Y?

a) Si **b)** S

c) Ca **d)** Fe

7. The correct formula for the compound calcium hydrogencarbonate is

a) $Ca(HCO)_3$ **b)** $CaCO_3$

c) $CaHCO_3$ **d)** $Ca(HCO_3)_2$

8. The correct name for Ba_3N_2 is

a) barium nitride **b)** tribarium dinitride

c) barium nitrate **d)** tribarium dinitrogen

9. Which of the following groups of ions all have the correct formula and valency?

I	Mg^{2+},	Cu^{+},	S^{2-},	F^{2-}
II	Fe^{2+},	K^{2+},	SO_3^{2-},	CO_2^{2-}
III	Cu^{2+},	Sn^{4+},	O^{2-},	PO_4^{3-}
IV	Na^{+},	Ba^{2+},	SO_4^{2-},	S^{2-}

a) I only **b)** II and III only

c) II, III and IV only **d)** III and IV only

10. The valency of copper in the compound that has the correct formula $CuHSO_4$ is

a) +1 **b)** +2 **c)** -1 **d)** -2

11. The reaction between potassium permanganate and oxalic acid can be represented by the equation below:

$$2MnO_4^-{}_{(aq)} + 5H_2C_2O_{4(aq)} + \mathbf{X}\,H^+{}_{(aq)} \longrightarrow 2Mn^{2+}{}_{(aq)} + 10\,CO_{2(g)} + 8H_2O_{(l)}$$

To balance the equation, the number of H^+ ions (represented by X in the equation above) needed would be:

a) 3 **b)** 5 **c)** 6 **d)** 8

12. The reaction between ammonium thiocyanate and barium hydroxide is endothermic (absorbs energy from the surroundings) and can be represented by the equation:

$$\mathbf{a}\ NH_4SCN + \mathbf{b}\ Ba(OH)_2 \longrightarrow \mathbf{c}\ Ba(SCN)_2 + \mathbf{d}\ NH_3 + \mathbf{e}\ H_2O$$

The correct sequence of numbers to replace a to e and balance the equation is

a) 1 2 1 2 1 **b)** 1 1 1 2 2

c) 2 2 1 2 2 **d)** 2 1 1 2 2

13. Which of the following equations is correctly balanced?

a) $Cu(NO_3)_2 + 2NaOH \rightarrow 2NaNO_3 + 2Cu(OH)_2$

b) $(NH_4)_2CO_3 \rightarrow NH_3 + CO_2 + H_2O$

c) $Pb(NO_3)_2 + NaCl \rightarrow PbCl_2 + 2NaNO_3$

d) $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

14. When an ionic substance is dissolved in water,

a) the water causes the molecules to separate to form the original atoms in the process called dissociation.

b) the water causes the ions to separate in the process called dissociation.

c) the water and the ionic substance react to form dissociated molecules.

d) the water dissociates to form hydroxide ions and hydrogen molecules.

15. Which of the following groups contains compounds that are all soluble in water?

a) $NaNO_3$, $CuSO_4$, $CuCO_3$

b) $CaCl_2$, AgBr, $PbSO_4$

c) K_3PO_4, $Ba(OH)_2$, $(NH_4)_2S$

d) $FeCO_3$, $PbSO_4$, AgCl

16. Which of the following pairs of solutions, upon mixing, will react and form a white precipitate?

a) 0.01 mol L^{-1} $NaNO_3$ and 0.01 mol L^{-1} K_2SO_4

b) 0.01 mol L^{-1} $CuSO_4$ and 0.01 mol L^{-1} NaCl

c) 0.01 mol L^{-1} Na_2SO_4 and 0.01 mol L^{-1} $Ba(NO_3)_2$

d) 0.01 mol L^{-1} K_3PO_4 and 0.01 mol L^{-1} NH_4Cl

17. When a white powder was mixed with a 1.00 mol L^{-1} solution of hydrochloric acid, bubbles of a colourless gas were formed. The white powder might have been:

a) sodium hydroxide

b) calcium carbonate

c) calcium metal

d) calcium phosphate

18. A chemist decides to store a series of solutions in containers made of different metals. Which of the following combinations would not be suitable?

a) 1 mol L^{-1} HCl in an Fe container.

b) 1 mol L^{-1} $Mg(NO_3)_2$ in an Fe container.

c) 1 mol L^{-1} H_2SO_4 in an Au container.

d) 1 mol L^{-1} $Zn(NO_3)_2$ in a Sn container.

19. When a polished strip of unknown metal X, was placed in a solution of lead (II) nitrate it turned black and silvery coloured crystals began to grow on the metal.

When a polished strip of zinc was placed in a solution of "X nitrate" it turned black and silvery coloured crystals began to grow on the zinc.

When a polished strip of zinc was placed in a solution of lead nitrate it turned black and silvery coloured crystals began to grow on the zinc.

The order of reactivity of the 3 metals (from least reactive to most reactive) is:

a) Pb Zn X **b)** X Zn Pb

c) Pb X Zn **d)** Pb Zn X

20. Which of the following combinations would not produce a gas when mixed?

a) magnesium ribbon + sulfuric acid

b) hydrochloric acid + sodium hydrogencarbonate

c) sodium metal + water

d) sodium hydroxide + sulfuric acid. *(20 marks)*

Written Section

21. Use CO_2 and O_2 to explain the differences between elements and compounds. *(1 mark)*

22. The structure of element X can be described using the symbolic format $^{A}_{Z}X$. Explain how the number of protons and neutrons can be determined for a neutral atom of element X. *(2 marks)*

23. Use the examples $^{12}_{6}C$ and $^{14}_{6}C$ to explain what isotopes are. *(1 mark)*

24. Correctly name the following elements and compounds.

a) $CaCl_2$ **b)** CCl_4 **c)** $Fe(NO_3)_3$ **d)** P_2O_5

e) Cl_2 **f)** Mg_3N_2 *(3 marks)*

25. Write the correct formula for each of the following compounds.

a) magnesium fluoride **b)** zinc phosphate

c) dinitrogen tetraoxide **d)** chromium (III) hydroxide

e) sodium sulfate **f)** ammonium carbonate *(3 marks)*

26. Copy and balance the following equations.

a) $Fe_2O_3 + CO \longrightarrow Fe + CO_2$

b) $C_4H_{10} + O_2 \longrightarrow CO_2 + H_2O$ *(2 marks)*

27. Copy and complete the following general equations.

a) acid + hydroxide ⟶

b) acid + carbonate ⟶

c) acid + reactive metal ⟶ *(3 marks)*

28. Write balanced equations for the reactions that occur when the following chemicals are mixed.

a) sodium hydroxide + hydrochloric acid ⟶

b) sodium metal + water ⟶

c) potassium hydrogencarbonate + sulfuric acid ⟶ *(6 marks)*

29. Name three metals that will not react with dilute hydrochloric acid. *(1 mark)*

30. Write balanced ionic equations for the reactions that occur when the following solutions are mixed. If no reaction occurs, write "no reaction".

a) $AgNO_{3\,(aq)} + NaCl_{(aq)} \longrightarrow$

b) $FeCl_{3\,(aq)} + NaOH_{(s)} \longrightarrow$

c) $K_2CO_{3\,(aq)} + Ca(NO_3)_{2\,(aq)} \longrightarrow$

d) $MgCl_{2\,(aq)} + (NH_4)_3PO_{4\,(aq)} \longrightarrow$ *(8 marks)*

End of Test. Total Marks: 50

2. Test 2 - Chemistry Calculations

Multiple Choice Section

1. Approximately how many carbon atoms have the same mass as a magnesium atom?

a) 2 **b)** 6 **c)** 12 **d)** 24

2. Which of the following has the greatest relative molecular mass (M_r)

a) H_2O **b)** CO_2 **c)** Cl_2 **d)** Ar

3. Which element in $CuSO_4 . 5H_2O$ constitutes the greatest percentage by mass?

a) Cu **b)** S **c)** O **d)** H

4. Which of the following statements is correct when referring to a mole of substance?

a) Its a very small amount of substance

b) Its Avagadro's number of particles of that substance

c) Its exactly 12.0 g of any substance

d) Its exactly 6.02×10^{23} g of that substance

5. Which of the following contains the greatest number of molecules?

a) 1.0 mol of CO_2 molecules **b)** 2.0 mol of H_2O molecules

c) 2.0 mol of NH_3 molecules **d)** 3.0 mol of H_2 molecules

6. The molar mass of a substance is:

a) the mass of one mole of the substance

b) the atomic number of each of the atoms expressed in grams

c) the total mass of each of the atoms in a molecule of that substance

d) the mass of one molecule of the substance

7. Which of the following has the greatest mass?

a) 1.0 mol of Cl_2 **b)** 2.0 mol of CO_2

c) 3.0 mol of O_2 **d)** 4.0 mol of H_2O

8. Which of the following has the greatest number of oxygen atoms?

a) 1.0 mol of $Pb(NO_3)_2$ **b)** 2.0 mol of H_2SO_4

c) 3.0 mol of SO_2 **d)** 4.0 mol of H_2O

9. The combustion of hydrogen gas can be represented by

$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$

Which of the following statements is correct for this reaction?

a) 2 moles of hydrogen molecules react with 1 mole of oxygen molecules

b) 2.0 grams of hydrogen gas react with 1.0 g of oxygen gas

c) 2 atoms of hydrogen gas react with 2 atoms of oxygen gas

d) 2 molecules of hydrogen gas react with 1 atom of oxygen gas.

10. $N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3\,(g)}$

If 9.0 mole of hydrogen gas is completely reacted as in the reaction shown above then:

a) 1.0 mol of N_2 is consumed and 2.0 mol of NH_3 are produced

b) 2.0 mol of N_2 is consumed and 6.0 mol of NH_3 are produced

c) 3.0 mol of N_2 is consumed and 6.0 mol of NH_3 are produced

d) 9.0 mol of N_2 is consumed and 18.0 mol of NH_3 are produced

11. Propane gas (bottled gas) burns as follows:

$C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{(g)}$

If 1.5 mol of C_3H_8 are burnt, then the mass of CO_2 produced would be:

a) 44.0 g **b)** 66.0 g **c)** 132 g **d)** 198 g

12. Methane gas (natural gas) burns as follows:

$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$

If 32.0 g of methane are burnt, how many moles of water will be produced?

a) 2.0 mol **b)** 4.0 mol **c)** 6.0 mol **d)** 64.0 mol

13. Magnesium metal reacts with hydrochloric acid as follows:

$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$

If 10.0 g of magnesium react, what mass of HCl acid will be consumed?

a) 15.0 g **b)** 20.0 g **c)** 30.0 g **d)** 73.0 g

14. Which of the following statements is **CORRECT** when referring to gases. Assume same conditions of temperature and pressure in all cases.

a) Equal volumes of gases contain equal number of particles

b) Equal volumes of gases contain equal masses of gas

c) Equal volumes of gases contain equal number of atoms

d) The number of moles of gases can only be determined from their molecular formula

15. The volume occupied at S.T.P. by 3.0 mol of CO_2 gas is:

a) 3.0 L **b)** 22.4 L **c)** 67.2 L **d)** 132.0 L

16. For the following reaction assume all volumes are at S.T.P. conditions

$$2CO_{(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)}$$

If 100 mL of CO are burnt then:

a) 50 mL of O_2 gas are consumed and 100 mL of CO_2 are produced

b) 200 mL of O_2 gas are consumed and 100 mL of CO_2 are produced

c) 100 mL of O_2 gas are consumed and 200 mL of CO_2 are produced

d) 32 mL of O_2 gas are consumed and 88 mL of CO_2 are produced

17. Calcium carbonate reacts with hydrochloric acid as follows:

$$CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

The mass of $CaCO_3$ required to produce 56 L of CO_2 gas at S.T.P. would be approximately

a) 2.5 g **b)** 56 g **c)** 127 g **d)** 250 g

18. Which of the following statements about gases is **FALSE**?

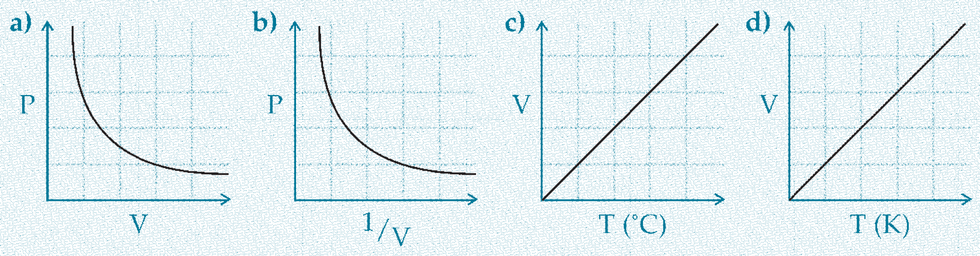
a) The volume occupied by gas particles is negligible compared to the total volume taken up by the gas

b) Gas pressure increases if temperature decreases

c) As volume is increased, pressure is decreased

d) Gas particles move rapidly and take up all available space in a container.

19. Which of the following graphs best represent Charles' Law?



20. A 20.0 mL sample of hydrogen gas at 200K and 100 kPa is changed to 400K and 25kPa. Its new volume will be:

a) 10.0 mL **b)** 40.0 mL **c)** 80.0 mL **d)** 160 mL *(20 marks)*

Written Section

21. Write down the correct formula and calculate the relative molecular mass (M_r) of

a) chlorine gas **b)** calcium hydroxide *(2 marks)*

22. Determine the percentage (%) by weight of each of the elements in the compound sodium sulfate (Na_2SO_4). *(2 marks)*

23. Calculate the mass of

a) 2.5 mol of NaOH **b)** 0.40 mol of $Al(NO_3)_3$ *(2 marks)*

24. Calculate the number of moles of :

a) water in 50.0 g of water

b) hydrogen atoms in 20.0 g of ammonia gas (NH_3) *(2 marks)*

25. Potassium metal reacts violently with water as follows:

$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH_{(aq)} + H_{2\,(g)}$$

Calculate the mass of H_2 gas produced if 6.0 mol of potassium is consumed. *(3 marks)*

26. The fertiliser ammonium sulfate can be produced from ammonia as follows:

$$2NH_{3\,(g)} + 2H_2SO_{4\,(l)} \longrightarrow (NH_4)_2SO_{4\,(s)}$$

Calculate the mass of ammonia needed to produce 80.0 g of ammonium sulfate. *(3 marks)*

27. Calculate the volume occupied at S.T.P. by:

a) 1.5 mol of H_2 gas **b)** 550 g of SO_2 gas

c) 3.01×10^{23} molecules of CO_2 gas *(3 marks)*

28. Sodium carbonate reacts with hydrochloric acid as follows:

$$Na_2CO_{3\,(aq)} + 2HCl_{\,(aq)} \longrightarrow 2NaCl_{\,(aq)} + H_2O_{\,(l)} + CO_{2\,(g)}$$

Determine the volume of carbon dioxide gas at S.T.P. that would be produced using 12.0 g of sodium carbonate. *(4 marks)*

29. Iron is produced by reducing iron (III) oxide as follows:

$$Fe_2O_{3\,(s)} + 3CO_{\,(g)} \longrightarrow 2Fe_{\,(s)} + 3CO_{2\,(g)}$$

If 1 tonne (1000kg) of iron (III) oxide is reduced, calculate:

a) the mass of iron produced

b) the volume of carbon dioxide produced (assume S.T.P.) *(4 marks)*

30. a) Determine the new volume when 200 L of gas at 200 kPa is compressed to 450 kPa (assume no change in temperature). *(1 marks)*

b) Determine the new volume when 15.0 L of gas at 30°C is heated to 60°C (assume no change in pressure). *(1 marks)*

c) A weather balloon is filled to 85 L at 25°C and 101 kPa and then released. Find its new volume when it rises to a height where the temperature is -12°C and pressure is 65 kPa. *(3 marks)*

End of Test. Total Marks: 50

ANSWERS

ANSWERS

Checkpoints Answers

1.1

$^{35}_{17}$Cl	.....chlorine	17	35	17	18
$^{40}_{20}$Ca	.....calcium	20	40	20	20
$^{52}_{24}$Cr	.....chromium	24	52	24	28
$^{133}_{55}$Cs	.....caesium	55	133	55	78
$^{64}_{29}$Cu	....copper	29	64	29	35
$^{247}_{96}$Cm	....curium	96	247	96	151
$^{140}_{58}$Ce	.....cerium	58	140	58	82
$^{112}_{48}$Cd	....cadmium	48	112	48	64
$^{251}_{98}$Cf	.....californium	98	251	98	153

1.2

a) Zn: 30 protons, 36 neutrons
b) Ru: 44 protons, 57 neutrons
c) Pb: 82 protons, 125 neutrons
d) Ra: 88 protons, 138 neutrons
e) K: 19 protons, 20 neutrons
f) Mn: 25 protons, 30 neutrons
g) Cl: 17 protons, 18 neutrons
h) U: 92 protons, 146 neutrons

