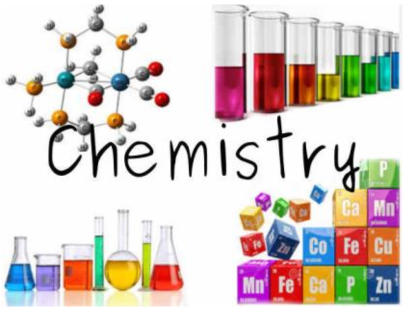


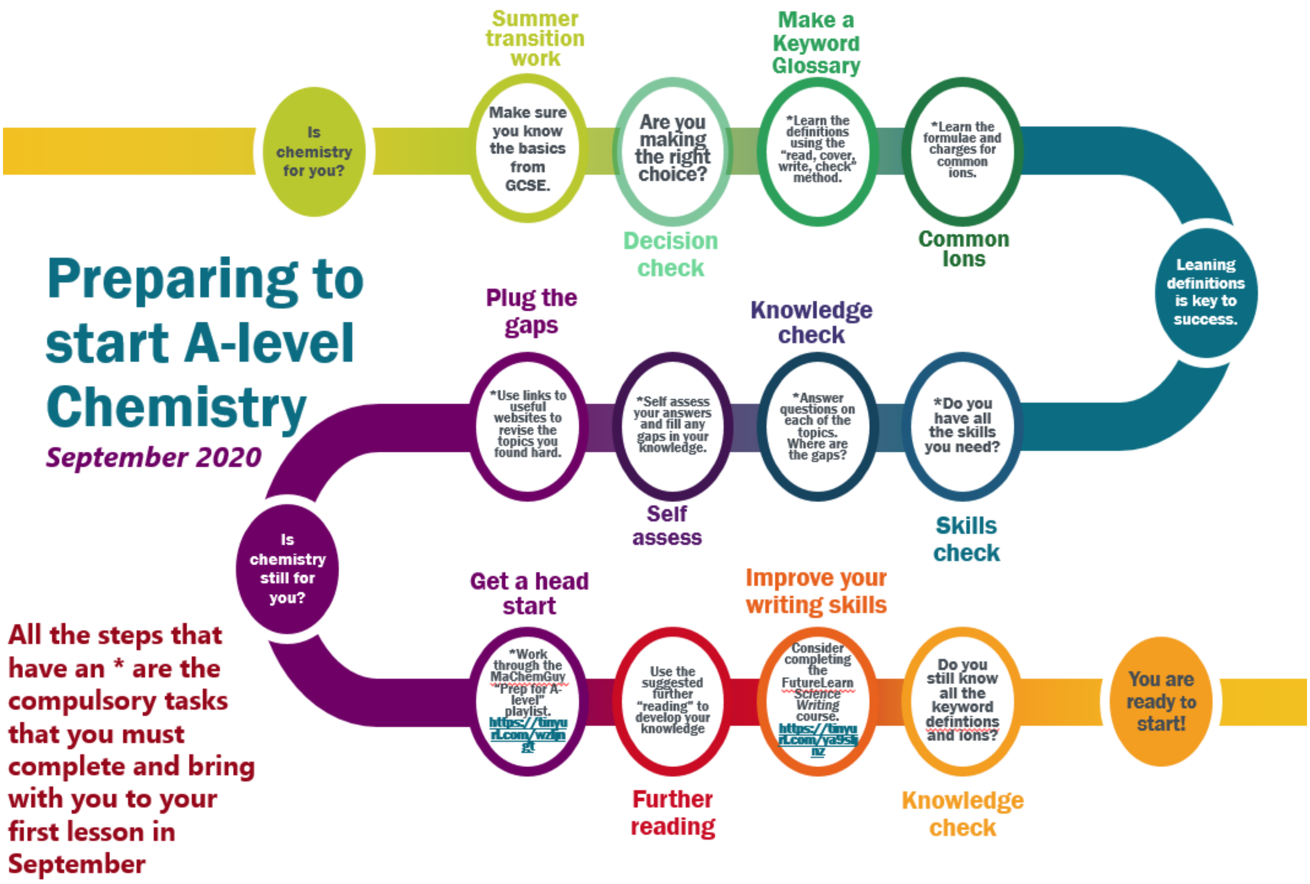
Welcome to A-Level Chemistry!

This work is designed to help you revise your GCSE Chemistry over the summer to prepare you for starting A-Level Chemistry in September. You may find it easy, not-so-easy, tricky or really tricky. There may be some questions you can't do at all. It doesn't matter. The aim is for you to practise your Chemistry and identify your strengths and weaknesses in the subject.

Use the Road Map: Preparing to start A Level Chemistry to see what are compulsory tasks and what are optional.

If you would like further work, or an insight into the wonderful world of AS-Level Chemistry and beyond, there are some further reading suggestions at the end. There is also a list of websites you will undoubtedly find useful throughout the course and may need to use to complete this task.

Good luck and happy Chemis-trying! From the Chemistry Team.



Newman Sixth A-Level Chemistry

Transition Task

This booklet gives information on the topics and skills in which you need to be completely confident before you start the first year on the A-level chemistry course.

Experience shows that students who are not secure in this knowledge and these skills find the transition from GCSE to A-level extremely challenging.

This booklet includes questions that will test your GCSE knowledge that you should complete before the start of the AS course and you will be able to self-assess your answers when you join Chemistry to find any areas that you need to focus your revision on from the start of the course. It also contains an extension opportunity: an A level sheet (including questions) that shows how you will be joining together some of the GCSE concepts you have met in an A level context.

All students starting A-level chemistry will have an assessment on the skills covered in this booklet and GCSE knowledge during the first week of term.

Items marked with * may only have been covered by those following Separate Sciences GCSEs.

COMPULSORY REVISION

Definitions:

Physical and Inorganic Chemistry

Atomic Structure:

Sub-atomic particle	Position in atom	Relative Mass	Relative charge
Proton	Nucleus	1	+1
Neutron	Nucleus	1	0
Electron	Electron shells/orbitals	0 (1/2000th)	-1

Acid: contains H^+ ions, pH of 1-6, a proton donor

Activation energy: this is the minimum energy needed for a reaction to start, the minimum energy the reactant particles need to collide with for a reaction to occur between them

Alkali: contains OH^- ions, pH of 8-14, a proton acceptor, a soluble base

Anhydrous: without water – a non-crystalline solid (powder)

Atom economy: the ratio or percentage of the atoms usefully used compared to the total number of atoms involved in a chemical synthesis

$$\frac{\text{Total } M_r \text{ of useful products}}{\text{Total } M_r \text{ of all reactants}} \text{ (x100) = atom economy (\%)}$$

*Avogadro's constant, N_A: is the number of particles per mole, 6.02×10^{23}

Base: a metal oxide or hydroxide, a proton acceptor.

Catalyst: a chemical that speeds up a reaction without taking part in the reaction itself

Concentration of a solution: moles of solute per $1 dm^3$ of solute, units mol dm^{-3} or g dm^{-3}

Covalent bond: each atom sharing one electron with another atom to complete the outer shell of both atoms, occurs in non-metal-non-metal molecules or giant structures

*Empirical formula: the simplest whole number ration of atoms of each element present in a compound

Endothermic reaction: the total enthalpy of the products is higher than that of the reactants, energy is taken in by the system. The temperature of the system will reduce

Energy transferred = Mass x specific heat capacity x temperature change

*Enthalpy Change: the energy change takin place in a reaction, often calculated using

Exothermic reaction: the total enthalpy of the products is lower than that of the reactants, energy is given out by the system. The temperature of the system will increase

Group: a vertical column in the Periodic Table, where all the elements in the group will have similar chemical properties due to having the same number of electrons in their outer shell. The group number tells you the number of electrons in the outer shell. The group number for metals shows you the positive charge on the ion of the metal atom. 8-the group number for non-metals shows you the negative charge on the ion of the non-metal atom.

COMPULSORY REVISION

Hydrated: with water – a crystalline solid

Ionic bond: the electrostatic force of attraction between oppositely charged ions, occurs in metal and non-metal compounds

Isotope: atoms of the same elements with different numbers of neutrons and different masses

Metal carbonate: metal ion with the carbonate ion

Metallic bond: the electrostatic attraction between the positive ions and delocalised electrons in a metallic lattice occurs between metal atoms.