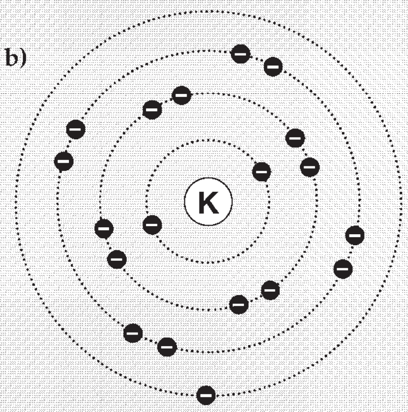
2.1 **a)** 1 **b)** 2 **c)** 53

2.2

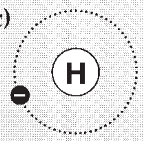
a) He ..2 **b)** Be ...2 2
c) Ca ..2 8 8 2 **d)** N ...2 5
e) Al ..2 8 3 **f)** Ne ..2 8
g) S ...2 8 6 **h)** Na ..2 8 1
i) P ...2 8 5 **j)** O ...2 6
k) Be ..2 2 **l)** Si ...2 8 4
m) Ar ..2 8 8 **n)** K ...2 8 8 1

2.3

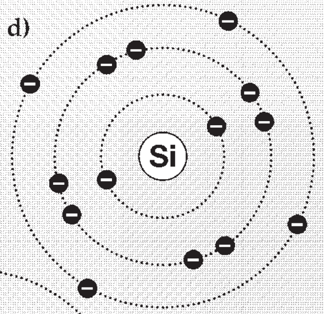
b)



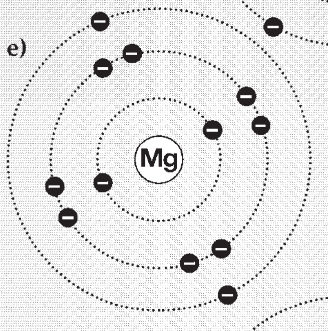
c)



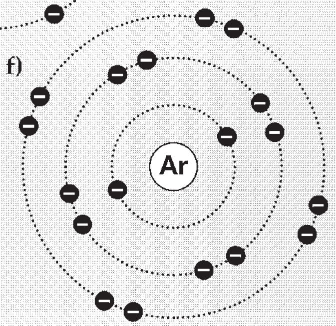
d)



e)



f)



2.4

a) O : 6 **b)** S : 6 **c)** Be : 2
d) Li : 1 **e)** Ar : 8

2.5

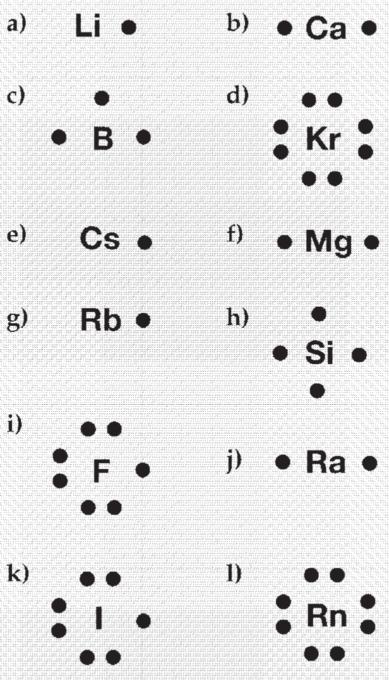
a) N : 5 **b)** Al : 3
c) He : 2 **d)** K : 1
e) P : 5 **f)** Li : 1
g) B : 3 **h)** Kr : 8
i) As : 5 **j)** Rb : 1

2.6

Mg	2 8 2	; 2 8	; lose 2 electrons
B	2 3	; 2	; lose 3 electrons
F	2 7	; 2 8	; gain 1 electron
P	2 8 5	; 2 8 8	; gain 3 electrons
Cl	2 8 7	; 2 8 8	; gain 1 electron
Ca	2 8 8 2	; 2 8 8	; lose 2 electrons
S	2 8 6	; 2 8 8	; gain 2 electrons
C	2 4	; 2 8	; gain 4 electrons

Checkpoints — Answers

2.7



3.1

a) metal **b)** non-metal
c) metal **d)** non-metal
e) non-metal **f)** metal
g) non-metal **h)** metal

3.2

a) ionic **b)** covalent
c) metallic **d)** ionic
e) covalent **f)** covalent
g) ionic **h)** covalent

4.1

a) carbon dioxide
b) bromine
c) diphosphorus pentaoxide
d) sulfur dioxide
e) hydrogen chloride
f) sulfur trioxide

4.2

a) Cl_2 **b)** OCl_2 **c)** NF_3
d) NO_2 **e)** SO_3 **f)** CCl_4

4.3

a) H_2O should be dihydrogen oxide not water

b) CO should be carbon oxide not carbon monoxide

4.4

Name: **barium chloride**
Step 1: Ba^{2+} Cl^-
Step 2: 1 Ba^{2+} balances 2 Cl^-
Step 3: $BaCl_2$

Name: **zinc nitride**
Step 1: Zn^{2+} N^{3-}
Step 2: 3 Zn^{2+} balances 2 N^{3-}
Step 3: Zn_3N_2

Name: **zinc oxide**
Step 1: Zn^{2+} O^{2-}
Step 2: 1 Zn^{2+} balances 1 O^{2-}
Step 3: ZnO

Name: **aluminium sulfide**
Step 1: Al^{3+} S^{2-}
Step 2: 2 Al^{3+} balances 3 S^{2-}
Step 3: Al_2S_3

Name: **aluminium nitride**
Step 1: Al^{3+} N^{3-}
Step 2: 1 Al^{3+} balances 1 N^{3-}
Step 3: AlN

4.5

	F^-	Cl^-	O^{2-}	S^{2-}	N^{3-}
Na^+	NaF	NaCl	Na_2O	Na_2S	Na_3N
Li^+	LiF	LiCl	Li_2O	Li_2S	Li_3N
Ag^+	AgF	AgCl	Ag_2O	Ag_2S	Ag_3N
K^+	KF	KCl	K_2O	K_2S	K_3N
Cu^+	CuF	CuCl	Cu_2O	Cu_2S	Cu_3N
Mg^{2+}	MgF_2	$MgCl_2$	MgO	MgS	Mg_3N_2
Ba^{2+}	BaF_2	$BaCl_2$	BaO	BaS	Ba_3N_2
Fe^{2+}	FeF_2	$FeCl_2$	FeO	FeS	Fe_3N_2
Cu^{2+}	CuF_2	$CuCl_2$	CuO	CuS	Cu_3N_2
Al^{3+}	AlF_3	$AlCl_3$	Al_2O_3	Al_2S_3	AlN
Cr^{3+}	CrF_3	$CrCl_3$	Cr_2O_3	Cr_2S_3	CrN
Fe^{3+}	FeF_3	$FeCl_3$	Fe_2O_3	Fe_2S_3	FeN
Sn^{4+}	SnF_4	$SnCl_4$	SnO_2	SnS_2	Sn_3N_4
Pb^{4+}	PbF_4	$PbCl_4$	PbO_2	PbS_2	Pb_3N_4

Checkpoints Answers

4.6

	bromide	iodide	oxide	sulfide	nitride
K^+	KBr	KI	K_2O	K_2S	K_3N
Cu^+	CuBr	CuI	Cu_2O	Cu_2S	Cu_3N
Ca^{2+}	$CaBr_2$	CaI_2	CaO	CaS	Ca_3N_2
Fe^{3+}	$FeBr_3$	FeI_3	Fe_2O_3	Fe_2S_3	FeN
Co^{2+}	$CoBr_2$	CoI_2	CoO	CaS	Co_3N_2
Cr^{3+}	$CrBr_3$	CrI_3	Cr_2O_3	Cr_2S_3	CrN
Sn^{2+}	$SnBr_2$	SnI_2	SnO	SnS	Sn_3N_2

4.7

	NO_3^-	OH^-	CH_3COO^-
Na^+	$NaNO_3$	NaOH	$NaCH_3COO$
Cu^+	$CuNO_3$	CuOH	$CaCH_3COO$
Cu^{2+}	$Cu(NO_3)_2$	$Cu(OH)_2$	$Cu(CH_3COO)_2$
Fe^{2+}	$Fe(NO_3)_2$	$Fe(OH)_2$	$Fe(CH_3COO)_2$
Fe^{3+}	$Fe(NO_3)_3$	$Fe(OH)_3$	$Fe(CH_3COO)_3$
Ca^{2+}	$Ca(NO_3)_2$	$Ca(OH)_2$	$Ca(CH_3COO)_2$
K^+	KNO_3	KOH	KCH_3COO
Sn^{4+}	$Sn(NO_3)_4$	$Sn(OH)_4$	$Sn(CH_3COO)_4$
Zn^{2+}	$Zn(NO_3)_2$	$Zn(OH)_2$	$Zn(CH_3COO)_2$
Al^{3+}	$Al(NO_3)_3$	$Al(OH)_3$	$Al(CH_3COO)_3$
NH_4^+	NH_4NO_3	NH_4OH	NH_4CH_3COO

	SO_4^{2-}	CO_3^{2-}	PO_4^{3-}
Na^+	Na_2SO_4	Na_2CO_3	Na_3PO_4
Cu^+	Cu_2SO_4	Cu_2CO_3	Cu_3PO_4
Cu^{2+}	$CuSO_4$	$CuCO_3$	$Cu_3(PO_4)_2$
Fe^{2+}	$FeSO_4$	$FeCO_3$	$Fe_3(PO_4)_2$
Fe^{3+}	$Fe_2(SO_4)_3$	$Fe_2(CO_3)_3$	$FePO_4$
Ca^{2+}	$CaSO_4$	$CaCO_3$	$Ca_3(PO_4)_2$
K^+	K_2SO_4	K_2CO_3	K_3PO_4
Sn^{4+}	$Sn(SO_4)_2$	$Sn(CO_3)_2$	$Sn_3(PO_4)_4$
Zn^{2+}	$ZnSO_4$	$ZnCO_3$	$Zn_3(PO_4)_2$
Al^{3+}	$Al_2(SO_4)_3$	$Al_2(CO_3)_3$	$AlPO_4$
NH_4^+	$(NH_4)_2SO_4$	$(NH_4)_2CO_3$	$(NH_4)_3PO_4$

4.8

$CuCl_2$	$(NH_4)_2CO_3$
Al_2O_3	MgI_2
$Fe_3(PO_4)_2$	AlN
Au_2S	$Ba(CH_3COO)_2$
K_2SO_4	$KHCO_3$
Cu_2CO_3	$CuSO_3$
$Ca(OH)_2$	Pb_3N_2
$SnCl_2$	Sn_3N_4
Cr_2O_3	$CoSO_4$
PbO_2	$Cu(OH)_2$
NH_4Cl	$Zn_3(PO_4)_2$
$Fe(OH)_3$	NH_4HSO_4

4.9
- **a)** sodium chloride
- **b)** ammonium nitrate
- **c)** silver oxide
- **d)** iron (II) sulfate
- **e)** iron (III) sulfate
- **f)** tin (IV) oxide
- **g)** copper (II) carbonate
- **h)** potassium phosphate
- **i)** lead (IV) oxide
- **j)** zinc nitride

5.1
- **a)** $3\ H_2SO_4$: 6 H 3 S 12 O
- **b)** $4\ KMnO_4$: 4 K 4 Mn 16 O
- **c)** $2\ PbO_2$: 2 Pb 4 O
- **d)** $5\ KClO_4$: 5 K 5 Cl 20 O
- **e)** $6\ NaHCO_3$: 6 Na 6 H 6 C 18 O

5.2
- **a)** $2\ Cu(OH)_2$: 2 Cu 4 O 4 H
- **b)** $3\ Al_2(SO_4)_3$: 6 Al 9 S 36 O
- **c)** $4\ Fe_2(CO_3)_3$: 8 Fe 12 C 36 O
- **d)** $3\ Mg(NO_3)_2$: 3 Mg 6 N 18 O
- **e)** $4\ Ca(HSO_4)_2$: 4 Ca 8 H 8 S 32 O

Answers

Checkpoints Answers

5.3

a) $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

b) $Fe_2(CO_3)_3 + 2H_3PO_4 \rightarrow 2FePO_4 + 3CO_2 + 3H_2O$

c) $4Na + O_2 \rightarrow 2Na_2O$

d) $Sn(NO_3)_2 + 2KOH \rightarrow Sn(OH)_2 + 2KNO_3$

e) $3NaHCO_3 + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O + 3CO_2$

6.1

a) Acidic substances: HCl, HNO_3, SO_3, CH_3COOH, H_3PO_4

Basic substances: $NaOH$, NH_3, $NaHCO_3$, $Mg(OH)_2$, K_2O, Fe_2O_3, Na_2CO_3

6.2

a) $NaCl$ b) K_2SO_4 c) $Ca(NO_3)_2$

d) $NaNO_3$ e) Na_3PO_4 f) K_2SO_4

6.3

a) $2H_3PO_4 + 3Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 6H_2O$

b) $2CH_3COOH + Ba(OH)_2 \rightarrow Ba(CH_3COO)_2 + 2H_2O$

c) $3H_2SO_4 + 2Cr(OH)_3 \rightarrow Cr_2(SO_4)_3 + 6H_2O$

d) $H_2CO_3 + 2KOH \rightarrow K_2CO_3 + 2H_2O$

e) $2HCl + Fe(OH)_2 \rightarrow FeCl_2 + 2H_2O$

6.4

a) $SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$

b) $P_2O_5 + 3Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 3H_2O$

c) $SO_3 + Cu(OH)_2 \rightarrow CuSO_4 + H_2O$

d) $CO_2 + Ba(OH)_2 \rightarrow BaCO_3 + H_2O$

e) $3SO_2 + 2Al(OH)_3 \rightarrow Al_2(SO_3)_3 + 3H_2O$

6.5

a) $2CH_3COOH + BaO \rightarrow Ba(CH_3COO)_2 + H_2O$

b) $2H_3PO_4 + 3CuO \rightarrow Cu(PO_4)_2 + 3H_2O$

c) $H_2CO_3 + K_2O \rightarrow K_2CO_3 + H_2O$

d) $6HNO_3 + Al_2O_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$

e) $3H_2SO_4 + 2Cr(OH)_3 \rightarrow Cr_2(SO_4)_3 + 6H_2O$

6.6

a) $2H_3PO_4 + 3(NH_4)_2CO_3 \rightarrow 2(NH_4)_3PO_4 + 3H_2O + 3CO_2$

b) $HCl + KHCO_3 \rightarrow KCl + H_2O + CO_2$

c) $2CH_3COOH + ZnCO_3 \rightarrow Zn(CH_3COO)_2 + H_2O + CO_2$

d) $6HNO_3 + Fe_2(CO_3)_3 \rightarrow 2Fe(NO_3)_3 + 3H_2O + 3CO_2$

e) $H_2SO_4 + Mg(HCO_3)_2 \rightarrow MgSO_4 + 2H_2O + 2CO_2$

7.1

a) $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

b) $Sn + H_2SO_4 \rightarrow SnSO_4 + H_2$

c) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

d) $2Fe + 2H_3PO_4 \rightarrow 2FePO_4 + 3H_2$

e) no reaction

7.2

a) $2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$

b) $2Na + 2H_2O \rightarrow 2NaOH + H_2$

c) no reaction

d) $Ni + H_2O \rightarrow NiO + H_2$

e) $Pb + H_2O \rightarrow PbO + H_2$

7.3

a) $4Al + 3O_2 \rightarrow 2Al_2O_3$

b) $4Na + O_2 \rightarrow 2Na_2O$

c) $2Cu + O_2 \rightarrow 2CuO$

d) $2Ni + O_2 \rightarrow 2NiO$

e) no reaction

7.4

a) insoluble b) soluble c) insoluble

d) insoluble e) soluble f) insoluble

g) soluble h) soluble

7.5

a) soluble b) insoluble c) soluble

d) insoluble e) insoluble

f) slightly soluble

Checkpoints Answers

7.6

a) ions present: Cu^{2+}, SO_4^{2-}, Na^+, OH^-

equation: $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2(s)}$

b) ions present: Na^+, S^{2-}, Ca^{2+}, NO_3^-

equation: $Ca^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CaS_{(s)}$

8.1

a) i) $35.5/12 \approx 3$ iii) $47.9/12 \approx 4$
ii) $107.9/12 \approx 9$ iv) $83.8/12 \approx 7$

b) i) $4.0/1.0 = 4$ iii) $12.0/1.0 = 12$
ii) $16.0/1.0 = 16$ iv) $55.8/1.0 = 55.8$

c) $107.9/27.0 \approx 4$

d) i) Na, Mg, Al ii) H, He, B

e) Ca

8.2

a) $M_r (CO_2) = (1 \times 12.0) + (2 \times 16.0) = 44$

b) $M_r (Cl_2) = (2 \times 35.5) = 71$

c) $M_r (CuSO_4) = 63.5 + 32.1 + (4 \times 16.0)$
$= 159.6$

d) $M_r (Pb(NO_3)_2)$
$= 207.2 + (2 \times 14.0) + (6 \times 16.0) = 331.2$

e) $M_r (Mg(OH)_2)$
$= 24.3 + (2 \times 16.0) + (2 \times 1.0) = 58.3$

8.3

a) $M_r (SO_2) = 32.1 + (2 \times 16.0) = 64.1$

b) $M_r (AlCl_3) = 27.0 + (3 \times 35.5) = 133.5$

c) $M_r (Cl_2) = (2 \times 35.5) = 71.0$

d) $M_r (NH_3) = 14.0 + (3 \times 1.0) = 17.0$

e) $M_r (BaCl_2) = 137.3 + (2 \times 35.5) = 208.3$

f) $M_r ((NH_4)_2SO_4) = (2 \times 14.0) + (8 \times 1.0)$
$+ 32.1 + (4 \times 16.0) = 132.1$

g) $M_r (Fe(OH)_2)$
$= 55.8 + (2 \times 16.0) + (2 \times 1.0) = 89.8$

8.4

a) %H (by mass) = $(6.0/46) \times 100 = 13.0\%$

b) %O (by mass) = $(16.0/46) \times 100 = 34.8\%$

8.5

a) $M_r (CO_2) = 12.0 + (2 \times 16.0) = 44.0$
% C = $(12.0 / 44) \times 100 = 27.3\%$
% O = $(32.0 / 44) \times 100 = 72.7\%$

b) $M_r (PbSO_4) = 207.2 + 32.1 + (4 \times 16.0)$
$= 303.3$
% Pb = $(207.2 / 303.3) \times 100 = 68.3\%$
% S = $(32.1 / 303.3) \times 100 = 10.6\%$
% O = $(64.0 / 303.3) \times 100 = 21.1\%$