*Molar gas volume: gas volume per mole, units $dm^3\ mol^{-1}$

*Molar mass: mass per mole of substance, units $g\ mol^{-1}$

*Mole 'mol' : is the units from the amount of a substance

Molecular formula: the number and type of each element in a molecule

Oxidation: is loss of electrons, or gain of oxygen

*Percentage composition: the % of each element that makes up the whole of a compound

Percentage yield: the % of a substance formed in a chemical synthesis compared to the theoretical yield calculated from the stoichiometric equation.

$$\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 = \%\ \text{yield}$$

Period: a horizontal row in the Periodic Table. Across a period the elements will show a recurring periodic pattern in structure, bonding, melting and boiling points, ionization energies and atomic radius. The Period number shows the number of quantum electron shells that the elements in that period will have.

Redox: this is a reaction where both oxidation and reduction happen to species taking part in the reaction

Reduction: is gain of electrons, or loss of oxygen

Relative atomic mass: Weighted mean mass of an atom compared with 1/12th mass of Carbon-12

Relative formula mass: is the sum of the relative atomic masses of the ratio of the all the atoms in a giant structure

Relative isotopic mass: mass of an isotope compared with 1/12th mass of Carbon-12

Relative Molecular mass (M_r) : is the sum of the relative atomic masses of all the atoms in a simple molecule

Salt: neutral compound made when an acid is neutralised, name is in two parts, the first part from the positive ion that the acid reacts with and the second part from the acid that is being neutralised

$\rightleftharpoons$ this shows a reaction is reversible, i.e. the reaction can go in both directions, and that t he system is in dynamic equilibrium

COMPULSORY REVISION

Organic Chemistry

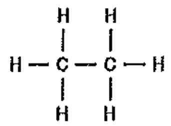
Addition polymerisation: the monomers join together to form a huge chain of monomers

Alkanes: a homologous series of saturated hydrocarbons that have the general formula C_nH_{2n+2}

Alkenes: a homologous series of unsaturated hydrocarbons that have the general formula C_nH_{2n}

Complete combustion: combustion of a fuel in unlimited oxygen only producing carbon dioxide and water as products, releasing the maximum amount of energy from the fuel

Displayed formula: the structure of a compound showing the relative positioning of atoms and the bonds between them e.g. for ethane:



Functional group: a group of atoms responsible for the characteristic reactions of a compound

General Formula: the simplest algebraic formula of a member of a homologous series

Homologous series: a series of organic compounds having the same functional group but with each successive member differing by CH_2

Hydrocarbon: a compound that only contains carbon and hydrogen atoms

Incomplete combustion: combustion of a fuel in limited oxygen that can produce a range of products including water, carbon dioxide, carbon monoxide and soot (unburnt carbon), does not release the maximum amount of energy from the fuel

Monomer: a single unit of a polymer, must contain a C=C double bond

Polymer: many single units joined together to form a huge molecule made of repeating units of monomers whose double bonds have broken to allow them to join together

Repeat unit: the repeating unit of a polymer, usually the monomer without double bonds

Saturated organic compound: an organic compound that only contains C-C single bonds

Unsaturated organic compound: an organic compound that contains at least one C=C double bond

Common Formula and Charges of Common Ions

Name of compound	Formula
Hydrochloric acid	HCl
Sulphuric acid	H_2SO_4
Nitric acid	HNO_3
*Ethanoic acid	CH_3COOH
Sodium hydroxide	NaOH
Potassium hydroxide	KOH
Ammonia	NH_3

COMPULSORY REVISION

Name of ion	Formula and charge of ion
Nitrate ion	NO_3^-
Sulphate ion	SO_4^{2-}
Carbonate ion	CO_3^{2-}
Phosphate ion	PO_4^{3-}
Hydroxide ion	OH^-
*Ethanoate ion	CH_3COO^-
Chloride ion	Cl^-
Iodide ion	I^-
Bromide ion	Br^-
Zinc ion	Zn^{2+}
Silver ion	Ag^+
Ammonium ion	NH_4^+

Chemical Tests and Reactions

Mostly KS3:

Bubbles in a reaction show that a gas is being produced this can be described as fizzing or effervescence.

A solution must be clear i.e. you can see through it

A precipitate is a solid that is formed by reacting two solutions. The solid formed is insoluble in the liquid that also forms and will settle to the bottom of the liquid if left to stand.

Reactions of Acids:

Acid + Metal → Salt + Hydrogen

Acid + Base → Salt + Water

Acid + Alkali → Salt + Water

Acid + Metal Carbonate → Salt + Water + Carbon Dioxide (this is also the test for a carbonate)

Acid + Ammonia → Ammonium Salt

Displacement reactions: a more reactive element will displace a less reactive element from its compounds

Tests for gases:

Hydrogen: 'squeaky' pop test – lit splint at the top of the test tube and a squeaky pop is heard if the gas is hydrogen

Oxygen: a glowing splint is placed into the test tube and if the gas released is oxygen the splint will relight

COMPULSORY REVISION

Carbon Dioxide: bubble the gas through limewater and the limewater will turn cloudy/milky if the gas is carbon dioxide due to the presents of insoluble calcium carbonate being formed

KS4:

Test for Ions:

Sulphate ion: React with Barium Hydroxide – white precipitate of Barium Sulphate forms

Carbonate ion: react with acid – Carbon Dioxide gas is given off

Chloride, Bromide and Iodide ions: react with silver nitrate and chloride gives a white precipitate of silver chloride, bromide gives a cream precipitate of silver bromide and iodide gives a yellow precipitate of silver iodide

Flame tests:

Group 1 element	Flame test colour
Lithium	Red
Sodium	Orange
Potassium	Lilac

Transition elements, hydroxide precipitates:

Name of metal ion	Formula of metal ion	Colour of metal hydroxide precipitate
Copper (II)	Cu^{2+}	Blue
Iron (II)	Fe^{2+}	Grey-green
Iron (III)	Fe^{3+}	Orange-brown

Test for Alkanes/Alkenes:

Add bromine water to the substance and shake. If it is an alkene the bromine water will decolourise – go from orange to colourless, if it is an alkane nothing will happen

Skills

You should be able to do the following:

- Recognise alcohols, carboxylic acids* and be able to describe the reaction to make esters
- Describe the different factors that affect the rate of a reaction and explain them using the particle theory
- Draw dot and cross diagrams of ionic and covalent bonds in some common substances

COMPULSORY REVISION

Practical science key terms

When is a measurement valid?	when it measures what it is supposed to be measuring
When is a result accurate?	when it is close to the true value
What are precise results?	when repeat measurements are consistent/agree closely with each other
What is repeatability?	how precise repeated measurements are when they are taken by the *same* person, using the *same* equipment, under the *same* conditions
What is reproducibility?	how precise repeated measurements are when they are taken by *different* people, using *different* equipment
What is the uncertainty of a measurement?	the interval within which the true value is expected to lie
Define measurement error	the difference between a measured value and the true value
What type of error is caused by results varying around the true value in an unpredictable way?	random error
What is a systematic error?	a consistent difference between the measured values and true values
What does zero error mean?	a measuring instrument gives a false reading when the true value should be zero
Which variable is changed or selected by the investigator?	independent variable
What is a dependent variable?	a variable that is measured every time the independent variable is changed
Define a fair test	a test in which only the independent variable is allowed to affect the dependent variable
What are control variables?	variables that should be kept constant to avoid them affecting the dependent variable

COMPULSORY QUESTIONS

IONIC BONDING

Table salt (sodium chloride, NaCl) is our most common ionic compound. It is also an excellent exemplar of how ionic substances behave. Under a microscope, or even on your kitchen table, you can see the beautiful crystalline lattice structure. Whilst it adds flavour to our food it doesn't melt when added to hot fish and chips. However, it dissolves readily in water, providing an ideal habitat for crocodiles and other marine organisms which rely on a salty aqueous environment. Brine conducts electricity and the products of its electrolysis provide us with vital chemical ingredients for our everyday life.

1) Complete the passage below using the following words:-

loses ions ionic protons negative electrons positive gains

Atoms are neutral because they have the same number of ………………….. and ………………… . If atoms lose or gain electrons they become electrically charged and are called ………… (they are not atoms any more). If atoms gain electrons they become ………………... ions, and if they lose electrons they become ………………… ions. When a metal reacts with a non-metal, the metal atoms …………….. electrons and the non-metal atoms …………… electrons, forming an ……………….. compound.

2) Describe the structure of sodium chloride.

3) a) Explain why ionic substances have high melting and boiling points.

b) Explain why ionic substances can conduct electricity when molten or dissolved.

c) Explain why ionic substances cannot conduct electricity when solid.

COMPULSORY QUESTIONS

4) Name the three products from the electrolysis of brine and give one example of how each is useful to us in everyday life.

Product	**Use**

5) Deduce the chemical formulae of the following ionic compounds:-

a) calcium chloride

d) aluminium hydroxide

b) sodium oxide

e) potassium carbonate

c) magnesium sulfide

f) calcium nitrate

COMPULSORY QUESTIONS

COVALENT BONDING

Covalently bonded molecules are everywhere! In fact, you are breathing some in (and out) as you read this. Their simple molecular structure is crucial to your survival. When you use your pencil to answer these questions you are relying on the properties of one of the World's most useful giant covalent structures, graphite. At the Brit Awards, Adele and other starlets adorn themselves with the World's strongest naturally occurring covalent structure, diamond. Which, as it just so happens, was also instrumental in the Hatten Garden robberies as a consequence of this very property!

Simple covalent molecules

1) Circle the correct answer.

Covalent bonding occurs between:-

Metal - Non-metal ; Metal – Metal ; Non-metal - Non-metal

2) How does a covalent bond form?

……

……

……

3) What are the properties of simple covalent substances such as chlorine or oxygen?

Melting point and boiling point	High/Low
Solubility in water	Soluble/Insoluble
Conduct electricity?	Conductors/Insulators
Bonding between molecules (intermolecular bonding)?	Weak/strong

4) Draw dot-and-cross diagrams of the following simple molecules:-

Methane	Water

COMPULSORY QUESTIONS

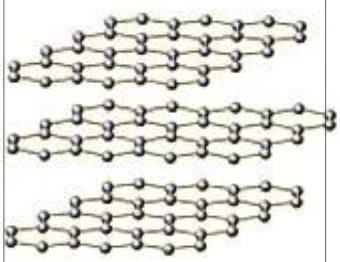
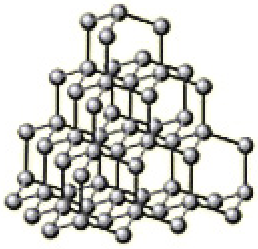
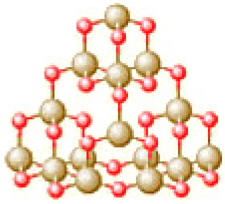
5) Describe and explain the difference in the boiling point of water compared to chlorine and oxygen.

....

....

....

Giant covalent structures

Structure			
Name			
Type of atoms? e.g. carbon/oxygen			
Properties			
High or low bp and mp?			
Conductor or insulator?			
Hard or soft?			
Solubility in H_2O			
Uses			

SUMMARY

1) Giant covalent structures tend to have low melting and boiling points. **True/false**
2) Most intermolecular forces are strong and make it difficult to separate the molecules. **True/false**
3) Most covalent substances do not conduct electricity. **True/false**
4) Graphite conducts electricity. **True/false**
5) Graphite is slippery because the intramolecular bonds are weak covalent bonds. **True/false**

Now explain your answer to each of the above statements.

COMPULSORY QUESTIONS

BALANCING EQUATIONS

It's a key skill in chemistry. You must be able to do it. Have a go and if you are struggling, get it sorted.

Balance the following equations:-

1) $Mg(s) + O_2(g) \rightarrow MgO(s)$

2) $H_2(g) + O_2(g) \rightarrow H_2O(l)$

3) $Fe(s) + HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

4) $CuO(s) + HNO_3(aq) \rightarrow Cu(NO_3)_2\ (aq) + H_2O(l)$

5) $Ca(OH)_2(aq) + HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$

6) $KHCO_3(s) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + CO_2(g) + H_2O(l)$

7) $Al(s) + Cl_2(g) \rightarrow AlCl_3(s)$

Useful websites

MaChemGuy
MaChemGuy is a chemistry teacher with a very comprehensive YouTube channel. This is a playlist to help prepare you for year 12 chemistry.
https://www.youtube.com/playlist?list=PLi6oabjl6coxUlfu8syK3K0iFXQIjwDUM

Khan Academy
Khan Academy produce lovely on-line tutorials. Brief, clear and informative. If you are struggling with equation balancing, this tutorial is well worth watching.
https://www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome/balancing-chemical-equations/v/balancing-chemical-equations-introduction

A chemical equation balancing game.
http://education.jlab.org/elementbalancing/

COMPULSORY QUESTIONS

Acids and Alkalis

Acids and alkalis play a crucial part in our everyday lives. Indigestion is caused by excess stomach acid. Gaviscon contains an alkali to neutralise the excess acid. Our breathing is controlled by the pH of our blood. Bee stings hurt thanks to formic acid. The effects can be neutralised by bicarbonate of soda. Chemists often carry out titrations to determine unknown concentrations of acids or alkali, particularly when quality checking products. A good example is checking the concentration of alkali in fertilisers before they go on shop shelves for us to buy; too much alkali can be just as bad (if not worse) than too much acid (caused by acid rain).

1) Acids have a pH of ………………. than 7.

Alkalis have a pH of …………. than 7.

Neutral substances have a pH of …………. .

2) Acid + Metal → …………………. + …………………….

Acid + Metal Oxide → …………………… + ……………………

Acid + Metal Hydroxide → ……………………. + …………………….

Acid + Metal Carbonate → ………………………. + ……………………… + ……………………….

3) Mr Withers needs to know how acidic the soil is in the school grounds. He decides to ask the chemistry A Level students to find out by doing a titration. They decide to use sodium hydroxide as their alkali of known concentration.

a) Fill in the boxes to balance the equation for this reaction.

$NaOH + \square\ H_2SO_4 \rightarrow Na_2SO_4 + \square\ H_2O$

b) The chemistry students use 24.2 cm^3 of sulfuric acid, extracted from the soil, to neutralise 25.0 cm^3 of 0.010 $moldm^{-3}$ sodium hydroxide. Determine the concentration of sulfuric acid in the school soil.

COMPULSORY QUESTIONS

REDOX

Without redox we wouldn't be able to get energy from our food. On a slightly less essential level, batteries and hydrogen fuel cells rely on redox to switch on torches and power modern cars. The key rule to remember in redox is that "the electrons have got to go somewhere!"…more on that in lesson time.

1) What is "redox"?

……

2) Give two examples of useful redox reactions in everday life excluding those mentioned above (there are millions!).

1)

2)

3) What does oxidation mean?

……

4) What does reduction mean?

……

5) Which element is oxidised and which is reduced in the reaction below?

$$ZnO + C \rightarrow Zn + CO$$

Oxidised ……………………………………………

Reduced ……………………………………………

COMPULSORY QUESTIONS

6) Many elements have variable oxidation states. What does this mean and how is it useful to us?

……

……

7) The ore haematite contains iron(III) oxide. Iron is extracted from this ore by reduction with carbon.

The products of this reaction are iron and carbon dioxide.

(a) Finish this **symbol** equation for the reaction.

………… Fe_2O_3 + ………… C → ………… + …………

(b) A haematite ore contains 80% by mass of iron(III) oxide.

Calculate the maximum mass of iron that can be extracted from each tonne of this ore.

Show each step of your calculation as indicated below.

HINTS: 1 tonne = 1000 kg; relative atomic mass (A_r) Fe = 56, O = 16

mass of iron(III) oxide in 1 tonne of haematite = ……………… kg

formula mass of iron(III) oxide = ………………

mass of iron in 1 tonne of haematite = ……………… kg

COMPULSORY QUESTIONS

CALCULATIONS

Calculations are a part of every chemist's world. They are sometimes something that A Level students find tricky but you can do it! The key is to sort out anything you don't understand and get plenty of practice to improve your confidence. These calculations build up in difficulty to those found on AS Level papers. Give them a shot; you may be surprised by how much you can do.

1) Magnesium sulfate is one of the chemicals in detergent powder.

Ana makes some magnesium sulfate using this reaction.

magnesium carbonate + sulfuric acid → magnesium sulfate + water + carbon dioxide

$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$

a) The theoretical yield for Ana's experiment is 12.0 g.

Ana dries and weighs the magnesium sulfate she makes. This is her actual yield.

Actual yield = 10.8 g.

Work out the percentage yield for Ana's experiment.

percentage yield = ...

b) The relative formula mass of magnesium carbonate is 84.

The relative formula mass of magnesium sulfate is 120.

Calculate the mass of magnesium carbonate that must react with sulfuric acid to produce 12.0 g of magnesium sulfate.

mass of magnesium carbonate = ... g

COMPULSORY QUESTIONS

2) A compound containing magnesium, silicon and oxygen is also present in rock types in Italy. A sample of this compound weighing 5.27 g was found to have the following composition by mass:

Mg 1.82 g; Si 1.05 g; O 2.40 g

Calculate the empirical formula of the compound.