8.6

a) $M_r (AgNO_3) = 107.9 + 14.0 + (3 \times 16.0)$
$= 169.9$
% Ag = $(107.9 / 169.9) \times 100 = 63.5\%$
% N = $(14.0 / 169.9) \times 100 = 8.2\%$
% O = $(48.0 / 169.9) \times 100 = 28.3\%$

b) $M_r (Na_2SO_4)$
$= (2 \times 23.0) + 32.1 + (4 \times 16.0) = 142.1$
% Na = $(46.0 / 142.1) \times 100 = 32.4\%$
% S = $(32.1 / 142.1) \times 100 = 22.6\%$
% O = $(64.0 / 142.1) \times 100 = 45.0\%$

c) $M_r ((NH_4)_2SO_4)$
$= (2 \times 14.0) + (8 \times 1.0) + 32.1 + (4 \times 16.0)$
$= 132.1$
% N = $(28 / 132.1) \times 100 = 21.2\%$
% H = $(8.0 / 132.1) \times 100 = 6.1\%$
% S = $(32.1 / 132.1) \times 100 = 24.3\%$
% O = $(64.0 / 132.1) \times 100 = 48.4\%$

9.1 The mass of copper atoms is greater than the mass of carbon atoms. The mass of Cu atoms is $63.5/12.0$ (≈ 5.3) times greater.

9.2 A mole of 5¢ coins = $6.02 \times 10^{23} \times 0.05$ dollars $\approx$ \$$3 \times 10^{22}$ dollars. This is much, much more than a million (10^6).

9.3

a) 6.02×10^{23} O atoms

b) 1.204×10^{24} O atoms

c) 1.204×10^{24} O atoms

d) 6.02×10^{24} O atoms

e) 1.806×10^{25} O atoms

9.4

a) $64.1\ g\ mol^{-1}$ – see text

b) $23.0 + 35.5 = 58.5\ g\ mol^{-1}$

c) $(2 \times 1.0) + 16.0 = 18.0\ g\ mol^{-1}$

d) $65.4 + (2 \times 35.5) = 136.4\ g\ mol^{-1}$

e) $(2 \times 27.0) + (3 \times 16.0) = 102\ g\ mol^{-1}$

Checkpoints Answers

9.5

a) M ($CaCl_2$) = 111.1 g mol^{-1} – see text

b) M ($ZnSO_4$) = 65.4 + 32.1 + (4 x 16.0)
= 161.5 g mol^{-1}

c) M (PbO_2) = 207.2 + (2 x 16.0)
= 239.2 g mol^{-1}

d) M ($FeCl_3$) = 55.8 + (3 x 35.5)
= 162.3 g mol^{-1}

e) M (P_4O_{10}) = (4 x 31.0) + (10 x 16.0)
= 284.0 g mol^{-1}

9.6

a) 0.846 mol of Fe_2O_3 – see text

b) n ($CuSO_4$) = 135.0/63.5+32.1+(4x16.0)
= 0.846 mol

c) n ($CuSO_4 . 5H_2O$) = 135.0/159.6+5(18)
= 0.541 mol

d) n (H_3PO_4) = 135.0/(3x1)+31.0+(4x16.0)
= 1.38 mol

e) n($BaCl_2$) = 135.0/137.3+(2 x 35.5)
= 0.648 mol

9.7

a) 370 g – see text

b) M (CaO) = 40.1 + 16.0 = 56.1 g mol^{-1}
m (CaO) = (4.62) (56.1) = 259.2 g

c) M ($CaCO_3$) = 40.1 + 12.0 + (16.0 x 3)
= 100.1 g mol^{-1}
m ($CaCO_3$) = (3.70)(100.1) = 370.4 g

d) M ($FeSO_4$) = 55.8 + 32.1 + (16.0 x 4)
= 151.9 g mol^{-1}
m ($FeSO_4$) = (0.015)(151.9) = 2.28 g

e) M ($AlPO_4$) = 27.0 + 31.0 + (16.0 x 4)
= 122.0 g mol^{-1}
m ($AlPO_4$) = (3.70)(122.0) = 451.4 g

f) M (NaO_2) = (23.0 x 2) + 32.1 + (16.0 x 4)
= 142.1 g mol^{-1}
m (NaO_2) = (1.15)(142.1) = 163.4 g

9.8 30 atoms of hydrogen, 10 atoms of phosphorus 40 atoms of oxygen

9.9 4.0 mol of C atoms , 12.0 mol of H atoms, 2.0 mol of O atoms

9.10

a) M ($Mg(NO_3)_2$) = 24.3 + 28.0 + 96.0
= 148.3 g mol^{-1}
∴ n ($Mg(NO_3)_2$) = m / M = = 2.0 mol

b) n (NO_3^-) ions = (2)(2.0) = 4.0 mol

c) n (Mg) atoms = (1)(2.0) = 2.0 mol
m (Mg) atoms = (2.0)(24.3) = 48.6 g

10.1

a) propane gas + oxygen gas ->
carbon dioxide gas + water vapour

b) $C_3H_{8(g)} + 5O_{2(g)}$ -> $3CO_{2(g)}$ $4H_2O_{(g)}$

c) 1 : 5 : 3 : 4

10.2

a) five, oxygen, three, four

b) 22.5 mol of oxygen

c) 5 mol of C_3H_8 gas

d) 12 mol of water vapour

10.3

a) 0.15 mol of NaOH produced

b) 50 mol of Na are required

10.4

a) equation **b)** known, unknown

c) mole **d)** moles, unknown
(Extra) n = m / M

e) convert to other units if required

10.5 mass of HCl = unknown
2.6 mol of $CaCO_3$ = known

$$\frac{n\ (HCl)}{n\ (CaCO_3)} = \frac{2}{1}$$

$$n\ (HCl) = \left(\frac{2}{1}\right)(2.6) = 5.2\ mol$$

= m (HCl) = n . M = (5.2)(36.5) = 189.8 g

10.6 moles of CO_2 = unknown
120.0 g of $NaHCO_3$ = known

$$\frac{n\ (CO_2)}{n\ (NaHCO_3)} = \frac{1}{2}$$

$$n\ (NaHCO_3) = m\ /\ M = \frac{120.0}{84.0}$$

= 1.43 mol

$$\therefore n\ (CO_2) = \left(\frac{1}{2}\right)(1.43) = 0.714\ mol$$

Checkpoints Answers

10.7 mass of Ag = unknown
10.0 g of Cu = known

$\frac{n(Ag)}{n(Cu)} = (\frac{2}{1})$

$n(Cu) = m / M = \frac{10.0}{63.5} = 0.157$ mol

$\therefore n(Ag) = (\frac{2}{1})(0.157) = 0.314$

$m(Ag) = n \cdot M = (0.314)(107.9)$
$= 34.0$ g of silver

S.T.P conditions in all cases.

11.1

gas	no. moles	no. particles	mass
O_2	1.0	6.02×10^{23}	32.0 g
O_2	0.5	3.01×10^{23}	16.0 g
NH_3	2.0	1.2×10^{24}	34 g
CO_2	0.5	3.0×10^{23}	22 g
Ne	1.5	9.03×10^{23}	30.3 g
SO_2	1.5	9.03×10^{23}	96.15 g

11.2 **a)** Same number of molecules in both balloons (same volume, same conditions)

b) same number of moles in both balloons (same volume, same conditions)

c) balloon B is heavier
(Ar (He) = 4 , Ar (H_2) = 2)

11.3 **a)** V = (2.0)(22.4) = 44.8 L
V = (0.15)(22.4) = 3.36 L

11.4 **a)** $n(O_2) = m / M = 8.0/32.0 = 0.25$ mol
$\therefore V(O_2) = (0.25)(22.4) = 5.6$ L

b) $n(NH_3) = m / M = 55.0/17.0 = 32.4$ mol
$\therefore V(NH_3) = (32.4)(22.4) = 725$ L

11.5 **a)** $n(SO_2) = m / M = 20.0/22.4 = 0.893$ mol
$\therefore m(SO_2) = (0.893)(64.1) = 57.2$ g

b) $n(CH_4) = m/M = 0.760/22.4 = 0.0339$ mol
$\therefore m(CH_4) = (0.0339)(16.0) = 0.543$ g

11.6 $N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3(g)}$

$\frac{n(H_2)}{n(N_2)} = (\frac{3}{1}) = 1$

$\therefore$ volume ratio = 3

$\therefore V(H_2) = (3)(500) = 1500$mL

11.7 $C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
25.0 L x L

$n(CO_2) / n(C_3H_8) = 3/1 = 3$

$\therefore$ volume ratio = 3

$\therefore V(CO_2) = (3)(25.0) = 75.0$ L

11.8 $H_{2\,(g)} + Cl_{2\,(g)} \rightarrow 2HCl_{(g)}$
12.0 g x L

$n(HCl) / n(H_2) = 2/1 = 2$

$n(H_2)$ reacted $= m / M = 12.0/2.0 = 6.0$ mol

$\therefore n(HCl)$ produced $= (2)(6.0) = 12.0$ mol

$\therefore V(HCl)$ produced $= (12.0)(22.4) = 268.8$L

11.9 $Na_2CO_{3(s)} + 2HCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + 2H_2O_{(l)} + CO_{2(g)}$
x g 400 mL

$n(Na_2CO_3) / n(CO_2) = 1/1 = 1$

$n(CO_2)$ produced $= V/22.4 = 0.400/22.4$
$= 0.0179$ mol

$\therefore n(Na_2CO_3)$ required $= (1)(0.0179)$
$= 0.0179$ mol

$\therefore m(Na_2CO_3)$ required $= (0.0179)(106.0)$
$= 1.89$ g

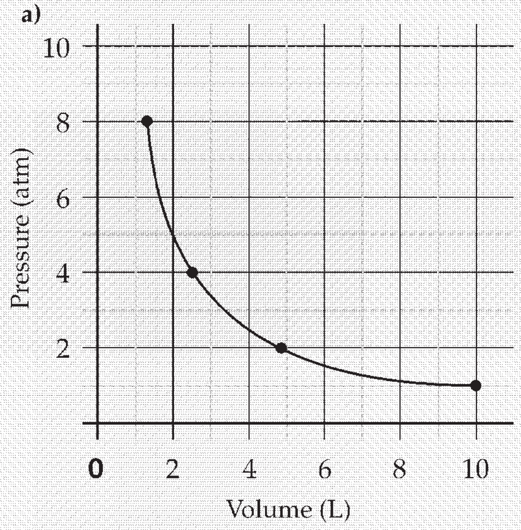
12.1 **a)** ii **b)** iii **c)** iii **d)** iii

12.2 **a)** There will be more molecules colliding with the walls of the tyre. Hence greater pressure.

b) At higher temperature the molecules will be moving faster. This means collisions with the walls of the tyre will be more forceful and more frequent.

Checkpoints Answers

12.3 a)



b) Pressure is inversely proportional to volume

c) P a 1/V or $PV = k$

d) Volume at 3.0 atm ≈ 3.3 L

12.4

$P_1 = 1.0$ atm

$V_1 = 20.0$ L

$P_2 = 7.5$ atm

$V_2 = ?$

$P_1V_1 = P_2V_2$

$\therefore V_2 = \dfrac{P_1V_1}{V_2} = \dfrac{(1.0)(20.0)}{7.5}$

$\therefore V_2 = 2.67$ L

12.5

$P_1 = 100$ kPa

$V_1 = 5.0$ L

$P_2 = ?$

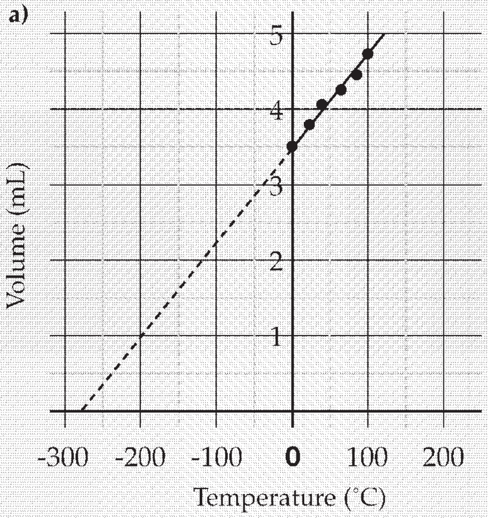
$V_2 = 4.0$ L

$P_1V_1 = P_2V_2$

$P_2 = \dfrac{P_1V_1}{V_2} = \dfrac{(100)(5.0)}{4.0}$

∴ New pressure = 125 kPa

12.6 a)



b) -273°C

c) Volume is directly proportional to Kelvin temperature.

d) V a T (K) or $\dfrac{V}{T\ (K)} = k$

12.7

$V_1 = 4.0$ L $T_1 = 35°C$ (308 K)

$V_2 = ?$ $T_2 = 20°C$ (293 K)

$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

$V_2 = \dfrac{V_1}{T_1} \times T_2 = \dfrac{(4.0)(293)}{308}$

$= 3.81$ L

12.8

$V_1 = 0.400$ L $T_1 = 25°C$ (298 K)

$V_2 = 0.300$ L $T_2 = ?$

$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

$T_2 = \dfrac{V_2}{V_1} \times T_1 = \dfrac{(0.300)(298)}{0.400}$

$= 223.5$ K $= -49.5°C$

Checkpoints Answers

12.9 $V_1 = 1.0\text{ L} \quad T_1 = ?$

$V_2 = 1.1\text{ L} \quad T_2 = 36°C\ (309K)$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_1 = \frac{V_1}{V_2} \times T_2 = \frac{(1.0)(309)}{1.1}$$

$$= 280.9\text{ K} = 7.9°C$$

12.10 a) $V_2 = \dfrac{P_1V_1}{T_1} \times \dfrac{T_2}{P_2}$

b) $P_2 = \dfrac{P_1V_1}{T_1} \times \dfrac{T_2}{V_2}$

c) $T_2 = \dfrac{P_2V_2}{P_1V_1} \times T_1$

d) $P_1 = \dfrac{P_2V_2}{T_2} \times \dfrac{T_1}{V_1}$

12.11 $P_1 = 102\text{ kPa} \quad V_1 = 240\text{ L}$

$P_2 = 54.0\text{ kPa} \quad V_2 = ?$

$T_1 = 15°C\ (288\text{ K}) \quad T_2 = -18°C\ (255\text{ K})$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \therefore V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

$$= \frac{(102)(240)(255)}{(288)(54)}$$

$\therefore$ New volume = 401 L

12.12 $P_1 = 16{,}500\text{ kPa} \quad V_1 = 4.5\text{ L}$

$P_2 = 101.3\text{ kPa} \quad V_2 = ?$

$T_1 = 15°C\ (288\text{ K}) \quad T_2 = 25°C\ (298\text{ K})$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \therefore V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

$$= \frac{(16{,}500)(4.5)(298)}{(288)(101.3)}$$

$\therefore$ New volume = 758 L

Sets Answers

Set 1: The Structure of the atom

1. a) helium b) magnesium
c) barium d) phosphorus
e) silicon f) cobalt
g) lithium h) nitrogen
i) iron j) mercury

2. a) Pb b) C c) Cl d) Cu
e) K f) Au g) Na h) Sn
i) I j) Cr

3. a) True
b) It may be true but more correct to say that in a neutral atom the number of protons equals the number of electrons.
c) False, mass of electron is 1/1836 that of a proton.
d) True
e) True
f) False, most of the mass is in the nucleus.
g) True
h) False, compounds have 2 or more elements chemically combined.