Show your working.

3) A student heats 12.41 g of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$, to remove the water of crystallisation. A white powder called anhydrous sodium thiosulfate forms.

a) What does the term "anhydrous" mean?

b) What is the relative formula mass of $Na_2S_2O_3.5H_2O$?

c) Calculate the expected mass of anhydrous sodium thiosulfate that forms.

ANSWERS

Ionic Bonding

1) Complete the passage below using the following words:

loses ions ionic protons negative electrons positive gains

Atoms are neutral because they have the same number of **protons** and **electrons**. If atoms lose or gain electrons they become electrically charged and are called **ions** (they are not atoms any more). If atoms gain electrons they become **negative** ions, and if they lose electrons they become **positive** ions. When a metal reacts with a non-metal, the metal atoms **lose** electrons and the non-metal atoms **gain** electrons, forming an **ionic** compound.

2) Sodium chloride is a giant ionic lattice. It contains sodium ions (Na^+) and chloride ions (Cl^-). The ionic bonds in sodium chloride are strong and are created by the attraction between the oppositely charged ions.

3) a) Ionic substances form giant ionic lattices containing oppositely charged ions. Strong ionic bonds between the ions result in high melting and boiling points because a lot of energy is needed to break these bonds.

b) The ions are charged particles. When molten or dissolved the **ions** are free to move enabling them to conduct electricity.

c) In solid crystal lattices the ions are **not** free to move therefore they cannot conduct electricity.

4)

Product	**Use**
Hydrogen	Making margarine Hydrogen fuel cells
Chlorine	Killing micro-organisms in e.g. swimming pool water and drinking water
Sodium hydroxide	Making soap

5) a) Calcium chloride **$CaCl_2$**

b) Sodium oxide **Na_2O**

c) Magnesium sulfide **MgS**

d) Aluminium hydroxide **$Al(OH)_3$**

e) Potassium carbonate **K_2CO_3**

f) Calcium nitrate **$Ca(NO_3)_2$**

Covalent Bonding

1) Circle the covalent bond:-

Metal - Non-metal ; Metal – Metal ; Non-metal - Non-metal

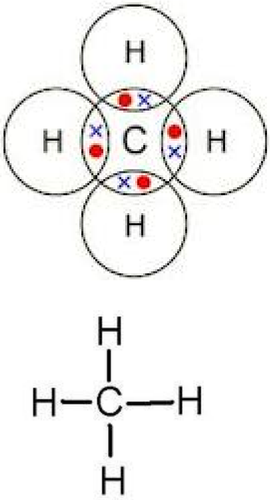
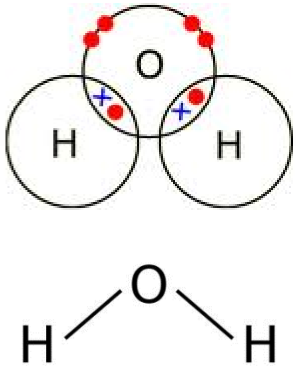
2) How does a covalent bond form?

Covalent bonds are predominantly a result of two non-metal atoms sharing a pair of electrons. There is then an attraction between the shared electron pair (negative) and the oppositely charged (positive) nuclei. The electrons involved are in the highest occupied energy levels (outer shells) of the atoms. Sometimes atoms form multiple covalent bonds by sharing more than one electron pair. The number of covalent bonds formed tends to depend on the group number (8 – group number).

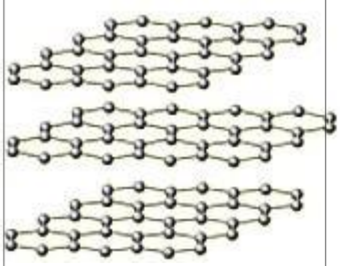
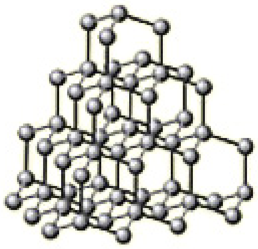
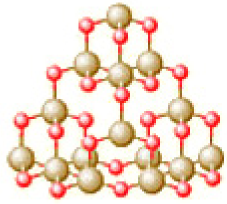
3) Properties of simple covalent molecules such as chlorine and oxygen:-

Melting point and boiling point	High/Low
Solubility in water	Soluble/Insoluble
Conduct electricity?	Conductors/Insulators
Bonding between molecules (intermolecular bonding)?	Weak/strong

4)

Methane	Water
	

4. Water has a relatively high boiling point compared to other simple covalent molecules such as chlorine and oxygen. This is because hydrogen bonds form between water molecules. These bonds are much stronger than the weak intermolecular forces (Instantaneous dipole-dipole interactions or London dispersion forces) between molecules such as chlorine and oxygen. Therefore a lot more energy is needed to break the hydrogen bonds between water molecules than is required to overcome the weak forces of attraction between chlorine or oxygen molecules.

Structure			
Name	Graphite	Diamond	Silicon dioxide
Type of atoms? e.g. carbon/oxygen	Carbon	Carbon	Silicon Oxygen
Properties			
High or low bp and mp?	High	High	High
Conductor or insulator?	Conductor	Insulator	Semi-conductor
Hard or soft?	Hard	Soft and slippery	Hard
Uses	Pencil "lead"	Jewellery Cutting and precision tool	Electronics (Transistors)

SUMMARY

1) **False** – giant covalent structures have strong bonds which need large amounts of energy to break them.
2) **False** – intermolecular forces are weak
3) **True** – covalent molecules do not have free electrons or ions to carry a charge (with the exception of graphite)
4) **True** – Graphite contains delocalised electrons which can carry a charge through the hexagonal layers.
5) **False** – Intramolecular covalent bonds are strong. Graphite is slippery due to the weak intermolecular forces.

<u>Balancing Equations</u>

1) $\mathbf{2}Mg(s) + O_2(g) \rightarrow \mathbf{2}MgO(s)$

2) $\mathbf{2}H_2(g) + O_2(g) \rightarrow \mathbf{2}H_2O(l)$

3) $Fe(s) + \mathbf{2}HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

4) $CuO(s) + \mathbf{2}HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$

5) $Ca(OH)_2(aq) + \mathbf{2}HCl(aq) \rightarrow CaCl_2(aq) + \mathbf{2}H_2O(l)$

6) $\mathbf{2}KHCO_3(s) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + \mathbf{2}CO_2(g) + \mathbf{2}H_2O(l)$

7) $\mathbf{2}Al(s) + \mathbf{3}Cl_2(g) \rightarrow \mathbf{2}AlCl_3(s)$

Acids and Alkalis

1) Acids have a pH of **less** than 7.

Alkalis have a pH of **more** than 7.

Neutral substances have a pH of **7**.

2) Acid + Metal → **salt** + **hydrogen**

Acid + Metal Oxide → **salt** + **water**

Acid + Metal Hydroxide → **salt** + **water**

Acid + Metal Carbonate → **salt** + **water** + **carbon dioxide**

3a) $\mathbf{2}\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + \mathbf{2}\ H_2O$

b) Moles NaOH = 0.025 x 0.01

= 0.00025

Moles H_2SO_4 = 0.000125

Concentration of H_2SO_4 = 0.000125/0.0242

= 0.00517 M

Redox

1) Redox is the oxidation of one element together with the reduction of another element during a chemical reaction.

2) Two examples of useful redox reactions in everyday life:-

1) Combustion of fossil fuels

2) Respiration

3) Photosynthesis

3) An element losing electrons.

4) An element gaining electrons.

5) Oxidised: **Carbon**

Reduced: **Zinc**

6) Elements with variable oxidation states are able to lose or gain different numbers of electrons depending on their environment. For example, iron can exist as Fe^{2+} and Fe^{3+} ions.

7 (a) **2** Fe_2O_3 + **3** $C \rightarrow$ **3** CO_2 + **4 Fe**

(b)

Mass of Fe_2O_3 = 80/100 x 1000

= 800 kg

Moles Fe_2O_3 = 800/160

= 5

Moles Fe = 5 x 2

= 10

Mass Fe = 10 x 56

= 560 kg

Calculations

1a) Percentage yield = 10.8/12 x 100

= 90%

1b) $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$

Moles $MgSO_4$ = 12.0/120

= 0.1

Moles $MgCO_3$ = 0.1

Mass $MgCO_3$ = 0.1 x 84

= 8.4 g

2) Mg 1.82/24 : Si 1.05/28 : O 2.4/16

Mg 0.07583 : Si 0.0375 : O 0.15

Mg 0.07583/0.0375 : Si 0.0375/0.0375 : O 0.15/0.0375

Mg 2 : Si 1 : O 4

Empirical formula = Mg_2SiO_4

3a) Anhydrous means without water.

b) RFM $Na_2S_2O_3.5H_2O$ = 23 x 2 + 32 x 2 + 16 x 3 + 5 x 18

= 248

c) $Na_2S_2O_3.5H_20 \rightarrow Na_2S_2O_3 + 5H_2O$

Moles $Na_2S_2O_3.5H_20$ = 12.41/248

= 0.05

Moles $Na_2S_2O_3$ produced = 0.05

Mass $Na_2S_2O_3$ = 0.05 x 158

= 7.9 g

COMPULSORY QUESTIONS

Vocabulary

1

GCSE Chemistry Checker Tasks

Each of the definitions below is for a common word or term used in chemistry. Identify the correct word or term to go with each definition and write it in the space provided.

Definition	Word/Term
The smallest particle of an element	
Positive nuclei held together by delocalised electrons	
Different physical structures of atoms of the same element	
The change in concentration of a reactant or product over time	
Chemically combined elements in a fixed ratio	
Able to dissolve in a particular solvent	
Breaking a substance apart using an electrical current	
A reaction in which a substance is burned in oxygen	
A substance able to speed up a chemical reaction that remains unchanged after the reaction is complete	
A bond formed by the sharing of a pair of electrons	
Negatively charged particle found within atoms	
The loss of electrons	
The reaction between an acid and a base to produce water and a solution of pH 7	
A bond formed by the exchange of electrons and resulting attraction between ions	
Positively charged particle found within atoms	
A type of reaction that gives out heat and causes a rise in temperature	
Centre of an atom, containing protons and neutrons	
Gain of electrons	
Particle with no charge found within atoms	
The amount of a dissolved substance in a given volume of solvent	
A type of reaction that takes in heat and causes a decrease in temperature	
A charged particle	
A more reactive element taking the place of a less reactive element	

2

COMPULSORY QUESTIONS

Atomic Structure

Every substance around you is made from atoms. But what is an atom and what does an atom contain?

In the space below produce a drawing that shows what makes up an atom. You should label your diagram fully and give explanations where necessary.

Once you are happy that you have included everything, compare it with the completed diagram in the Answers to check you have all the essential points.

COMPULSORY QUESTIONS

Chemical Equations and Reactions

Chemists tell the story of reactions by using equations. These can be word equations, which give the names of chemicals, but most often they use formulae equations. You are going to study a series of equations and interpret the information they can tell you.

Task 1

Write word equations for each of the following formulae equations:

1. $HCl + NaOH \rightarrow NaCl + H_2O$
2. $Mg + 2HCl \rightarrow MgCl_2 + H_2$
3. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
4. $H_2 + I_2 \rightarrow 2HI$
5. $2Ca + O_2 \rightarrow 2CaO$

Task 2

Choosing from displacement, thermal decomposition, neutralisation, polymerisation or combustion, identify which type of reaction is occurring for each of the following formulae equations:

1. $H_2SO_{4\,(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4\,(aq)} + 2H_2O_{(l)}$
2. $CuCO_{3\,(s)} \rightarrow CuO_{(s)} + CO_{2\,(g)}$
3. $Mg_{(s)} + CuSO_{4\,(aq)} \rightarrow MgSO_{4\,(aq)} + Cu_{(s)}$
4. $CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(l)}$
5. $nC_2H_4 \rightarrow [C_2H_4]_n$

Task 3

Balance the following equations:

1. $HCl + Mg \rightarrow MgCl_2 + H_2$
2. $Li + H_2O \rightarrow LiOH + H_2$
3. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
4. $K + H_2SO_4 \rightarrow K_2SO_4 + H_2$
5. $C_7H_{16} + O_2 \rightarrow CO_2 + H_2O$

4

GCSE Chemistry Checker Tasks

COMPULSORY QUESTIONS

Chemical Bonding

Atoms can join together to form molecules of elements and chemical compounds. They do this by using bonds. Complete the following table on the different types of bonding.

Type of bonding	Ionic	Covalent	Metallic
Example of substance with this bonding	NaCl	Cl_2	Fe
Diagram of the bonding within this substance (ensure you accurately represent any outer electrons)			
What happened to the electrons to form this type of bond?			
Would a substance with this type of bond conduct electricity?			
Does a substance with this type of bond contain charged particles?			

COMPULSORY QUESTIONS

Endothermic and Exothermic Reactions

5

GCSE Chemistry Checker Tasks

All chemical reactions involve bonds being broken and bonds being formed. Every time a bond is broken or formed, energy is either required or released by the reaction. These energy transfers that occur during reactions cause temperature changes. The amount of energy required or released depends on the bond being broken or formed.

Methane, CH_4, reacts with oxygen in the following way:

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

Average bond enthalpies ($kJ\,mol^{-1}$)			
C–H	O=O	C=O	H–O
412	496	743	463

1 Use the average bond enthalpies provided to calculate the energy change for this reaction. Show all your workings.

2 Would this energy change be endothermic or exothermic?

3 What would happen to the temperature during this reaction?

4 Sketch an 'energy level diagram' to represent this reaction.

Handling Numbers

The ability to work with numbers is essential for chemistry, from working out how many moles of a substance you have produced to calculating an energy change for a reaction. Numbers you will encounter in chemistry will range from the incredibly small, for example the radius of an individual atom, to the incredibly large, for example the number of atoms in a mole of an element. The following number-handling skills will be needed throughout your chemistry studies.

Decimal places

Answers to calculations aren't always whole numbers. The calculator will show a 'decimal point' after the whole number and then one or more numbers, for example 12.5 – this is read as '12 point five' and means 12 and a half, or exactly halfway between 12 and 13.

More usually calculators display lots of numbers after the decimal point, and you will need to decide how many of these numbers to use in each stage of your calculations and how many to write down when you give an answer. Each number after the decimal point is referred to as a 'decimal place'.

Decimal place is abbreviated to 'dp' and exam papers will often ask you to give answers to a certain number of decimal places, usually two. This is written as '2dp'. If this isn't the case, it's best to write down any answer with all the decimal places shown and then round up or down to two decimal places.

In exams, make sure you give answers to the number of decimal places the exam paper has asked for – too many students lose marks because they don't do this.

If a calculation gave an answer of 4.87509545, there are eight decimal places shown. This would be written as:

- 4.9 to 1dp
- 4.88 to 2dp
- 4.875 to 3dp
- 4.8751 to 4dp, and so on

You may have noticed that the last decimal place often differs from the original number – if you aren't sure why, read the section below on rounding up or rounding down.

Rounding up and rounding down

Once you know how many numbers after the decimal point you need to include, you may need to 'round up' or 'round down'. This is because if the first number you are *not* including is closer to the next highest whole number, it's too big to ignore.

If you were asked to quote 7.083754 to 1dp, it would become 7.1 – the eight that comes after the zero is too large to ignore, so you have to **round up** the preceding number (in this case the zero). If you had been asked to quote the same number to 2dp, however, it would be 7.08 – the eight wouldn't change because the three that comes after it is small enough to ignore, so you **round down** and keep the preceding number the same.

The general rule is: find the number that represents the last decimal place you need to quote. If the next number is smaller than five, round down (you won't change the last decimal place you quote). If it is five or more, round up (the last decimal place you quote will increase by one).

COMPULSORY REVISION

Handling Numbers

You can only round up or down once. If you rounded 55.445 up to 55.45, you cannot then round this up to 55.5, as 55.445 to 1dp is only 55.4.

When carrying out calculations, it is best to leave rounding up and down until you have your final answer. If you round up or down too early you may end up with the wrong figure at the end.

Significant figures

Significant figures are useful when quoting numbers to a certain number of decimal places isn't appropriate.

If you quoted 0.0002 to 2dp, it would appear that you had a value of zero (0.00) but the two, which has been ignored, may be highly important (for example, the required concentration of a poison): it is **significant**.

Significant figures (sig. fig. or SF for short) are numbers that tell you something about the magnitude (rough size) of a figure. You start counting significant figures as soon as you come across a non-zero number reading from left to right. Zeros between other numbers and at the end of numbers are classed as significant also. Where the decimal place is has no bearing on whether a number is significant or not – all numbers are significant as soon as you encounter a number that isn't zero.