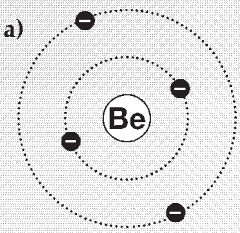
4. a) 2 protons, 2 neutrons and 2 electrons
b) 29 protons, 35 neutrons and 29 electrons
c) 18 protons, 22 neutrons and 18 electrons
d) 53 protons, 74 neutrons and 53 electrons
e) 79 protons, 118 neutrons and 79 electrons
f) 92 protons, 144 neutrons and 92 electrons

5. Co is the formula for the element cobalt, it indicates that cobalt is an element as it is composed of only one type of atom. CO represents the compound carbon dioxide, it is composed of 1 carbon atom joined to one oxygen atom.

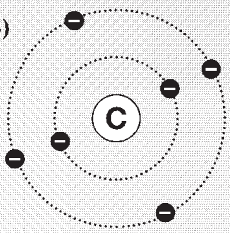
6. The two isotopes will have the same number of protons and electrons. They will have the same chemical properties. They have different numbers of neutrons and different masses.

Set 2: Electrons

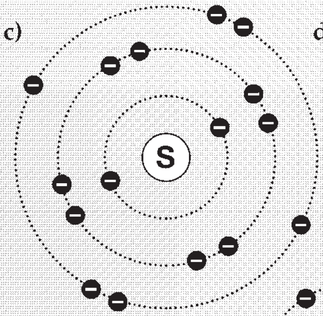
1. a)



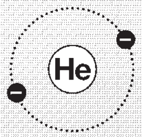
b)



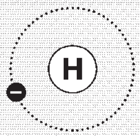
c)



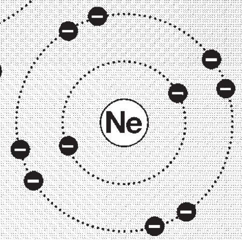
d)



e)



f)

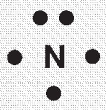


2. a) Li . . .2 1 b) B . . .2 3
c) Na . .2 8 1 d) F . . .2 7
e) Cl . . .2 8 7 f) Ca . .2 8 8 2

3. a) K 1 b) Si 4 c) N 5
d) Kr 8 e) Cs 1 f) Xe 8

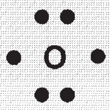
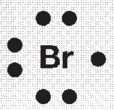
4. a) Li : lose 1 electron
b) F : gain 1 electron
c) Si : gain 4 electrons
d) Be : lose 2 electrons
e) O : gain 2 electrons
f) I : gain 1 electron

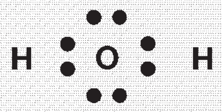
Sets Answers

5. a)  b) 

c)  d) 

e)  f) 

g)  h) 

6.  each hydrogen shares a pair of electrons with oxygen

Set 3: Valencies

1.

a) hydrogen	b) magnesium
c) copper (II)	d) iron (II)
e) aluminium	f) iron (III)
g) barium	h) zinc

2.

a) oxide	b) fluoride
c) nitride	d) sulfide
e) chloride	f) carbide
g) phosphide	h) iodide

3.

a) Ag^+	b) Cu^+	c) F^-
d) NH_4^+	e) SO_4^{2-}	f) Zn^{2+}
g) Ba^{2+}	h) PO_4^{3-}	i) NO_3^-
j) N^{3-}	k) O^{2-}	l) Fe^{3+}

4.

a) Cu^{2+} , Cl^-	b) Zn^{2+} , O^{2-}
c) Fe^{3+} , S^{2-}	d) Fe^{2+} , S^{2-}
e) Mg^{2+} , N^{3-}	f) Al^{3+} , Br^-

5. a) Al^{3+} , PO_4^{3-} b) Zn^{2+}, NO_3^-

c) Fe^{3+}, SO_4^{2-}

6. negative 2, $Cr_2O_7^{2-}$

Set 4: Bonding

1.

a) Zn – metal	e) N – non-metal
b) Se – non-metal	f) K – metal
c) I – non-metal	g) Kr – non-metal
d) W – metal	h) Ti – metal

2.

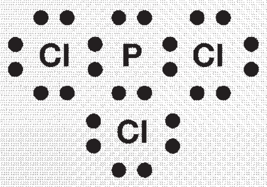
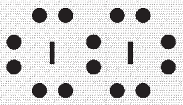
Fe	metal only	metallic
MgO	metal with non-metal	ionic
Al_2S_3	metal with non-metal	ionic
NH_3	non-metals only	covalent
OCl_2	non-metals only	covalent
BaI_2	metal with non-metal	ionic

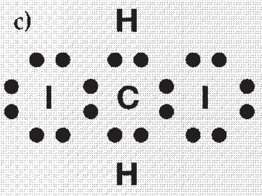
3.

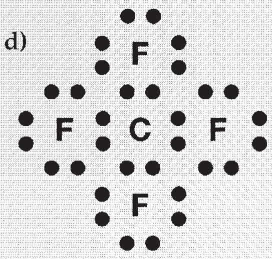
a) covalent	b) metallic	c) ionic
d) ionic	e) covalent	f) covalent
g) ionic	h) covalent	

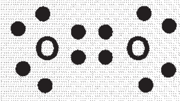
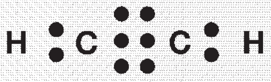
4.

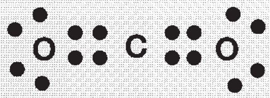
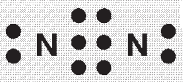
a) lost 3	b) gained 2	c) gained 1
d) lost 2	e) lost 4	f) gained 2
g) lost 3	h) gained 3	i) lost 1
j) gained 3		

5. a)  b) 

c) 

d) 

6. a)  b) 

c)  d) 

Sets Answers

Set 5: Writing formulae (I)

1. a) carbon dioxide b) hydrogen bromide
c) oxygen dichloride d) sulfur dioxide
e) carbon tetrachloride f) hydrogen iodide
g) diphosphorus pentaoxide
h) nitrogen tri iodide

2. a) CF_4 b) HCl c) SO_3
d) N_2O_4 e) NI_3 f) NH_3

3. a) +1 b) -1 c) +1 d) -3
e) -1 f) +3 g) -1 h) +1
i) -3 j) +3

4. a) zinc b) chloride
c) hydrogen sulfate d) silver
e) sulfate f) iron (III)
g) nitrite h) tin (IV)
i) lead (II) j) sulfide

5. a) CuO b) $FeCO_3$
c) $Mg(NO_3)_2$ d) $Zn(OH)_2$
e) $(NH_4)_2SO_4$ f) $SnCl_4$
g) AgCl h) Al_2S_3

6. a) P_4O_{10} b) OF_2 c) $Ca(HCO_3)_2$
d) Fe_2S_3 e) $Al_2(CO_3)_3$ f) $Ba_3(PO_4)_2$

Set 6: Writing formulae (II)

1. a) zinc sulfide
b) calcium hydrogensulfate
c) iron (III) nitrate
d) magnesium hydroxide
e) ammonium nitrate
f) aluminium oxide
g) copper (II) carbonate
h) chromium (III) chloride
i) aluminium sulfate
j) calcium ethanoate

2. a) carbon monoxide
b) ammonia
c) magnesium sulfide
d) water
e) iron (III) oxide
f) copper (II) nitrate
g) diphosphorus pentaoxide
h) aluminium chloride
i) barium sulfite
j) nitrogen dioxide

3. a) KOH b) $Al(OH)_3$ c) $Sn(NO_3)_4$
d) SO_2 e) CBr_4 f) Pb_3N_2

4. a) aluminium chloride b) $Zn(NO_3)_2$
c) $Fe(OH)_3$ d) correct
e) $MgBr_2$ f) $Al_2(SO_4)_3$

5. a) $Al_2(SO_3)_3$ b) $Cr_2(CO_3)_3$
c) $Pb(SO_4)_2$ d) Co_3N_2

6. a) NO_3 b) SiO_2
c) $Ba(HSO_4)_2$ d) Fe_2S_3
e) $Fe(CH_3COO)_3$ f) $(NH_4)_3PO_4$

Set 7: Balancing equations (I)

1. a) $2Na + 2H_2O \text{ -> } 2NaOH + H_2$
b) $Cu(NO_3)_2 + 2NaOH \text{ -> } Cu(OH)_2 + 2NaNO_3$
c) $CaCO_3 + 2HCl \text{ -> } CaCl_2 + CO_2 + H_2O$

2. a) $3Mg + N_2 \text{ -> } Mg_3N_2$
b) $3NaOH + H_3PO_4 \text{ -> } Na_3PO_4 + 3H_2O$
c) $Cu(OH)_2 + 2HCl \text{ -> } CuCl_2 + 2H_2O$

Sets Answers

3. a) $3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3H_2O + 3CO_2$
   b) $ZnO + H_2S \rightarrow ZnS + H_2O$
   c) $2H_2O_2 \rightarrow O_2 + 2H_2O$

4. a) $2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$
   b) $2Na_2O_2 + 2H_2O \rightarrow 4NaOH + O_2$
   c) $2Cr(OH)_3 + 3H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 6H_2O$

5. a) $Mg + 2HCl \rightarrow MgCl_2 + H_2$
   b) $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$
   c) $3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$

6. a) $MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$
   b) $2Al(OH)_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O$
   c) $Fe_2O_3 + 6HNO_3 \rightarrow 2Fe(NO_3)_3 + 3H_2O$

Set 8: Balancing equations (II)

1. a) $Na_2CO_3 + Ca(NO_3)_2 \rightarrow 2NaNO_3 + CaCO_3$
   b) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$
   c) $3ZnSO_4 + 2Al \rightarrow Al_2(SO_4)_3 + 3Zn$

2. a) $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$
   b) $4Al + 3O_2 \rightarrow 2Al_2O_3$
   c) $3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$

3. a) $3KHCO_3 + H_3PO_4 \rightarrow K_3PO_4 + 3H_2O + 3CO_2$
   b) $3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$
   c) $Pb(NO_3)_2 + 2NaI \rightarrow 2NaNO_3 + PbI_2$

4. a) $Cr_2(CO_3)_3 + 3H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3CO_2 + 3H_2O$
   b) $NaCH_3COO + HCl \rightarrow NaCl + CH_3COOH$
   c) $Ca(OH)_2 + 2CH_3COOH \rightarrow Ca(CH_3COO)_2 + 2H_2O$

5. a) $NH_4HCO_3 + HNO_3 \rightarrow NH_4NO_3 + CO_2 + H_2O$
   b) $KOH + HCl \rightarrow KCl + H_2O$
   c) $2H_2 + O_2 \rightarrow 2H_2O$

6. a) $2Fe + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2$
   b) $Fe_2O_3 + 6HNO_3 \rightarrow 2Fe(NO_3)_3 + 3H_2O$
   c) $Cu(OH)_2 + 2HCl \rightarrow CuCl_2 + H_2O$

Set 9 : Writing equations

1. a) acid + metal hydroxide -> salt + water
   b) acid + metal carbonate -> salt + water + carbon dioxide
   c) acid + metal oxide -> salt + water
   d) acid + metal hydrogencarbonate -> salt + water + carbon dioxide
   e) non-metal oxide + metal hydroxide -> salt + water

2. a) $3H_2SO_4 + 2Al(OH)_3 \rightarrow Al_2(SO_4)_3 + 6H_2O$
   b) $2HNO_3 + Ba(OH)_2 \rightarrow Ba(NO_3)_2 + 2H_2O$
   c) $2CH_3COOH + Mg(HCO_3)_2 \rightarrow Mg(CH_3COO)_2 + 2H_2O + 2CO_2$
   d) $SO_3 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

3. a) $2Fe(OH)_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 6H_2O$
   b) $2HCl + CaO \rightarrow CaCl_2 + H_2O$
   c) $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

4. a) $2HCl + FeCO_3 \rightarrow FeCl_2 + H_2O + CO_2$
   b) $2HNO_3 + Na_2O \rightarrow 2NaNO_3 + H_2O$
   c) $3H_2SO_4 + 2Cr(OH)_3 \rightarrow Cr_2(SO_4)_3 + 6H_2O$

5. a) $3HCl + Fe(OH)_3 \rightarrow FeCl_3 + 3H_2O$
   b) $2HNO_3 + BaCO_3 \rightarrow Ba(NO_3)_2 + H_2O + CO_2$
   c) $2CH_3COOH + Ca(OH)_2 \rightarrow Ca(CHCOO)_2 + 2H_2O$
   d) $H_2SO_4 + 2LiOH \rightarrow Li_2SO_4 + 2H_2O$
   e) $H_2CO_3 + Mg(OH)_2 \rightarrow MgCO_3 + 2H_2O$

Sets Answers

6. a) $2H_3PO_4 + Fe_2O_3 \rightarrow 2FePO_4 + 3H_2O$

b) $SO_3 + Ba(OH)_2 \rightarrow BaSO_4 + H_2O$

c) $P_2O_5 + 6NaOH \rightarrow 2Na_3PO_4 + 3H_2O$

d) $3H_2SO_4 + Fe_2(CO_3)_3 \rightarrow Fe_2(SO_4)_3 + 3H_2O + 3CO_2$

e) $3HCl + Cr(HCO_3)_3 \rightarrow CrCl_3 + 3H_2O + 3CO_2$

Set 10: Reactions involving metals

1. a) K, Al, Zn, Au b) Fe, Pb, Hg, Ag

c) Na, Ca, Ni, Cu

2. a) Cu or Hg b) Ag, Pt, or Au

c) K, Na or Ca d) Al, Zn, Fe, Ni, Sn or Pb

3. a) $Ca_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_{2(g)}$

b) $Fe_{(s)} + 2HCl_{(aq)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$

c) $Ag_{(s)} + H_2SO_{4(aq)} \rightarrow$ No Reaction

d) $2Na_{(s)} + H_2CO_{3(aq)} \rightarrow Na_2CO_{3(aq)} + H_{2(g)}$

4. a) $2Na_{(s)} + 2H_2O_{(g)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$

b) $Zn_{(s)} + H_2O_{(g)} \rightarrow ZnO_{(s)} + H_{2(g)}$

c) $Pt_{(s)} + H_2O_{(g)} \rightarrow$ No Reaction

d) $Mg_{(s)} + H_2O_{(g)} \rightarrow MgO_{(s)} + H_{2(g)}$

5. a) $4K_{(s)} + O_{2(g)} \rightarrow 2K_2O_{(s)}$

b) $Au_{(s)} + O_{2(g)} \rightarrow$ No Reaction

c) $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$

d) $2Cu_{(s)} + O_{2(g)} \rightarrow 2CuO_{(s)}$

6. a) Using the activity series the unknown metal lies somewhere between Zn and Cu. Metal may be Fe, Ni, Sn, Pb (Pb unlikely as not shiny).

b) Further tests with solutions of Ni and Sn would determine identity.

Set 11: Ionic Solutions

1. a) cation – Ca^{2+} , anion – OH^-

b) cation – Fe^{3+} , anion – CO_3^{2-}

c) cation – Al^{3+} , anion – PO_4^{3-}

d) cation – Cr^{3+} , anion – SO_4^{2-}

e) cation – Ba^{2+} , anion – NO_3^-

f) cation – Rb^+ , anion – CO_3^{2-}

2. a) cation – Ca^{2+} , anion – PO_4^{3-}

b) cation – Co^{2+} , anion – NO_3^-

c) cation – Ni^{2+} , anion – Br^-

3.	$AgNO_3$	$Cu(NO_3)_2$	$Fe(NO_3)_2$	$Ba(NO_3)_2$
K_2SO_4	Ag_2SO_4	Nil	Nil	$BaSO_4$
NaCl	AgCl	Nil	Nil	Nil
$(NH_4)_2CO_3$	Ag_2CO_3	$CuCO_3$	$FeCO_3$	$BaCO_3$
NaOH	AgOH	$Cu(OH)_2$	$Fe(OH)_2$	Nil

4. a) $Ni^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ni(OH)_{2(s)}$

b) $Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2(s)}$

c) $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

d) $Hg^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow HgI_{2(s)}$

5. a) $Ni^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow NiS_{(s)}$

b) $2Al^{3+}_{(aq)} + 3SO_4^{2-}{}_{(aq)} + 3Ba^{2+}_{(aq)} + 6OH^-_{(aq)} \rightarrow 3BaSO_{4(s)} + 2Al(OH)_{3(s)}$

c) $Ag^+_{(aq)} + Br^-_{(aq)} \rightarrow AgBr_{(s)}$

d) $Al^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Al(OH)_{3(s)}$

6. Add a small amount of each solution to different test tubes of sodium sulfate solution. No change would be noticed for the $NaNO_3$ and $FeCl_3$ solutions. However the $Ba(NO_3)_2$ solution would form the white precipitate $BaSO_4$.

Then add small amounts of $NaNO_3$ and $FeCl_3$ solutions to separate test tubes of KOH solution. The $NaNO_3$ will not react but the $FeCl_3$ solution will form a precipitate

Sets Answers

Set 12: Relative atomic mass

1. a) nitrogen, oxygen, neon

b) carbon, aluminium, chlorine

c) chromium, iron, zinc

2. a) titanium

b) krypton

c) iodine

3. a) 16.0/4.0 = 4

b) 107.9/10.8 ≈ 10

c) 12.0/1.0 = 12

4. argon (40) and calcium (40.1)

5. The presence of different isotopes for a particular element means that the average relative atomic mass for that element may not be a whole number e.g. chlorine has two isotopes, chlorine-35 (≈ 75%) and chlorine-37 (≈ 25%) giving an average A_r of 35.5.