All of the following are quoted to three significant figures:

- 3.67
- 0.000000899
- 4.01
- 7.00

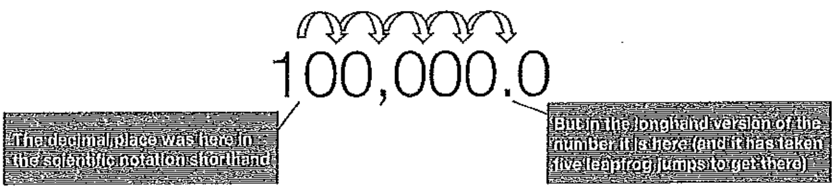
Scientific notation (standard form)

Some numbers in science are just so large that they would take too long to write out in their full form, so we use shorthand called 'scientific notation' or 'standard form'.

This shorthand always takes the form of a number between 1.0 and 9.9 multiplied by 10 raised to a given power, for example 3.6×10^3 (this would be read as 'three point six times 10 to the power of three').

Consider the number 100,000. If we write this in scientific notation it becomes 1.0×10^5, because if we multiply 1.0 by 10^5, we get 100,000. A simple way to remember how to convert numbers into scientific notation is to imagine that the power the number 10 is raised to tells you how many numbers the decimal place needs to 'leapfrog' over to get back to its place in the longhand answer.

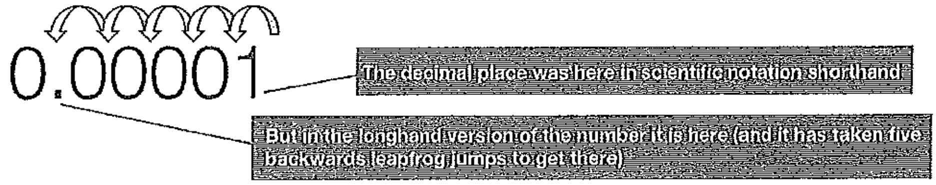
It is often helpful to draw this out:



COMPULSORY QUESTIONS

Handling Numbers

It works for very small numbers too, except the decimal place has to leapfrog backwards, so the scientific notation shows a number between 1.0 and 9.9 multiplied by 10 raised to a negative power, for example 1.0×10^{-5} is 0.00001.



Questions

1. What is 0.867666 to 2dp?
2. What is 67.02887 to 3dp?
3. What is 489.0448 to 2dp?
4. What is 20.49 to the nearest whole number?
5. What is 0.0034577 to three significant figures?
6. What is 1.000642 to three significant figures?
7. What is 1.00546 to three significant figures?
8. How many significant figures are shown in 4000?
9. How many significant figures are shown in 9.000034?
10. What is 2000 in scientific notation?
11. What is 0.00067 in scientific notation?
12. What is 4570 in scientific notation?
13. What is 0.00000000044 in scientific notation?
14. Is 0.9×10^{3} expressed in scientific notation?
15. What is 5.5×10^{4} in longhand notation?
16. What is 2.7×10^{7} in longhand notation?
17. What is 3.0×10^{-2} in longhand notation?
18. What is 2.5×10^{-5} in longhand notation?
19. What is 602000000000000000000000 in scientific notation?
20. What is 326700 in scientific notation, quoted to three significant figures?

COMPULSORY REVISION

SI Units

Chemists across the world need to be able to communicate with one another. For this reason it is important that all chemists know the units of measurement to follow. It would be very difficult if a chemist in one country set out to check and confirm another chemist's experimental results by measuring something out in pounds and ounces if the original work was done in another country, working in grams!

A universal set of **base units** has been established that tells scientists the correct units of measurement to work with. They are known as **SI units,** which stands for Système International d'Unités. The SI units you are likely to encounter in A-level chemistry are outlined in the table below:

What is being measured	Unit name (symbol)	Useful conversion factors
Length	Metre (m)	1 m = 100 cm 1 m = 1000 mm 1 m = 1,000,000 µm (micrometres)
Time	Seconds (s)	1 minute = 60 s 1 hour = 3600 s 1 day = 24 hours
Temperature	Kelvin (K)	Temperature in K = temperature in °C + 273.15
Mass	Kilogram (kg)	1 kg = 1000 g 1 g = 1000 mg 1 g = 1,000,000 µg (micrograms) 1 tonne = 1000 kg
Amount of substance	Mole (mol)	1 mole = 6.02×10^{23} atoms or molecules Mass of 1 mole of an atom = that atom's atomic mass in g

You will not always be required to work in SI units in your studies; for example, you will usually work in Celsius when measuring temperature and in grams rather than kilograms when recording mass. However, you must be aware of how to convert measurements into SI units.

COMPULSORY QUESTIONS

SI Units

Questions

Convert the following into SI units:

1 67 cm

2 30 minutes

3 100°C

4 –27°C

5 0.1 g

6 2.7 tonnes

7 5 g

8 1.806×10^{24} atoms of a given element

9 6.02×10^{20} atoms

10 12 g carbon into moles (carbon's atomic mass is 12)

COMPULSORY REVISION

Calculator Skills

You are going to be building a strong friendship over the course of your A-level Chemistry studies… with your scientific calculator!

A scientific calculator is an invaluable tool for any chemist, so you need to be confident about using it, and you will need to practise using some of the functions to make sure you don't get calculations wrong.

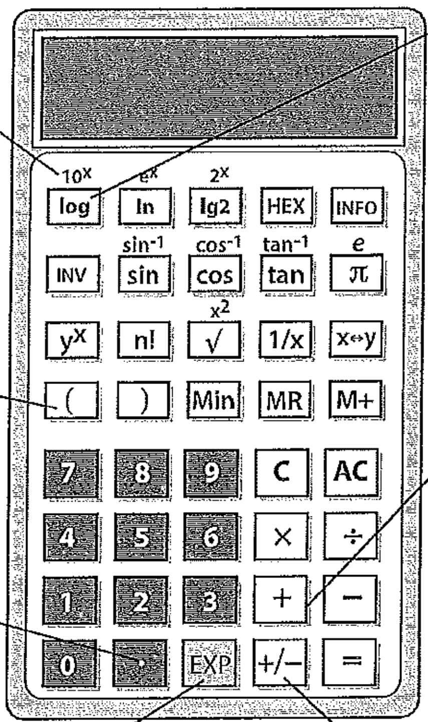
Obviously the calculator described here may not be exactly the same as yours, in which case check the instruction booklet that came with your calculator so you can find the equivalent functions – and do this long before any exams.

The functions you are most likely to need are as follows:

The 10^x function is the inverse function to the **log** button. You will need to use this when you are dealing with pH values and pOH values. You will need to press 'Shift' or 'Second Function' then input the value '10' is raised to, for example '3' for '10^3'.

These buttons allow you to input **brackets** into a calculation; this tells the calculator to work these parts out first, for example when you calculate relative atomic masses.

This '.' button lets you input **decimal places**, for example when you carry out calculations about concentrations, such as 0.1 (mol dm^{-3}).



The **log** function allows you to input numbers that are 'logarithms to base 10', 'log_{10}' or 'logs' for short. These allow you to deal with very large numbers that are part of a 'logarithmic scale', such as pH values. For example, to calculate the log of 1000, press 'log' then input 1000, and then '=' to get the answer '3'.

Here are your standard buttons: '+' for addition, '−' for subtraction, '×' for multiplication, '÷' for division and '=' for equals (that is, the answer!).

The **EXP** button lets you input numbers that are multiplied by a power of 10. After pressing it, '00' usually appears and you input the power you need, for example Avogadro's number 6.02×10^{23} would be inputted as 6.02 'EXP' 23. Powers of 10 can be negative.

This '+/−' button lets you input a negative number, for example when you perform calculations about exothermic enthalpy changes.

Finally, before inputting calculations into your calculator, there is an important rule to learn about the order in which functions have to happen. Remember it as BEDMAS: Brackets first, then Exponents (powers/roots), then Division or Multiplication, then Addition or Subtraction.

It doesn't matter which order division or multiplication and addition or subtraction happen in, except if they are the only functions needed for a calculation, in which case you should work from left to right.

COMPULSORY QUESTIONS

Questions

Complete these questions, using your scientific calculator where required. Questions one to five test your knowledge of BEDMAS; complete these without a calculator first to check how well you have understood this rule.

Check against the answers to ensure you are using your calculator correctly.

1 $3 + 5 \div 4 =$

2 $10^2 - 10 \div 2 =$

3 $77 - (3 \times 2) + 2^2 =$

4 $77 - (3 \times 2) \times 2^2 =$

5 $10 - 7 + 2 + 11 - 3 + 1 - 4 \times 2 =$

6 $-10 + 25 =$

7 $-99 \div -98 =$

8 $6.02 \times 10^{23} \times 5 =$

9 $0.025 \times 1.5 \times 10^3 =$

10 $10 \times 2.0 \times 10^3 =$

11 $1.0 \times 10^3 \div 3 =$

12 $10^{4.5} =$

13 $10^3 =$

14 $\log_{10} 1000 =$

15 $\log_{10} 0.1 =$

COMPULSORY REVISION

Rearranging Equations

An equation is a mathematical way of showing a relationship between two or more **variables**. For example, '$a = b + c$' tells us that 'a' is the same as 'b' and 'c' added together; a, b and c could stand for anything, for example 'a' (total revision time) = 'b' (maths revision time) + 'c' (chemistry revision time).

Symbolic equations (equations that contain symbols) are used extensively in chemistry and you must be confident at rearranging them and recognising the symbols they contain.

How do I rearrange an equation?

Equations show individual variables and how these are connected; they will be connected by **operations** such as '+', '−', '÷', '×'and '√'.

Operations can be thought of as coming in pairs, where the two operations forming the pair perform opposite functions.

Opposite operations	
+ (addition)	− (subtraction)
× (multiplication)	÷ (division) division is sometimes written as /
x^2 (square)	√ (square root)

'Rearranging an equation' means re-writing it in a new order, so a different variable is on its own and equal to some combination of all the others. This variable becomes the **subject** of the equation.

The key thing to remember when rearranging equations is that you must do the same things to *both* sides of the equation (the left *and* right side of the '=' sign).

Returning to '$a = b + c$', if we had values for just 'a' and 'c', we would need to rearrange this to make 'b' the subject to be able to find its value.

As the equation is written, 'b' is being added to 'c', so to 'undo' this we need to perform the opposite operation. In this case we need to subtract 'c' from both sides of the equation, giving:

Because 'c' is being added and then subtracted again, these cancel out, so we don't need to write them

$$a - c = b + c - c$$

$$\text{or } b = a - c$$

It's usual practice to put the main subject on the left

What if the equation is more complicated?

Let's imagine we want to find a value for 'c' in the following equation:

When symbols are written together like this, they are being multiplied

$$ab = c^2 / d$$

At the moment, 'c' is being squared *then* divided by 'd' (if you are unsure why this is the case, take a look at Task 10)

COMPULSORY QUESTIONS

Rearranging Equations

So, step 1 is to multiply both sides by 'd', giving:

$$abd = c^2 (/ d \times d)$$

or, $abd = c^2$

'/ d' and '× d' cancel each other out, so we don't need to write them anymore

Step 2 is to take the square root of both sides, giving:

$$\sqrt{abd} = \sqrt{c^2}$$

or, $c = \sqrt{abd}$

The square root and the square cancel each other out. Don't forget, the square root applies to all the variables that were there when you applied it.

Students often get confused when symbols within equations are unusual or unfamiliar. Take your time – the process is always the same, no matter what the equation. Identify the symbol you need as the subject, then just unpick the equation one step at a time by using opposite operations. But remember – you must always do the same to both sides.

Questions

Rearrange the following equations:

1 Find a if $ab = cd$

2 Find x if $x^2 = y$

3 Find a if $abc = d$

4 Find mass if number of moles = mass / molar mass

5 Find molar mass if number of moles = mass / molar mass

6 Find volume if number of moles = concentration × volume

7 Find m if $q = mc\Delta T$

8 Find h if $E = h\nu$

9 Find ΔH if $\Delta G = \Delta H - T\Delta S$

10 Find R if $pV = nRT$

13

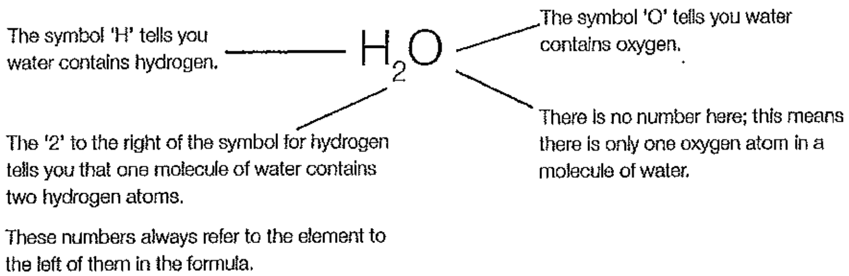
COMPULSORY REVISION

Chemical Formulae

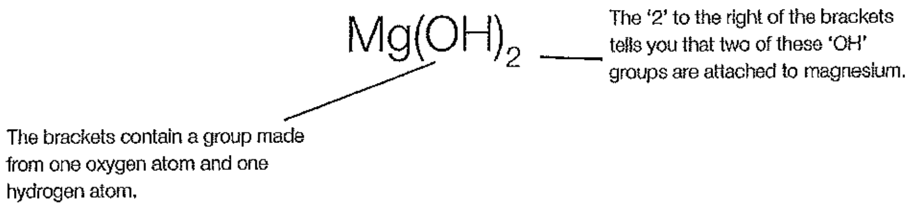
If you buy a piece of furniture that needs to be assembled, you are provided with a set of instructions to tell you the parts you need and how it fits together. A chemical formula is exactly that too – it tells you what elements are needed for a given compound or molecule and the ratios you need them in.

Chemical formulae are written in shorthand, using the element symbols found on the periodic table.

Most people know the formula for water is H_2O, but what does that actually mean?



Sometimes formulae contain brackets. These show groups of elements within compounds. Any number immediately outside the bracket tells you how many of these groups are present. For example, when magnesium reacts with water, one of the products is magnesium hydroxide, $Mg(OH)_2$.



Simple chemical names can usually be worked out from looking at the formula. If a metal is present, it will come first in the compound name. Subsequent chemicals will come next, and their name endings will change depending on the type of compound they form.

- The ending '-ide' tells you a compound has been formed from only two elements (it won't necessarily be just two atoms though), for example sodium chlor**ide**, NaCl
- The ending '-ate' tells you the compound has been formed from more than two elements, one of them being oxygen, for example calcium carbon**ate**, $CaCO_3$

Helpful tip

You may be asked to predict the formulae for some simple compounds. Remember, an element's group number shows how many electrons it has in its outer shell. When elements bond, they usually bond with elements that can either accept all their outer electrons or that can help them gain/share enough electrons to make a full outer shell with eight electrons in it. For example, chlorine (group 7) happily accepts sodium's electron (group 1), and magnesium (group 2) gives its two outer electrons to two chlorine atoms.

If a prefix is added to an element's name, this tells you how many of its atoms are involved in the compound. (Some prefixes are different when naming hydrocarbon chains however.)

- 'Mono' (sometimes abbreviated to 'mon') means one; for example carbon **mon**oxide, CO, contains one oxygen atom

COMPULSORY QUESTIONS

Chemical Formulae

- 'Di' means two; for example carbon **di**oxide, CO_2, contains two oxygen atoms
- 'Tri' means three; for example boron **tri**fluoride, BF_3, contains three fluorine atoms
- 'Tetra' means four; for example carbon **tetra**fluoride, CF_4, contains four fluorine atoms
- 'Hexa' means six; for example sulphur **hexa**fluoride, SF_6, contains six fluorine atoms

Questions

1 How many atoms of oxygen are represented in the formula for sulphuric acid, H_2SO_4?

2 How many atoms of silver are represented in the formula for silver nitrate, $AgNO_3$?

3 How many atoms of hydrogen are represented in the formula for calcium hydroxide, $Ca(OH)_2$?

4 How many atoms in total are represented in the formula for iron oxide, Fe_2O_3?

5 How many atoms in total are represented in the formula for manganese hydroxide, $Mn(OH)_2$?

6 What is the name of HF?

7 What is the name of MgO?

8 What is the name of $BaCO_3$?

9 What is the name of SO_2?

10 What is the name of CCl_4?

11 Predict the formula for calcium oxide.

12 Predict the formula for nitrogen monoxide.

13 Ammonia's formula is NH_3. What elements does it contain?

14 One beryllium atom can bond with two chlorine atoms. What would the name and formula of the product of this reaction be?

15 What is the name of I_2?

14 COMPULSORY REVISION

Balancing Chemical Equations

It is essential to be able to balance chemical equations, and as long as you follow some general rules and think logically about how to do this, it needn't cause you too much of a headache.