6. Since we are dealing with *relative* masses the new definition suggested by the chemists would work equally as well. Also since $^1/_{16}$ of the mass of an oxygen-16 atom is the same as $^1/_{12}$ the mass of a carbon-12 atom, the relative masses of the elements as listed on Table 1 would not be affected.

Set 13: Relative molecular mass

1. a) M_r (N_2) = 28 d) M_r (SO_2) = 64.1

b) M_r (Cl_2) = 71 e) M_r (SO_3) = 80.1

c) M_r (CO_2) = 44 f) M_r (CH_4) = 16

2. a) M_r (NaCl) = 23.0 + 35.5= 58.5

b) M_r (CaO) = 40.1 + 16 = 56.1

c) M_r ($AlCl_3$) = 27.0 + (3 x 35.5) = 133.5

d) M_r (ZnS) = 65.4 + 32.1 = 97.5

e) M_r (MgO) = 24.3 + 16.0= 40.3

f) M_r (KOH)= 39.1 + 16.0 + 1.0 = 56.1

3. a) M_r ($Zn(NO_3)_2$)
= 65.4 + (2 x 14.0) + (6 x 16.0) = 189.4

b) M_r ($Al_2(SO_4)_3$)
= (2 x 27.0) + (3 x 32.1) + (12 x 16) = 342.3

c) M_r ($(NH_4)_2CO_3$)
= (2x14.0) + (8 x 1.0) + 12.0 + (3 x 16.0) = 96.0

d) M_r ($Mg(OH)_2$)
= 24.3 + (2 x 16.0) + (2 x 1.0) = 58.3

e) M_r ($CuCO_3$)
= 63.5 + 12.0 +(3 x 16.0) = 123.5

f) M_r (FeO) = 55.8 + 16.0 = 71.8

4. a) O_2 b) SO_2 c) I_2 d) SO_3

5. M_r (H_2O) = 18 , M_r (CO) = 28 ,
M_r (CH_3COOH) = 60, M_r (C_2H_5OH) = 46 ,
M_r (NH_3) = 17 , M_r (C_3H_8) = 44

a) 5 C atoms = 60 \ same as CH_3COOH

b) 17 H atoms = 17 \ same as NH_3

6. Not all substances are made up of molecules and so it would be incorrect to use the term relative *molecular* mass in all cases.
For substances such as ionic compounds (which are made up of an infinite array of ions) we refer to their relative *formula* mass.

Set 14: Percentage composition

1. a) M_r (SO_2) = 32.1 + (2 x 16.0) = 64.1
% S = (32.1 / 64.1) x 100 = 50.1%
% O = (32.0 / 64.1) x 100 = 49.9%

b) M_r (CO) = 12.0 + 16.0 = 28
% C = (12 / 28) x 100 = 42.9%
% O = (16 / 28) x 100 = 57.1%

c) M_r (NaCl) = 23.0 + 35.5= 58.5
% Na = (23 / 58.5) x 100 = 39.3%
% Cl = (35.5 / 58.5) x 100 = 60.7%

d) M_r ($Mg(OH)_2$)
= 24.3 + (2 x 16.0) + (2 x 1.0) = 58.3
% Mg = (24.3 / 58.3) x 100 = 41.7%
% O = (32.0 / 58.3) x 100 = 54.9%
% H = (2.0 / 58.3) x 100 = 3.4%

Sets Answers

e) M_r ($AgNO_3$)
= 107.9 + 14.0 + (3 x 16.0)= 169.9
% Ag = (107.9 / 169.9) x 100= 63.5%
% N = (14.0 / 169.9) x 100= 8.2%
% O = (48.0 / 169.9) x 100 = 28.3%

2. a) M_r (H_2O) = 18
∴ % H = (2 / 18) x 100 = 11.1%

b) M_r (C_3H_8) = 44
∴ % C = (36 / 44) x 100= 81.8%

c) M_r (Na_2SO_4) = 142.1
∴ % Na = (46 / 142.1) x 100 = 32.4%

d) M_r ($Pb(NO_3)_2$)= 331.2
∴ % Pb = (207.2 / 331.2) x 100= 62.6%

e) M_r ($(NH_4)_2CO_3$)= 96.0
∴ % C = (12.0 / 96.0) x 100 = 12.5%

3. a) M_r ($BaCl_2 . 2H_2O$) = 244.3
% H_2O = (36 / 244.3) x 100 = 14.7%

b) M_r ($CaSO_4 . 2H_2O$) = 172.2
% H_2O = (36 / 172.2) x 100 = 20.9%

c) M_r ($MgSO_4 . 7H_2O$) = 246.4
% H_2O = (126 / 246.4) x 100 = 51.1%

d) M_r ($Na_2CO_3 . 10H_2O$) = 286.0
% H_2O = (180 / 286) x 100 = 62.9%

e) M_r ($FeCl_3 . 6H_2O$) = 270.3
% H_2O = (108 / 270.3) x 100 = 40.0%

4. a) M_r (NH_3) = 17
% N = (14 / 17) x 100 = 82.4%

b) M_r (NH_4NO_3) = 80
% N = (28 / 80) x 100 = 35.0%

c) M_r ($(NH_4)_2SO_4$) = 132.1
% N = (28 / 132.1) x 100= 21.1%

d) M_r ($CO(NH_2)_2$) = 60
% N = (28 / 60) x 100 = 46.7%

5. a) M_r (Fe_2O_3) = 159.6
% Fe = (111.6 / 159.6) x 100 = 69.9%

b) M_r (Al_2O_3) = 102
% Al = (54 / 102) x 100 = 52.9%

c) M_r ($CuFeS_2$) = 183.5
% Cu = (63.5 / 183.5) x 100 = 34.6%

d) M_r ($CaCO_3$) = 100.1
% Ca = (40.1 / 100.1) x 100 = 40.1%

e) M_r (PbS) = 239.3
% Pb = (207.2 / 239.3) x 100 = 86.6%

6. M_r (Al_2O_3) = 102   % Al in alumina (Al_2O_3)
= (54/102) x 100 = 52.9%.
Since this bauxite ore contains 10% alumina then % Al in the ore = 10% of 52.9% ≈ 5.3%.

Set 15: Moles/particles

1. a) $6.02 \times 10^{23} / 6.02 \times 10^{23}$ = 1.0 mol

b) $2.41 \times 10^{24} / 6.02 \times 10^{23}$ = 4.0 mol

c) $3.01 \times 10^{24} / 6.02 \times 10^{23}$ = 5.0 mol

d) $1.20 \times 10^{25} / 6.02 \times 10^{23}$ = 19.9 mol

2. a) $(0.25)(6.02 \times 10^{23})$ = 1.5×10^{23} Ag atoms

b) $(2.0)(6.02 \times 10^{23})$ = 1.2×10^{24} Pb atoms

c) $(0.05)(6.02 \times 10^{23})$ = 3.01×10^{22} CO molecules

d) $(20)(6.02 \times 10^{23})$ = 1.2×10^{25} NH_3 molecules

3. a) $(2.5)(6.02 \times 10^{23}) = 1.5 \times 10^{24}$ N_2 molecules

b) $(2.5)(6.02 \times 10^{23})(2) = 3.01 \times 10^{24}$ N atoms

c) $(0.40)(6.02 \times 10^{23})(4) = 9.63 \times 10^{23}$ H atoms

d) $(6.25)(6.02 \times 10^{23})(7) = 2.63 \times 10^{25}$ atoms in all

4. a) sodium atoms are heavier

b) mass of Na atoms / mass C atom
= 46.0 / 24.0 = 1.92

5. a) 2 mol H_2 –> 4 mol H atoms

b) 6 mol Zn –> 6 mol Zn atoms

c) 2 mol NH_3 –> 8 mol atoms

d) 1 mol NH_4OH –> 7 mol atoms

The greatest number of atoms is contained in 2 mol of NH_3 gas.

6. 1 billion = $1,000,000,000
∴ n ($) = $1.0 \times 10^6 / 6.02 \times 10^{23} \approx 1.66 \times 10^{-18}$ mol

Sets Answers

Set 16: Molar mass

1. a) M (Na) = 23.0 g mol^{-1}

b) M (NaCl) = 58.5 g mol^{-1}

c) M (N_2) = 28.0 g mol^{-1}

d) M (SO_2) = 64.1 g mol^{-1}

2. a) M (NaOH) = 23.0 + 16.0 + 1.0 = 40.0 g mol^{-1}

b) M ($ZnCO_3$) = 65.4 + 12.0 + (16.0 x 3)
= 125.4 g mol^{-1}

c) M (PbO) = 207.2 + 16.0 = 223.2 g mol^{-1}

d) M ($MgCl_2$) = 24.3 + (35.5 x 2) = 95.3 g mol^{-1}

3. a) M ($Al_2(SO_4)_3$)
= (27.0 x 2) + (32.1 x 3) + (16.0 x 12)
= 342.3 g mol^{-1}

b) M ($Mg(HCO_3)_2$)
= 24.3 + (1.0 x 2) + (12.0 x 2) + (16.0 x 6)
= 146.3 g mol^{-1}

c) M (P_4O_{10}) = (31.0 x 4) + (16.0 x 10)
= 284 g mol^{-1}

d) M ($Na_2CO_3 . 10H_2O$)
= (23.0 x 2) + 12.0 + (16.0 x 3) + (18.0 x 10)
= 286 g mol^{-1}

4. a) A_r compares the mass of an **atom** to that of ($^1/_{12}$ of a carbon-12 atom), while M_r compares the mass of a **molecule**.

b) M_r is a relative measurement (i.e. no units) whereas molar mass (M) is the mass of 1 mole of a substance (M is M_r expressed in grams).

5. a) A_r (O) = 16.0

b) A_r (O_2) = 32.0

c) M (O_2) = 32.0 g mol^{-1}

6. a) M_r (X_2) = 2 x 14 = 28
∴ M = 28 g mol^{-1}

b) M_r (Y_2) = 2 x 19 = 38
∴ M (Y_2) = 38 g mol

c) M_r (XY_3) = 14 + (3 x 19) = 71 g mol^{-1}

Set 17: Mass to moles

1. a) n (Ca) = 80.2 / 40.1 = 2.0 mol

b) n (CO_2) = 8.8 / 44.0 = 0.20 mol

c) n (HCl) = 10.0 / 36.5 = 0.274 mol

d) n (C_2H_5OH) = 25.0 / 46.0 = 0.54 mol

2. a) n (H_2) = 20.0 / 2.0 = 10 mol

b) n (H) = 2 x 20.0 / 2.0 = 20 mol

c) n (NH_3) = 20.0 / 17.0 = 1.176 mol
∴ n (H) = (3) (1.176) = 3.53 mol

d) n (C_2H_2) = 20 / 26 = 0.769 mol
∴ n (H) = (0.769) (2) = 1.54 mol

3. a) n (AgCl) = 125 / 143.4 = 0.872 mol

b) n ($Al(NO_3)_3$) = 4.5 / 213 = 0.021 mol

c) n ($(NH_4)_2CO_3$) = 25.0 / 96 = 0.26 mol

d) n (KOH) = 240 / 56.1 = 4.28 mol

4. a) n (CO_2) = 2.20 / 44.0 = 0.05 CO_2 molecules

b) n (C) = n (CO_2) = 0.05 mol

c) n (O) = 2 x n (CO_2) = 0.10 mol

5. a) n ($Cu(NO_3)_2$) = 20.0/187.5 = 0.107 mol

b) n (Cu^{+2} ions) = n ($Cu(NO_3)_2$) = 0.107 mol

c) n (NO_3^- ions) = 2 x n ($Cu(NO_3)_2$) = 0.214 mol

d) n (O atoms) = 6 x n ($Cu(NO_3)_2$) = 0.642 mol

6. M ($C_{12}H_{22}O_{11}$)

= (12 x 12.0) + (22 x 1.0) + (11 x 16.0)

= 342 g mol^{-1}

∴ n ($C_{12}H_{22}O_{11}$) = 30.0 / 342 = 0.0877 mol

∴ n (O) = (11)(0.0877) = 0.965 mol of O atoms also

M (H_2O) = 18 g / mol^{-1}

n (H_2O) = 100 / 18 = 5.55 mol

n (O) = (1)(5.55) = 5.55 mol of O atoms

Hence the 100 g of water contains more atoms of oxygen than the 30 g of sugar.

Sets — Answers

Set 18 – Moles to mass

1. **a)** M (H_2O) = (2 x 1.0) + 16.0 = 18 g mol^{-1}
i.e. mass of 1 mol of H_2O = 18 g

b) M (O) = 16.0 g mol^{-1}
i.e. mass of 1 mol of O atoms = 16.0 g

c) M (CO_2) = 12.0 + (2 x 16.0) = 44.0 g mol^{-1}
i.e. mass of 1 mol of CO_2 molecules = 44.0 g

d) M (P) = 31.0 g mol^{-1}
i.e. mass of 1 mol of P atoms = 31.0 g

2. **a)** M (NaOH) = 40.0 g mol
m (NaOH) = n . M = (1.25)(40.0) = 50.0 g

b) m (Zn) = n . M = (0.25)(65.4) = 16.35 g

c) M ($Pb(NO_3)_2$) = 207.2 + (2 x 14.0) + (6 x 16.0)
= 331.2 g mol^{-1}
m ($Pb(NO_3)_2$) = n. M = (20.0)(331.2) = 6624 g

d) M (C_8H_{18}) = (8 x 12.0) + (18 x 1.0)
= 114 g mol^{-1}
m (C_8H_{18}) = n . M = (3.5)(114) = 399 g

3. **a)** M ($CuSO_4$) = 63.5 + 32.1 + (4 x 16.0)
= 159.6 g mol^{-1}
m = n . M = (0.025)(159.6)= 3.99 g

b) M ($AgNO_3$) = 107.9 + 14.0 + (3 x 16.0)
= 169.9 g mol^{-1}
m = n . M = (0.025)(169.9) = 4.23 g

c) M (NH_4Cl) = 14 + (4 x 1.0) + 35.5
= 53.5 g mol^{-1}
m = n . M = (15.0)(53.5) = 802.5 g

d) M ($(NH_4)_2SO_4$)
= (2 x 14.0) + (8 x 1.0) + 32.1 + (4 x 16.0)
= 132.1 g mol^{-1}
m = n . M = (15.0)(132.1) = 1982 g

4. **a)** 1 mol Cl_2 (71.0 g) > 1 mol SO_2 (64.1 g)

b) 1 mol HCl (36.5 g) > 2 mol NH_3 (34.0 g)

c) 1 mol PbO (223.2 g) > 1.5 mol $ZnCO_3$ (188.1 g)

d) 3.0 mol $NaHCO_3$ (252.0 g)
> 1.0 mol $Mg(HSO_4)_2$ (218.2 g)

5. **a)** M ($Al_2(SO_4)_3$)
= (2 x 27.0) + (3 x 32.1) + (12 x 16.0)
= 342.3 g mol^{-1}
m = n . M = (0.60)(342.3) = 205.4 g

b) M ($(NH_4)_2CO_3$)
= (2 x 14.0) + (8 x 1.0) + 12.0 + (3 x 16.0)
= 96 g mol^{-1}
m = n . M = (1.25)(96) = 120 g

c) M ($KHCO_3$) = 39.1 + 1.0 + 12.0 + (3 x 16.0)
= 100.1 g mol^{-1}
m = n . M = (0.55)(100.1) = 55.1 g

d) M ($Na_2CO_3 . 10H_2O$)
= (2 x 23.0) + 12.0 + (3 x 16.0) + (10 x 18.0)
= 286 g mol^{-1}
m = n . M = (3.20)(286) = 915.2 g

6. **a)** H_2 (2.0 g mol^{-1}) , NH_3 (17.0 g mol^{-1}) ,
CO (28.0 g mol^{-1}) , N_2 (28.0 g mol^{-1}) ,
O_2 (32.0 g mol^{-1}) , CO_2 (44.0 g mol^{-1}) ,
SO_2 (64.0 g mol^{-1}) , Cl_2 (71.0 g mol^{-1})

Set 19: Moles - constituents

1. **a)** 1 mol H_2 gas contains 2 mol of H atoms

b) 1 mol H_2SO_4 acid contains 2 mol of H atoms

c) 1 mol CH_3COOH acid contains 4 mol of H atoms

d) 1 mol $C_6H_{12}O_6$ contains 12 mol of H atoms

2. **a)** 5.0 mol SO_2 contains 10.0 mol of O atoms

b) 15.0 mol of $C_{12}H_{22}O_{11}$ contains 165.0 mol of O atoms

c) 1.25 mol of $Ba(NO_3)_2$ contains 7.5 mol of O atoms

d) 0.02 mol of $MgSO_4 . 7H_2O$ contains 0.22 mol of O atoms

3. **a)** 2.25 mol of CO_2 contains:
2.25 mol of C and 4.5 mol of O

b) 3.40 mol of HNO_3 contains:
3.40 mol of H, 3.40 mol of N and
10.2 mol of O

c) 0.50 mol of Na_2SO_4 contains:
1.0 mol of Na, 0.050 mol of S and 2.0 mol of O

d) 4.0 mol of $Ca(HCO_3)_2$ contains:
4.0 mol of Ca, 8.0 mol of H, 8.0 mol of C and 24.0 mol of O

Sets Answers

4. **a)** n (H_2O) = m / M = 50 / 18 = 2.78 mol
∴ n (O) = 2.78 mol

b) n (H_2SO_4) = m / M
= 2.50 / (2.0 + 32.1 + 64) = 0.0255 mol
∴ n (O) = (4)(0.0255) = 0.102 mol

c) n (Al_2O_3) = m / M
= (1000 x 1000) / (54.0 + 48.0) = 9804 mol
∴ n (O) = (3)(9804)= 29412 mol

d) n ($(NH_4)_2CO_3$) = m / M
= 100 / (28.0 + 8.0 + 12.0 + 48.0) = 1.04 mol
∴ n (O) = (3)(1.04)= 3.12 mol

5. **a)** n (NaCl) = m / M = 60.0 / (23.0 + 35.5)
= 1.03 mol
∴ n (Na^+) = 1.03 mol
∴ n (Cl^-) = 1.03 mol

b) n $(NH_4)_2SO_4$ = m / M
= 2.25 / (28.0 + 8.0 + 32.1 + 64.0) = 0.0170 mol
∴ n (NH_4^+) = (2)(0.0170) = 0.0340 mol
∴ n (SO_4^{2-}) = 0.0170 mol

c) n ($Pb(NO_3)_2$) = m / M
= 200.0 / (207.2 + 28.0 + 96.0) = 0.604 mol
∴ n (Pb^{2+}) = 0.604 mol
∴ n (NO_3^-) = 1.21 mol

d) n (Fe_2O_3) = m / M
= 10.0 / (111.6 + 48.0) = 0.0627 mol
∴ n (Fe^{3+}) = (2)(0.0627) = 0.125 mol
∴ n (O^{2-}) = (3)(0.0627) = 0.188 mol

6. Mass of ethanoic acid in 50.0g vinegar is 6% of 50g.
∴ m (CH_3COOH) = (6 / 100)(50) = 3.0 g

a) ∴ n (CH_3COOH)
= m / M = 3.0 / (24.0 + 4.0 + 32.0)
= 0.050 mol

b) ∴ n (C) atoms = (2)(0.050 mol) = 0.10 mol
∴ m (C) atoms = (n)(m) = (0.10)(12.0) = 1.2 g

Set 20: Moles – mass/particles

1. **a)** n (Ag) = m / M = 10.0 / 107.9 = 0.0927 mol
∴ N (Ag) = (0.0927)(6.02 x 10^{23})
= 5.58 x 10^{22} atoms

b) n (Al) = m / M = 10.0 / 27.0 = 0.370 mol
∴ N (Al) = (0.370)(6.02 x 10^{23})
= 2.23 x 10^{23} atoms

c) n (H_2O) = m / M = 20.0 / 18.0 = 1.11 mol
∴ total n (of atoms) = (3)(1.11) = 3.33 mol
∴ total N (of atoms) = (3.33)(6.02 x 10^{23})
= 2.01 x 10^{24} atoms

d) n (CH_3COOH) = m / M
= 20.0 / 60.0 = 0.333 mol
∴ total n (of atoms) = (8)(0.333) = 2.67 mol
∴ total N (of atoms) = (2.67)(6.02 x 10^{23})
= 1.61 x 10^{24} atoms

2. **a)** n (Cl_2) = m / M = 71.0 / (2 x 35.5)= 1.0 mol
∴ N (Cl_2) = 6.02 x 10^{23} molecules

b) n (NH_3) = m / M = 30.0 / 17.0 = 1.76 mol
∴ N (NH_3) = 1.76 x 6.02 x 10^{23}
= 1.06 x 10^{24} molecules

c) n (H_2) = m / M = 6.0 / 2.0 = 3.0 mol
∴ N (H_2) = (3)(6.02 x 10^{23})
= 1.81 x 10^{24} molecules

d) n (CO) = m / M = 40.0 / 28.0 = 1.43 mol
∴ N (CO) = (1.43)(6.02 x 10^{23})
= 8.60 x 10^{23} molecules

3. **a)** n ($CaCO_3$) = m / M
= 125.0 / (40.1 + 12.0 + 48.0)
= 1.249 mol
∴ total n (of atoms) = (5)(1.249) = 6.24 mol
∴ total N (of atoms)= (6.24)(6.02 x 10^{23})
= 3.76 x 10^{24} atoms

b) n ($CuSO_4$) = m / M
= 10.6 / (63.5 + 32.1 + 64.0)
= 0.0664 mol
∴ total n (of atoms) = (6)(0.0664) = 0.398 mol
∴ total N (of atoms)= (0.398)(6.02 x 10^{23})
= 2.40 x 10^{23} atoms

c) n (NH_4NO_3) = m / M
= 22.5 / (28.0 + 4.0 + 48.0)
= 0.281 mol
∴ total n (of atoms) = (9)(0.281) = 2.53 mol
∴ total N (of atoms)= (2.53)(6.02 x 10^{23})
= 1.52 x 10^{24} atoms

d) n (NaOH) = m / M
= 84.0 / (23.0 + 16.0 + 1.0) = 2.10 mol
∴ total n (of atoms) = (3)(2.10) = 6.30 mol
∴ total N (of atoms) = (6.30)(6.02 x 10^{23})
= 3.79 x 10^{24} atoms

Sets — Answers

4. **a)** n (HCl) = m / M = 17.6 / 36.5 = 0.482 mol
∴ n (Cl) = 0.482 mol
∴ N (Cl) = $(0.482)(6.02 \times 10^{23})$
= 2.90×10^{23} atoms

b) n ($PbSO_4$) = m / M
= 155.0 / (207.2 + 32.1 + 64.0)
= 0.511 mol
∴ n (Pb) = 0.511 mol
∴ N (Pb) = $(0.511)(6.02 \times 10^{23})$
= 3.08×10^{23} atoms

c) n ($MgCO_3$) = m / M
= 22.2 / (24.3 + 12.0 + 48.0)
= 0.263 mol
∴ n (O) = (3)(0.263) = 0.790 mol
∴ N (O) = $(0.790)(6.02 \times 10^{23})$
= 4.77×10^{23} atoms

d) n ($Cu(NO_3)_2$) = m / M
= 6.8 / (63.5 + 28.0 + 96.0)
= 0.0363 mol
∴ n (O) = (6)(0.0363) = 0.218 mol
∴ N (O) = $(0.218)(6.02 \times 10^{23})$
= 1.31×10^{23} atoms

5. **a)** n (SO_2) = $6.02 \times 10^{23} / 6.02 \times 10^{23}$
= 1.0 mol
∴ m (SO_2) = n . M = (1.0)(32.1 + 32.0)
= 64.1 g

b) n (Zn) = $3.01 \times 10^{24} / 6.02 \times 10^{23}$ = 5.0 mol
∴ m (Zn) = n . M = (5.0)(65.4) = 327 g

c) n (C_8H_{18}) = $2.60 \times 10^{22} / 6.02 \times 10^{23}$
= 0.0432 mol
∴ m (C_8H_{18}) = n . M = (0.0432)(96.0 + 18.0)
= 4.92 g

d) n (Ca^{2+}) = 4.5 x 1024/6.02×10^{23} = 7.475 mol
n (OH^-) = $9.0 \times 10^{24} / 6.02 \times 10^{23}$ = 14.95 mol
i.e. 7.475 mol of $Ca(OH)_2$
∴ m ($Ca(OH)_2$) = n . M
= (7.475)(40.1 + 32.0 + 2.0) = 554 g
OR m (Ca^{2+}) = (7.475)(40.1) = 299.8 g
m (OH^-) = (14.95)(17.0) = 254.2 g
total = 554 g

6. n (S) = $2.0 \times 10^{24} / 6.02 \times 10^{23}$ = 3.32 mol
since 1 mole of H_2SO_4 contains 1 mole of sulfur
n (H_2SO_4) = 3.32 mol
m (H_2SO_4) = (3.32)(98.1) = 325.9 g

Set 21: Equations – mole/mole

1. $CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$
1 mol $CH_{4\,(g)}$ gives 1 mol $CO_{2\,(g)}$

2. n(O_2) / n (MgO) = $^1/_2$
∴ n (O_2) = ($^1/_2$) (5.0)
= 2.5 mol

3. n (HCl) / n (Zn) = $^2/_1$
∴ n (HCl) = (2) (0.15)
= 0.30 mol

4. n ($NaNO_3$) / n (Na_2CO_3) = $^2/_1$
∴ n (Na_2CO_3) = (2) (0.05)
= 0.10 mol

5. n ($KClO_3$) / n (O_2) = $^2/_3$
∴ n ($KClO_3$) = ($^2/_3$) (4.5)
= 3.0 mol

6. From the equation we can see that for every mole of $CaCO_3$ we need two moles of HCl. Hence since we have equal amounts of these reactants it means that the HCl will be the limiting reagent (i.e. will run out first). Hence consider only HCl for calculating amount of CO_2 produced.

n (CO_2) / n (HCl) = $^1/_2$
∴ n (CO_2) = ($^1/_2$) (5.0)
= 2.5 mol

Set 22: Equations – mole/mass

1. $2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$
n (H_2O) / n (H_2) = $^2/_2$ = 1
∴ n (H_2O) produced = (1) (1.0) = 1.0 mol
∴ m (H_2O) produced = (1.0) (18.0) = 18.0 g

2. n (Hg) / n (HgO) = $^2/_2$ = 1
∴ n (Hg) produced = (1)(0.55) = 0.55 mol
∴ m (Hg) produced = (0.55)(200.6) = 110.3 g

3. n (NaCl) / n ($AgNO_3$) = $^1/_1$ = 1
∴ n (NaCl) required = (1) (12.0) = 12.0 mol
∴ m (NaCl) required = (12.0) (58.5) = 702 g

Sets Answers

4. n (CuO) / n ($CuCO_3$) = $^1/_1$ = 1
n (CO_2) / n ($CuCO_3$) = $^1/_1$ = 1
∴ n (CuO) produced = (1) (0.40) = 0.40 mol
∴ m (CuO) produced = (0.40) (79.5) = 31.8 also
∴ n (CO_2) produced = (1) (0.40) = 0.40 mol
∴ m (CO_2) produced = (0.40) (44) = 17.6 g

5. $C_3H_8 + 5O_{2\,(g)}$ -> $3CO_{2\,(g)} + 4H_2O_{(g)}$
n (CO_2) / n (C_3H_8) = $^3/_1$ = 3
∴ n (CO_2) produced = (3) (1.5) = 4.5 mol
∴ m (CO_2) produced = (4.5) (44) = 198 g

6. n (CO_2) / n (C_8H_{18}) = $^{16}/_2$ = 8
∴ n (CO_2) produced = (8) (10.0) = 80.0 mol
∴ m (CO_2) produced = (80) (44) = 3520 g
n (H_2O) / n (C_8H_{18}) = $^{18}/_2$ = 9
∴ n (H_2O) produced = (9) (10.0) = 90.0 mol
∴ m (H_2O) produced = (90.0) (18.0) = 1620 g
∴ total mass of gases = 5140 g

Set 23: Equations – mass/mole

1. $2H_{2\,(g)} + O_{2\,(g)}$ -> $2H_2O_{(g)}$
n (H_2O) / n (H_2) = $^2/_2$ = 1
n (H_2) available = m/M = $^1/_2$ = 0.5 mol
∴ n (H_2O) produced = (1)(0.5) = 0.5 mol

2. n (HCl) / n (Mg) = $^2/_1$ = 2
n (Mg) available = m/M = ($^{4.86}/_{24.3}$)
= 0.20 mol
∴ n (HCl) produced = (2) (0.20) = 0.40 mol

3. n (H_2SO_4) / n ($(NH_4)_2SO_4$) = $^1/_1$ = 1
n ($(NH_4)_2SO_4$) produced = m/M = ($^{80.0}/_{132.1}$)
= 0.606 mol
∴ n (H_2SO_4) required = (1) (0.606)
= 0.606 mol

4. n (CO_2) / n ($CuCO_3$) = $^1/_1$ = 1
n ($CuCO_3$) reacted = m/M = ($^{2.4}/_{123.5}$)
= 0.0194 mol
∴ n (CO_2) produced = (1) (0.0194)
= 0.0194 mol

5. n (Mg) / n (Mg_3N_2) = $^1/_1$ = 3
n (Mg_3N_2) required = m/M = ($^{1.56}/_{100.9}$)
= 0.0155 mol
∴ n (Mg) needed = (3)(0.0155)
= 0.0465 mol

6. n (CO_2) / n (C_4H_{10}) = $^8/_2$ = 4
n (H_2O) / n (C_4H_{10}) = $^{10}/_2$ = 5
n (C_4H_{10}) reacted = m / M = ($^{0.50}/_{58.0}$)
= 8.62 x 10^{-3} mol
∴ n (CO_2) produced = (4)(8.62 x 10^{-3})
= 0.035 mol
n (H_2O) produced = (5)(8.62 x 10^{-3}) mol
= 0.043 mol
∴ total moles gaseous products = 0.078 mol

Set 24: Equations – mass/mass

1. $2H_{2\,(g)} + O_{2\,(g)}$ -> $2H_2O_{(g)}$
n (H_2O) / n (H_2) = $^2/_2$ = 1
n (H_2) reacted = m / M = ($^1/_2$)
= 0.5 mol
∴ n (H_2O) produced = (1) (0.5) = 0.5 mol
∴ m (H_2O) produced = (0.5) (18.0) = 9.0 g

2. n (Ag) / n (Cu) = $^2/_1$ = 2
n (Cu) reacted = m / M = ($^{6.35}/_{63.5}$)
= 0.10 mol
∴ n (Ag) produced = (2) (0.10) = 0.20 mol
∴ m (Ag) produced = (0.20) (107.9) = 21.6 g

3. n(NaOH)/n(Na_2O_2) = $^4/_2$ = 2
n (O_2) / n (Na_2O_2) = $^1/_2$ = 0.5
n (Na_2O_2) reacted = m / M = ($^{25.0}/_{78.9}$)
= 0.32 mol
∴ n (NaOH) produced = (2) (0.32) = 0.64 mol
∴ m (NaOH) produced = (0.64) (40) = 25.6 g
also n (O_2) produced = (0.5) (0.32) = 0.16 mol
∴ m (O_2) produced = (0.16) (32.0) = 5.12 g

4. n (PbI_2) / n ($Pb(NO_3)_2$) = $^1/_1$ = 1
n ($Pb(NO_3)_2$) reacted = m/M = ($^{7.50}/_{331.2}$)
= 0.0226 mol
∴ m (PbI_2) produced = (0.0226)(461.0)
= 10.4 g

Sets — Answers

5. $n(HNO_3) / n(Ca(OH)_2) = {}^2/_1 = 2$

$n(Ca(OH)_2)$ reacted $= m/M = ({}^{50.0}/_{74.1}) = 0.675$ mol

$\therefore n(HNO_3)$ required $= (2)(0.675) = 1.35$ mol

$\therefore m(HNO_3)$ required $= (1.35)(63.0) = 85.0$ g

6. a) $Ca_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_{2\,(g)}$

b) $n(Ca)$ available $= m / M = ({}^{4.0}/_{40.1}) = 0.10$ mol

$n(HCl)$ available $= m / M = ({}^{4.0}/_{36.5}) = 0.11$ mol

i) From the equation we can see that for every mole of calcium that reacts two moles of hydrochloric acid are required. Hence there is insufficient hydrochloric acid to consume all the calcium. (i.e. HCl will be completely used up)

ii) $n(H_2) / n(HCl) = {}^1/_2 = 0.5$ mol

$\therefore n(H_2)$ produced $= (0.5)(0.11) = 0.055$ mol

$\therefore m(H_2)$ produced $= (0.055)(2.0) = 0.11$ g

Set 25: Molar volume

1. a) $n(He) = V/22.4 = 11.2/22.4 = 0.50$ mol

b) $n(Cl_2) = V/22.4 = 0.560/22.4 = 0.025$ mol

c) $n(CO_2) = V/22.4 = 200/22.4 = 8.90$ mol

d) $n(CH_4) = V/22.4 = 384/22.4 = 17.1$ mol

2. a) $V(SO_2) = (2.0)(22.4) = 44.8$ L

b) $V(NH_3) = (0.15)(22.4) = 3.36$ L

c) $V(O_2) = (125)(22.4) = 2800$ L

d) $V(C_4H_{10}) = (0.042)(22.4) = 0.941$ L

3. a) $n(H_2) = m/M = 24.0/2.0 = 12.0$ mol

$V(H_2) = (12.0)(22.4) = 268.8$ L

b) $n(O_2) = m/M = 200/32 = 6.25$ mol

$V(O_2) = (6.25)(22.4) = 140$ L

c) $n(SO_2) = m/M = 1.25/64.1 = 0.0195$ mol

$V(SO_2) = (0.0195)(22.4) = 0.437$ L

d) $n(CO) = m/M = 60.0/28.0 = 1.75$ mol

$V(CO) = (0.0195)(22.4) = 0.437$ L

4. a) $n(O_2) = m/M = 20/22.4 = 0.893$ mol

$\therefore m(O_2) = (0.893)(32.0) = 28.6$ g

b) $n(Cl_2) = V/22.4 = 20.0/22.4 = 0.893$ mol

$\therefore m(Cl_2) = (0.893)(71.0) = 63.4$ g

c) $n(CO_2) = V/22.4 = 0.560/22.4 = 0.025$ mol

$\therefore m(CO_2) = (0.025)(44.0) = 1.10$ g

d) $n(NH_3) = V/22.4 = 3500/22.4 = 156.25$ mol

$\therefore m(NH_3) = (156.25)(17.0) = 2656$ g

5. a) Gas jar B contains the greatest number of molecules (Avogadro's hypothesis: equal volumes of gases contain equal number of particles).

b) Gas jar A contains greatest mass of gas.

6. $n(N_2) = V/22.4 = 0.780/22.4 = 0.0348$ mol

$\therefore m(N_2) = (0.0348)(28.0) = 0.975$ g, similarly

$n(O_2) = 0.210/22.4 = 9.37 \times 10^{-3}$ mol

$\therefore m(O_2) = (9.37 \times 10\text{-}3)(32.0) = 0.300$ g

$n(Ar) = 0.010/22.4 = 4.46 \times 10^{-4}$ mol

$\therefore m(Ar) = (4.46 \times 10^{-4})(40.0) = 0.018$ g

$\therefore$ mass of 1 L of dry air $\approx$ 1.293 g

Set 26: Equations - volume /volume

1. $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$

1 vol 1 vol

$vol(CO_2) / vol(O_2) = 1/1 = 1$

$vol(O_2)$ consumed = 50 L

$\therefore vol(CO_2)$ produced = (1)(50) = 50 L

2. a) $vol(CO) / vol(CO_2) = 2/2 = 1$

$\therefore vol(CO)$ consumed = (1)(0.060) = 0.060 L = 60 mL

Sets Answers

b) vol (O_2) / vol (CO_2) = 1/2 = 0.5

∴ vol (O_2) consumed = (0.5)(0.060) = 0.030 L

= 30 mL

3. a) $2H_2O_{(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$
2 vol   1 vol

b) vol (O_2) / vol (H_2) = 1/2 = 0.5

vol (O_2) produced = (0.5)(0.125) = 0.0625 L

= 62.5 mL

4. $H_{2\,(g)} + Cl_{2\,(g)} \rightarrow 2HCl_{(g)}$
1 vol   1 vol   2 vol

vol (HCl) / vol (H_2) = 2/1 = 2

∴ vol (HCl) produced = (2)(0.450) = 0.900 L

= 900 mL

5. a) From the equation we can see that 1 volume of methane combines with 2 volumes of oxygen. Since there are 200 mL of each of these gases initially, the oxygen gas will be completely consumed (limiting reagent).

b) consider limiting reagent only (O_2)
200 mL (O_2) gives 100 mL $CO_{2(g)}$
also gives 200 mL H_2O(g)

∴ total vol gases produced = 300 mL

c) vol (CH_4) / vol (O_2) = 1/2 = 0.5

∴ vol (CH_4) consumed = (0.5)(0.20)

= 0.1 L (100 mL)

Hence total vol gases remaining after reaction

= 300 mL (products) + 100 mL (unreacted)

= 400 mL

6. a) $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$
1 vol   5 vol   3 vol   4 vol

$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)}$
2 vol   5 vol   4 vol   2 vol

b) for C_3H_8(g)
vol (products) / vol (reactants) = 7/6 = 1.17

for C_2H_2(g)
vol (products) / vol (reactants) = 6/7 = 0.86

∴ propane gas creates the greatest increase in volume

Set 27: Equations - mass/volume

1. $CaCO_{3\,(s)} \rightarrow CaO_{(l)} + CO_{2\,(g)}$
500 g   x (L)

n (CO_2) / n ($CaCO_3$) = 1/1 = 1

n ($CaCO_3$) available = m /M = 500/100.1
= 5.0 mol

∴ n (CO_2) produced = (1)(5.0) = 5.0 mol

∴ V (CO_2) produced = (5.0)(22.4) = 112 L

2. n (K) / n (H_2) = 2/1 = 2

n (H_2) produced = V/22.4 = 0.1/22.4
= 4.46×10^{-3} mol

∴ n (K) required = (2)(4.46×10^{-3})

= 8.92×10^{-3} mol

∴ m (K) required = (8.92×10^{-3})(39.1) = 0.349 g

3. n (HCl) / n (NaCl) = 1/1 = 1

n (NaCl) available = m /M = 24.0/58.5
= 0.41 mol

∴ n (HCl) produced = (1)(0.41) = 0.41 mol

∴ V (HCl) produced = (0.41)(22.4) = 9.18 L

4. n (CO_2) / n ($KHCO_3$) = 1/2 = 0.5

n ($KHCO_3$) available = m /M = 20.0/100.1
= 0.20 mol

∴ n (CO_2) produced = (0.5)(0.20) = 0.10 mol

∴ V (CO_2) produced = (0.20)(22.4) = 2.24 L

5. n (N_2) ∴ n (Mg_3N_2) = 1/1 = 1

n (Mg_3N_2) produced = m /M = 60.0/100.9
= 0.595 mol

∴ n (N_2) required = (1)(0.595) = 0.595 mol

∴ V (N_2) required = (0.595)(22.4) = 13.3 L

Sets Answers

6. The two reactions involved are

$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$ and

$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

now, n (H_2) / n (Al) = 3/2 = 1.5

n (Al) available = m /M = 1.0/27.0 = 0.0370mol

∴ n (H_2) produced = (1.5)(0.0370) = 0.0555 mol

∴ V (H_2) produced = (0.0555)(22.4) = 1.24 L

also, n (H_2) / n (Mg) = 1/1 = 1

n(Mg) available = m /M = 1.0/24.3 = 0.0411mol

∴ n (H_2) produced = (1)(0.0411) = 0.0411 mol

∴ V (H_2) produced = (0.0411)(22.4) = 0.92 L

Hence Al produces more $H_{2(g)}$.

Set 28: Equations - volume/mass

1. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$
x g 100 L

n (C) / n (CO_2) = 1/1 = 1

n (CO_2) available = V/22.4 = 100/22.4
= 4.46 mol

∴ n (C) required = (1)(4.46) = 4.46 mol

∴ m (C) required = (4.46)(12.0) = 53.5 g

2. $CuCO_{3(l)} \rightarrow CuO_{(s)} + CO_{2(g)}$
x g 500 mL

n (CuO) / n (CO_2) = 1/1 = 1

n (CO_2) produced = V/22.4 = 0.500/22.4
= 0.022 mol

∴ n (CuO) produced = (1)(0.022) = 0.022 mol

∴ m (CuO) produced = (0.022)(79.5) = 1.77 g

3. n (Mg) / n (H_2) = 1/1 = 1

n (H_2)produced = V/22.4 = 40.0/22.4 = 1.79mol

∴ n (Mg) required = (1)(1.79) = 1.79 mol

∴ m (Mg) required = (1.79)(24.3) = 43.4 g

4. n (Na_2O_2) / n (O_2) = 2/1 = 2

n (O_2) produced = V/22.4 = 2.5/22.4
= 0.1115 mol

∴ n (Na_2O_2) required = (2)(0.111) = 0.223 mol

∴ m (Na_2O_2) required = (0.223)(78.0) = 17.4 g

5. n (HNO_3) / n (CO_2) = 2/1 = 2

n (CO_2) produced = V/22.4 = 5.0/22.4
= 0.223 mol

∴ n (HNO_3) consumed = (2)(0.223) = 0.446 mol

∴ m (HNO_3) consumed = (0.446)(63.0) = 28.1 g

6. **a)** $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$C_3H_{8(s)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$

b) for CH_4

n (CO_2) / n (CH_4) = 1/1 = 1

n (CH_4) available = V/22.4 = 1.0/22.4
= 0.0446 mol

∴ n (CO_2) produced = (1)(0.0446)
= 0.0446 mol

∴ m (CO_2) produced = (0.0446)(44.0) = 1.96 g

for C_3H_8

n (CO_2) / n (C_3H_8) = 3/1 = 3

n (C_3H_8) available = V/22.4 = 1.0/22.4
= 0.0446 mol

∴ n (CO_2) produced = (3)(0.0446)
= 0.134 mol

∴ m (CO_2) produced = (0.134)(44.0)
= 5.89 g

Hence C_3H_8 produces the greatest mass of CO_2(g).

Sets Answers

Set 29: Equations - miscellaneous revision

1. **a)** $2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$
5.0 kg x L

b) n (CO_2) / n ($NaHCO_3$) = 1/2 = 0.5

n ($NaHCO_3$) available = m /M
= 5000/84.0 = 59.52 mol

∴ n (CO_2) produced = (0.5)(59.5)
= 29.76 mol

∴ V (CO_2) produced = (29.76)(22.4)
= 666.7 L

2. **a)** V (H_2) / V (NH_3) = 3/2 = 1.5

V (NH_3) produced = 40.0 L

∴ V (H_2) required = (1.5)(40.0) = 60.0 L

b) n (N_2) / n (NH_3) = 1/2 = 0.5

n (NH_3) produced = V/22.4 = 40.0/22.4
= 1.786 mol

∴ n (N_2) required = (0.5)(1.786) = 0.893mol

∴ m (N_2) required = (0.893)(28.0) = 25.0 g

3. **a)** n (CO_2) / n (Fe) = 3/2 = 1.5

n (Fe) produced = m /M = 1.0 x10^6 / 55.8
= 17921 mol

∴ n (CO_2) produced = (1.5)(17921)
= 26882 mol

∴ V (CO_2) produced = (26882)(22.4)
= 6.02 x 10^5 L

b) n (Fe_2O_3) / n (Fe) = 1/2 = 0.5

n (Fe) produced = 17921 mol (as above)

∴ n (Fe_2O_3) required = (0.5)(17921)
= 8960 mol

∴ m (Fe_2O_3) required = (8960)(159.6)
= 1.43 x 10^6 g
= 1.43 tonne

4. **a)** $2Al_{(s)} + 6HCl \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$
x g 200 mL

b) n (Al) / n (H_2) = 2/3 = 0.667

n (H_2) produced = V/22.4 = 0.200/22.4
= 8.93 x 10^{-3} mol

∴ n (Al) required = (0.667)(8.93 x 10^{-3})
= 5.95 x 10^{-3} mol

∴ m (Al) required = (5.95 x 10^{-3})(27.0)
= 0.161 g

5. **a)** n (C_2H_2) = m /M = 4.0/26.0 = 0.154 mol

n (O_2) = m /M = 5.0/32.0 = 0.156 mol

b) From the equation we can see that 2 moles of C_2H_2 requires 5 moles of O_2 for a complete reaction. Hence there is insufficient O_2 gas. i.e. O_2(g) is completely consumed (limiting reagent).

c) consider only limiting reagent

n (CO_2) / n (O_2) = 4/5 = 0.8

n (O_2) consumed = 0.156 mol

∴ n (CO_2) produced = (0.8)(0.156)
= 0.125 mol

∴ V(CO_2) produced = (0.125)(22.4)
= 2.81 L

6. for $(NH_4)_2SO_4$

n (NH_3) / n ($(NH_4)_2SO_4$) = 2/1 = 2

n ($(NH_4)_2SO_4$) produced
= m /M = 1000/132.1 = 7.57 mol

∴ n (NH_3) required = (2)(7.57) = 15.1 mol

∴ V (NH_3) required = (15.1)(22.4) = 339 L

for NH_4NO_3

n (NH_3) / n (NH_4NO_3) = 1/1 = 1

n (NH_4NO_3) produced
= m /M = 1000/80.0 = 12.5 mol

∴ n (NH_3) required = (1)(12.5) = 12.5 mol

∴ V (NH_3) required = (12.5)(22.4) = 280 L

Hence $(NH_4)_2SO_4$ requires the greatest volume of NH_3(g).

Sets — Answers

Set 30: Boyle's Law

1. **a)** There is a lot of space between the molecules that make up air.

b) Within the smaller volume molecules collide with the walls of the container more often and hence create a higher pressure.

2. $V_1 = 0.085$ L $\quad P_1 = 101.3$ kPa

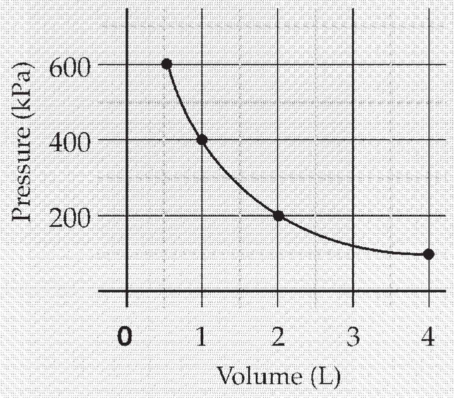
$V_2 = 0.030$ L $\quad P_2 = ?$

$P_1V_1 = P_2V_2$

$\therefore P_2 = \dfrac{P_1V_1}{V_2} = \dfrac{(101.3)(0.085)}{0.030}$

$\therefore P_2 = 287$ kPa

3. **a)**



b) Pressure is inversely proportional to volume, i.e. P a 1/V

c) P x V = 400 in each case

d) $(800)(V) = 400 \quad \therefore V = 0.50$ L

4. $P_1V_1 = P_2V_2$

$\therefore V_2 = \dfrac{P_1V_1}{P_2}$

a) $V_2 = \dfrac{(120)(500)}{12000} = 5.0$ L

b) $V_2 = \dfrac{(4.0)(14000)}{101} = 554$ L

5. $P_1V_1 = P_2V_2 \quad \therefore P_2 = \dfrac{P_1V_1}{V_2}$

a) $P_2 = \dfrac{(98)(2500)}{24.0} = 10210$ kPa

b) $P_2 = \dfrac{(101.3)(15.0)}{16.0} = 95.0$ kPa

6. $P_1 = 101.3$ kPa $\quad V_1 = ?$

$P_2 = 160$ kPa $\quad V_2 = 1.60$ L

$P_1V_1 = P_2V_2$

$\therefore V_1 = \dfrac{P_2V_2}{P_1} = \dfrac{(160)(1.60)}{101.3}$

$\therefore V_1 = 2.53$ L

Since pump is able to compress only 100 mL (0.10L) of air each time, it will need to be operated 26 times to complete the task (2.53 / 0.1 = 25.3 times).

Set 31: Charles' Law

1. **a)** i) 0°C = 273 K $\quad$ ii) 25°C = 298 K

iii) 100°C = 373 K $\quad$ iv) -50°C = 223 K

b) i) 100 K = -173°C $\quad$ ii) 273 K = 0°C

iii) 300 K = 27°C $\quad$ iv) 400 K = 127°C

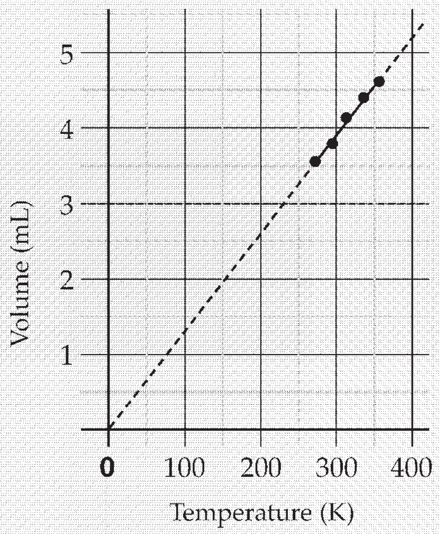
2. Molecules move faster at higher temperatures. Hence they collide with the walls of the tyre more often and with greater force.

3. **a)**

Temp °C	0.0	20.0	40.0	60.0	80.0
Temp K	273	293	313	333	353
Volume mL	3.60	3.87	4.13	4.40	4.65

Sets Answers

b)



c) Volume is directly proportional to Kelvin temperature, i.e. V a T (K)

d) At 200 °C volume ≈ 6.23 mL

4. $\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \therefore V_2 = \frac{V_1}{T_1} \times T_2$

a) $V_2 = \frac{(85.0)(473)}{373} = 107.8 \text{ L}$

b) $V_2 = \frac{(20.0)(278)}{308} = 18.0 \text{ L}$

5. $\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \therefore T_2 = \frac{V_2}{V_1} \times T_1$

a) $T_2 = \frac{(0.200)(353)}{0.220}$

$= 321 \text{ K} = 48°\text{C}$

b) $T_2 = \frac{(35.0)(288)}{25.0}$

$= 403.2 \text{ K} = 130.2°\text{C}$

c) $T_2 = \frac{(200)(393)}{340}$

$= 231 \text{ K} = -42°\text{C}$

6. a) i) $V_1 = 1.0 \quad T_1 = 300°\text{C} \ (573 \text{ K})$

$V_2 = \ ? \quad T_2 = 600°\text{C} \ (873 \text{ K})$

Assume original volume = 1.0 L

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$V_2 = \frac{V_1}{T_1} \times T_2 = \frac{1.0}{573} \times 873$

$= 1.52 \text{ L}$

i.e. 52% increase in volume

ii) $V_1 = 1.0 \quad T_1 = 300\text{K}$

$V_2 = \ ? \quad T_2 = 600\text{K}$

$V_2 = \frac{1.0}{300} \times 600 = 2.0 \text{ L}$

i.e. 100% increase in volume (volume doubled)

b) The two results are different because in one case there was a doubling of Celsius temperature while in the other there was a doubling of Kelvin temperature. Volume is directly proportional to Kelvin temperature only.

Set 32: Combined Gas Law

1. Pressure in the balloon could be increased by

a) increasing the temperature (e.g. take it outside if it's a hot day)

b) reducing its volume (e.g. squeeze it or place it under water)

c) add more air (e.g. pump more air into it).

2. $P_1 = 1.0 \text{ atm} \quad P_2 = 0.62 \text{ atm}$

$V_1 = 140 \text{ L} \quad V_2 = \ ?$

$T_1 = 18°\text{C} \ (291 \text{ K}) \quad T_2 = -11°\text{C} \ (262 \text{ K})$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \therefore V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$

$= \frac{(1.0)(140)(262)}{(291)(0.62)}$

$\therefore$ New volume $= 203.3 \text{ L}$

Sets Answers

3. P_1 = 250 kPa P_2 = 105 kPa

V_1 = 15 mL V_2 = ?

T_1 = 10°C (283 K) T_2 = 17°C (290 K)

As before

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} = \frac{(250)(0.015)(290)}{(283)(105)}$$

∴ New volume = 36.6 mL

4. P_1 = 98.5 kPa P_2 = 101.3 kPa

V_1 = 0.400 L V_2 = ?

T_1 = 21°C (294 K) T_2 = 0°C (273 K)

As before

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} = \frac{(98.5)(0.400)(273)}{(294)(101.3)}$$

= 0.361 L

∴ New volume = 361 mL

5. P_1 = 101.3 kPa V_1 = 5.0 L

T_1 = 0°C (273 K)

a) P_2 = 2 x 101.3 kPa V_2 = ?

T_2 = 50°C (323 K)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{P_2} \quad \therefore V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

$$= \frac{(101.3)(5.0)(323)}{(273)(202.6)}$$

∴ New volume = 2.96 L

b) P_2 = ? V_2 = 10.0 L

T_2 = 100°C (373 K)

$$P_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{V_2}$$

$$= \frac{(101.3)(5.0)(373)}{(273)(10)}$$

∴ New pressure = 69.2 kPa

c) P_2 = 50 kPa V_2 = 8.0 L

T_2 = ?

$$T_2 = \frac{P_2V_2}{P_1V_1} \times T1$$

$$= \frac{(50)(8.0)(273)}{(101.3)(5.0)}$$

= 215.6 K

∴ New temperature = - 57.4°C

6. P_1 = 14500 kPa P_2 = 115 kPa

V_1 = 2.4 L V_2 = ?

T_1 = 20°C (293 K) T_2 = 32°C (305 K)

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} = \frac{(14500)(2.4)(305)}{(293)(115)}$$

= 315 L

∴ No of balloons = 315 / 10 = 31.5

Michelle will be able to fill 31 balloons.

1 Test 1 - Chemistry Fundamentals Answers

1. b **2.** d **3.** c **4.** a **5.** d

6. b **7.** d **8.** a **9.** d **10.** a

11. c **12.** d **13.** d **14.** b **15.** c

16. c **17.** b **18.** a **19.** c **20.** d

21. Elements are composed of one type of atom only. O_2 is composed of atoms of O. Compounds are composed of two or more elements chemically combined in a fixed ratio. CO_2 is not an element as it is composed of the elements C and O. It is a compound because it is composed of two elements joined in the ratio 1 C : 2 O.

22. Number of protons = Z
Number of neutrons = A – Z

23. Isotopes are atoms of the same element, same Z, that have different A because of a differing number of neutrons. Both examples have 6 protons and are the same element. C-12 has 6 neutrons while C-14 has 8 neutrons.

24. **a)** calcium chloride
b) carbon tetrachloride
c) iron(III) nitrate
d) diphosphorus pentaoxide
e) chlorine gas
f) magnesium nitride

25. **a)** MgF_2 **b)** $Zn_3(PO_4)_2$
c) N_2O_4 **d)** $Cr(OH)_3$
e) Na_2SO_4 **f)** $(NH_4)_2CO_3$

26. **a)** $Fe_2O_3 + 3CO \rightarrow 2\,Fe + 3CO_2$
b) $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

27. **a)** acid + hydroxide -> salt + water
b) acid + carbonate -> salt + water + carbon dioxide
c) acid + reactive metal -> salt + hydrogen gas

28. **a)** $NaOH + HCl \rightarrow NaCl + H_2O$
b) $2Na + 2H_2O \rightarrow 2NaOH + H_2$
c) $2KHCO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O + 2CO_2$

29. Copper, mercury, silver, platinum, gold (any three).

30. **a)** $Ag^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$
b) $Fe^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightarrow Fe(OH)_{3\,(s)}$
c) $Ca^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3\,(s)}$
d) $3Mg^{2+}{}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Mg_3(PO_4)_{2\,(s)}$

2 Test 2 - Chemistry Calculations Answers

1. a **2.** c **3.** c **4.** b **5.** d

6. a **7.** c **8.** b **9.** a **10.** c

11. d **12.** b **13.** c **14.** a **15.** c

16. a **17.** d **18.** b **19.** d **20.** d

21. **a)** $M_r(Cl_2) = 71.0$
b) $M_r(Ca(OH)_2) = 40.1 + 16.0 \times 2 + 1.0 \times 2 = 76.1$

22. $M_r(Na_2SO_4) = 142.1$

$\therefore \%\,Na = \frac{46.0}{142.1} \times 100 = 32.4\%$

$\therefore \%\,S = \frac{32.1}{142.1} \times 100 = 22.6\%$

$\therefore \%\,O = \frac{64.0}{142.1} \times 100 = 45.0\%$

2 Test 2 - Chemistry Calculations — Answers

23. a) $M\ (NaOH) = 23.0 + 16.0 + 1.0 = 40.0\ g\ mol^{-1}$

$m\ (NaOH) = n \cdot M = (2.5)(40.0) = 100.0\ g$

b) $M\ (Al(NO_3)_3) = 27.0 + (14.0 \times 3) + (16.0 \times 9) = 213.0\ g\ mol^{-1}$

$m\ (Al(NO_3)_3) = n \cdot M = (0.40)(213.0) = 85.2\ g$

24. a) $n\ (H_2O) = \frac{m}{M} = \frac{50.0}{18.0} = 2.78\ mol$

b) $n\ (NH_3) = \frac{m}{M} = \frac{20.0}{17.0} = 1.176\ mol$

1 mol of NH_3 contains 3 mol H atoms

$\therefore\ n\ (H)\ atoms = (3)(1.176) = 3.53\ mol$

25. $\frac{n\ (H_2)}{n\ (K)} = \frac{1}{2}$ *(mole ratio from equation)*

$\therefore\ n\ (H_2)\ produced = (\frac{1}{2})(6.0) = 3.0\ mol$

$\therefore\ m\ (H_2)\ produced = n \cdot M = (3.0)(2.0) = 6.0\ g$

26. $\frac{n\ (NH_3)}{n\ (NH_4)_2SO_4} = \frac{2}{1}$ *(mole ratio from equation)*

convert known $(NH_4)_2SO_4$ to moles

$n\ (NH_4)_2SO_4 = \frac{m}{M} = \frac{80.0}{132.1} = 0.606\ mol$

$\therefore\ n\ (NH_3) = (2)(0.606) = 1.21\ mol$

$\therefore\ n\ (NH_3) = (1.21)(17.0) = 20.6\ g$

27. a) $V = (n)(22.4)$

$\therefore\ V(H_2) = (1.5)(22.4) = 33.6\ L$ at S.T.P.

b) $n\ (SO_2) = \frac{m}{M} = \frac{550}{64.1} = 8.58\ mol$

$\therefore\ V(SO_2) = (8.58)(22.4) = 192.2\ L$ at S.T.P.

c) $n = \frac{N}{6.02 \times 10^{23}} = \frac{3.01 \times 10^{23}}{6.02 \times 10^{23}} = 0.50\ mol$

$\therefore\ V(CO_2) = (0.50)(22.4) = 11.2\ L$ at S.T.P.

28. $\frac{n\ (CO_2)}{n\ (Na_2CO_3)} = \frac{1}{1}$ *(mole ratio from equation)*

convert known, Na_2CO_3, to moles

$n\ (Na_2CO_3) = \frac{m}{M} = \frac{12.0}{106.0} = 0.113\ mol$

$\therefore\ n\ (CO_2)\ produced = (1)(0.113) = 0.113\ mol$

$\therefore\ V\ (CO_2)\ produced = (0.113)(22.4) = 2.54\ L$ at S.T.P.

29. $\frac{n\ (Fe)}{n\ (Fe_2O_3)} = \frac{2}{1}$ and $\frac{n\ (CO_2)}{n\ (Fe_2O_3)} = \frac{3}{1}$

convert known, Fe_2O_3, to moles

$n\ (Fe_2O_3) = \frac{m}{M} = \frac{(1000)(1000)}{159.6} = 6265.6\ mol$

$\therefore\ n\ (Fe)\ produced = (2)(6265.6) = 12531.3\ mol$

$\therefore\ m\ (Fe)\ produced = (12531.3)(55.8) = 6.99 \times 10^5 g$ or 699 Kg

$\therefore\ n\ (CO_2)\ produced = (3)(6265.6) = 18797.0\ mol$

$\therefore\ V\ (CO_2)\ produced = (18797.0)(22.4) = 4.21 \times 10^5\ L$ at S.T.P.

30. a) $P_1 = 200\ kPa$ $\quad V_1 = 200\ L$

$P_2 = 450\ kPa$ $\quad V_2 = ?$

$P_1V_1 = P_2V_2 \quad \therefore V_2 = \frac{(200)(200)}{450} = 88.9\ L$

b) $T_1 = 30°C\ (303\ K)$ $\quad V_1 = 15.0\ L$

$T_2 = 60°C\ (333\ K)$ $\quad V_2 = ?$

$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \therefore V_2 = \frac{(15.0)}{303} \times 333 = 16.5\ L$

c) $P_1 = 101\ kPa$ $\quad P_2 = 65\ kPa$

$V_1 = 85\ L$ $\quad V_2 = ?$

$T_1 = 25°C\ (298\ K)$ $\quad T_2 = -12°C\ (261\ K)$

$\frac{P_1V_1}{T_1} = \frac{P_1V_1}{T_2} \quad \therefore V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$

$= \frac{(101)(85)(261)}{(298)(65)} = 115.7\ L$

Element	Symbol	Atomic Number	Relative Atomic Mass	Element	Symbol	Atomic Number	Relative Atomic Mass
Actinium	Ac	89	(227)	Molybdenum	Mo	42	95.94
Aluminium	Al	13	26.98	Neodymium	Nd	60	144.24
Americium	Am	95	(243)	Neon	Ne	10	20.18
Antimony	Sb	51	121.76	Neptunium	Np	93	(237)
Argon	Ar	18	39.95	Nickel	Ni	28	58.69
Arsenic	As	33	74.92	Niobium	Nb	41	92.91
Astatine	At	85	(210)	Nitrogen	N	7	14.01
Barium	Ba	56	137.33	Nobelium	No	102	(259)
Berkelium	Bk	97	(247)	Osmium	Os	76	190.23
Beryllium	Be	4	9.01	Oxygen	O	8	16.00
Bismuth	Bi	83	208.98	Palladium	Pd	46	106.42
Bohrium	Bh	107	(264)	Phosphorus	P	15	30.97
Boron	B	5	10.81	Platinum	Pt	78	195.08
Bromine	Br	35	79.90	Plutonium	Pu	94	(244)
Cadmium	Cd	48	112.41	Polonium	Po	84	(209)
Caesium	Cs	55	132.91	Potassium	K	19	39.10
Calcium	Ca	20	40.08	Praseodymium	Pr	59	140.91
Californium	Cf	98	(251)	Promethium	Pm	61	(145)
Carbon	C	6	12.01	Protactinium	Pa	91	231.04
Cerium	Ce	58	140.12	Radium	Ra	88	(226)
Chlorine	Cl	17	35.45	Radon	Rn	86	(222)
Chromium	Cr	24	52.00	Rhenium	Re	75	186.21
Cobalt	Co	27	58.93	Rhodium	Rh	45	102.91
Copper	Cu	29	63.55	Rubidium	Rb	37	85.47
Curium	Cm	96	(247)	Ruthenium	Ru	44	101.07
Dubnium	Db	105	(262)	Rutherfordium	Rf	104	(261)
Dysprosium	Dy	66	162.50	Samarium	Sm	62	150.36
Einsteinium	Es	99	(252)	Scandium	Sc	21	44.96
Erbium	Er	68	167.26	Seaborgium	Sg	106	(266)
Europium	Eu	63	151.96	Selenium	Se	34	78.96
Fermium	Fm	100	(257)	Silicon	Si	14	28.09
Fluorine	F	9	19.00	Silver	Ag	47	107.87
Francium	Fr	87	(223)	Sodium	Na	11	22.99
Gadolinium	Gd	64	157.25	Strontium	Sr	38	87.62
Gallium	Ga	31	69.72	Sulfur	S	16	32.06
Germanium	Ge	32	72.64	Tantalum	Ta	73	180.95
Gold	Au	79	196.97	Technetium	Tc	43	(98)
Hafnium	Hf	72	178.49	Tellurium	Te	52	127.60
Hassium	Hs	108	(277)	Terbium	Tb	65	158.93
Helium	He	2	4.00	Thallium	Tl	81	204.38
Holmium	Ho	67	164.93	Thorium	Th	90	232.04
Hydrogen	H	1	1.008	Thulium	Tm	69	168.93
Indium	In	49	114.82	Tin	Sn	50	118.71
Iodine	I	53	126.90	Titanium	Ti	22	47.87
Iridium	Ir	77	192.22	Tungsten	W	74	183.84
Iron	Fe	26	55.85	Uranium	U	92	238.03
Krypton	Kr	36	83.80	Vanadium	V	23	50.94
Lanthanum	La	57	138.91	Xenon	Xe	54	131.29
Lawrencium	Lr	103	(262)	Ytterbium	Yb	70	173.04
Lead	Pb	82	207.2	Yttrium	Y	39	88.91
Lithium	Li	3	6.94	Zinc	Zn	30	65.41
Lutetium	Lu	71	174.97	Zirconium	Zr	40	91.22
Magnesium	Mg	12	24.30				
Manganese	Mn	25	54.94				
Meitnerium	Mt	109	(268)				
Mendelevium	Md	101	(258)				
Mercury	Hg	80	200.59				

( ) = mass number of the isotope with the longest half life.

Data as published by IUPAC Commission on Atomic Weights 2001.

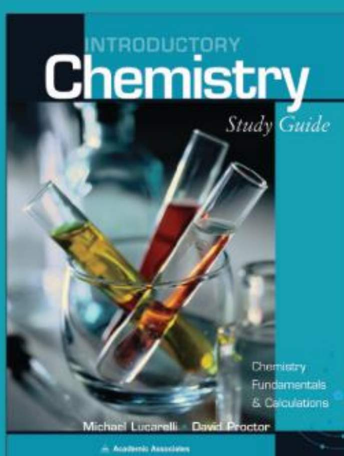
INTRODUCTORY

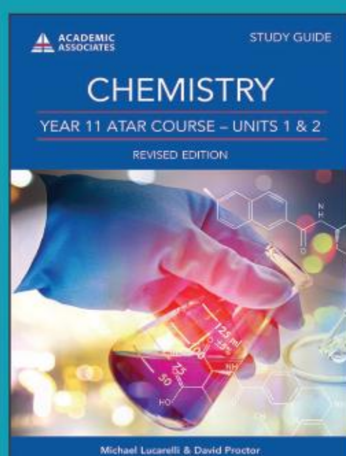
Chemistry

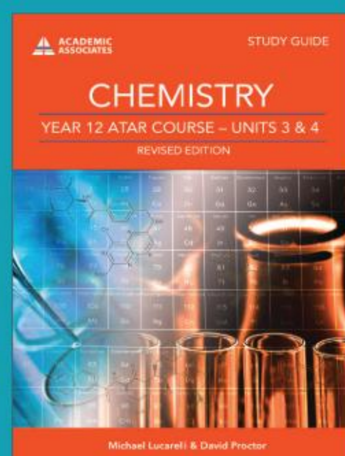
A study guide for students preparing for upper school chemistry

- Fundamental chemistry concepts and calculations clearly explained and illustrated
- Checkpoint questions designed to self test and extend student progress
- Review questions which will help students consolidate their understanding and problem solving skills
- Trial tests for convenient self assessment
- Fully detailed answers to all questions and tests.

ACADEMIC ASSOCIATES CHEMISTRY STUDY GUIDES







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