Chemical formulae tell you which elements are in compounds or molecules and the ratios they are in; these facts can't change, if they did, you would no longer have the same chemical. A simple analogy for this is a kitchen table and its component parts: a table top and four legs. Lets give the table top the symbol 'T' and the legs the symbol 'L'. If we wrote an equation for constructing the table it would be:

$$T + 4L \rightarrow TL_4$$

The table's formula is TL_4 as it's made from one table top and four individual legs.

All the individual formulae are fixed; all you are able to change is how many of each component you can use up. You can't just change the table's formula to TL_2 because the table would fall over!

It's the same for chemicals: water is always H_2O, oxygen is always O_2, chlorine is always Cl_2, sulphuric acid is always H_2SO_4, and so on. You *cannot* and *must not* change the numbers within formulae when you balance equations, as that would change the chemical. And, equally as important, the parts you had at the beginning must all still be there at the end (that is, on either side of the arrow), just in different combinations.

Balancing equations can sometimes seem confusing when you have to consider how all the chemicals are typically found. Let's return to our table analogy. If table tops are always bought as packs of two, you can't just make a single table so you'd need more legs. The equation would now be:

$$T_2 + 8L \rightarrow 2TL_4$$

Because 'T' is found as a pair, we need twice the amount of 'L'. All the starting materials have to be used up, so we end up with two tables, $2TL_4$. Both sides of the equation have two T and eight L, so it's balanced.

It's exactly the same with chemicals, we cannot change how the chemicals are found, so all we can do is change the amount of them we use, by changing the numbers *in front* of the formulae.

Consider sodium and chlorine reacting to form sodium chloride. First, **write out the element symbols**, showing how they are found naturally, with reactants on the left and products on the right, then count how many of each atom is present at the start:

$$Na + Cl_2 \rightarrow NaCl$$

The numbers of sodium remains constant, but there is one chlorine missing at the end.

Now **adjust the numbers in front of the formulae until the numbers of each atom match** at the beginning and end of the reaction. If we make another NaCl (that is, 2NaCl) and add another sodium at the start, it will balance:

Chlorine is always found in pairs of atoms, so we will need two individual sodium atoms.

$$2Na + Cl_2 \rightarrow 2NaCl$$

One sodium atom can only react with one of the chlorine atoms, hence the formula NaCl. So, we have to make two NaCl to use up all the starting atoms. So, on both sides of the equation we still have two Na and two Cl; it's balanced.

Finally, remember that in a balanced equation each element symbol actually represents one **mole** of that element (see Task 26 if you are unsure on moles), so it is possible to have half a mole of an element as that's actually 3.01×10^{23} atoms; this can sometimes help balance the equation.

COMPUSLORY QUESTIONS

14

Basic Skills for the A-level Chemist

Balancing Chemical Equations

For example, when carbon monoxide is formed as follows you could write the equations in either of these ways:

$C + \frac{1}{2}O_2 \rightarrow CO$ OR $2C + O_2 \rightarrow 2CO$

For the purposes of balancing equations, half a mole of oxygen molecules can be considered equivalent to a mole of oxygen atoms, as the same number of oxygen atoms are present.

Questions

Balance the following equations.

1. $H_2 + Cl_2 \rightarrow HCl$
2. $Mg + HCl \rightarrow MgCl_2 + H_2$
3. $Cu + O_2 \rightarrow CuO$
4. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
5. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$
6. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
7. $N_2 + H_2 \rightarrow NH_3$
8. $Ca + HNO_3 \rightarrow Ca(NO_3)_2 + H_2$
9. $PbS + O_2 \rightarrow PbO + SO_2$
10. $Fe + Cl_2 \rightarrow FeCl_3$

COMPULSORY REVISION

Maths skills

1 Core mathematical skills

A practical chemist must be proficient in standard form, significant figures, decimal places, SI units, and unit conversion.

1.1 Standard form

In science, very large and very small numbers are usually written in standard form. Standard form is writing a number in the format $A \times 10^x$ where A is a number from 1 to 10 and x is the number of places you move the decimal place.

For example, to express a large number such as 50 000 mol dm^{-3} in standard form, A = 5 and x = 4 as there are four numbers after the initial 5.

Therefore, it would be written as 5×10^4 mol dm^{-3}.

To give a small number such as 0.000 02 Nm^2 in standard form, A = 2 and there are five numbers before it so x = −5.

So it is written as 2×10^{-5} Nm^2.

Practice questions

1 Change the following values to standard form.

a boiling point of sodium chloride: 1413 °C

b largest nanoparticles: 0.0 001$\times10^{-3}$ m

c number of atoms in 1 mol of water: 1806×10^{21}

2 Change the following values to ordinary numbers.

a 5.5×10^{-6} **b** 2.9×10^{2} **c** 1.115×10^{4} **d** 1.412×10^{-3} **e** 7.2×10^{1}

1.2 Significant figures and decimal places

In chemistry, you are often asked to express numbers to either three or four significant figures. The word significant means to ‘have meaning’. A number that is expressed in significant figures will only have digits that are important to the number’s precision.

It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

For example, 6.9301 becomes 6.93 if written to three significant figures.

Likewise, 0.000 434 56 is 0.000 435 to three significant figures.

Notice that the zeros before the figure are *not* significant – they just show you how large the number is by the position of the decimal point. Here, a 5 follows the last significant digit, so just as with decimals, it must be rounded up.

Any zeros between the other significant figures are significant. For example, 0.003 018 is 0.003 02 to three significant figures.

Sometimes numbers are expressed to a number of decimal places. The decimal point is a place holder and the number of digits afterwards is the number of decimal places.

For example, the mathematical number pi is 3 to zero decimal places, 3.1 to one decimal place, 3.14 to two decimal places, and 3.142 to three decimal places.

COMPULSORY QUESTIONS

Practice questions

3 Give the following values in the stated number of significant figures (s.f.).

a 36.937 (3 s.f.) **b** 258 (2 s.f.) **c** 0.043 19 (2 s.f.) **d** 7 999 032 (1 s.f.)

4 Use the equation:

number of molecules = number of moles × 6.02 × 10^{23} molecules per mole

to calculate the number of molecules in 0.5 moles of oxygen. Write your answer in standard form to 3 s.f.

5 Give the following values in the stated number of decimal places (d.p.).

a 4.763 (1 d.p.) **b** 0.543 (2 d.p.) **c** 1.005 (2 d.p.) **d** 1.9996 (3 d.p.)

1.3 Converting units

Units are defined so that, for example, every scientist who measures a mass in kilograms uses the same size for the kilogram and gets the same value for the mass. Scientific measurement depends on standard units – most are *Système International* (SI) units.

If you convert between units and round numbers properly it allows quoted measurements to be understood within the scale of the observations.

Multiplication factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n

Unit conversions are common. For instance, you could be converting an enthalpy change of 488 889 J mol^{-1} into kJ mol^{-1}. A kilo is 10^3 so you need to divide by this number or move the decimal point three places to the left.

488 889 ÷ 10^3 kJ mol^{-1} = 488.889 kJ mol^{-1}

Converting from mJ mol^{-1} to kJ mol^{-1}, you need to go from 10^3 to 10^{-3}, or move the decimal point six places to the left.

333 mJ mol^{-1} is 0.000 333 kJ mol^{-1}

If you want to convert from 333 mJ mol^{-1} to nJ mol^{-1}, you would have to go from 10^{-9} to 10^{-3}, or move the decimal point six places to the right.

333 mJ mol^{-1} is 333 000 000 nJ mol^{-1}

Practice questions

6 Calculate the following unit conversions.

a 300 µm to m

b 5 MJ to mJ

c 10 GW to kW

COMPULSORY QUESTIONS

2 Balancing chemical equations

2.1 Conservation of mass

When new substances are made during chemical reactions, atoms are not created or destroyed – they just become rearranged in new ways. So, there is always the same number of each type of atom before and after the reaction, and the total mass before the reaction is the same as the total mass after the reaction. This is known as the conservation of mass.

You need to be able to use the principle of conservation of mass to write formulae, and balanced chemical equations and half equations.

2.2 Balancing an equation

The equation below shows the correct formulae but it is not balanced.

$H_2 + O_2 \rightarrow H_2O$

While there are two hydrogen atoms on both sides of the equation, there is only one oxygen atom on the right-hand side of the equation against two oxygen atoms on the left-hand side. Therefore, a two must be placed before the H_2O.

$H_2 + O_2 \rightarrow 2H_2O$

Now the oxygen atoms are balanced but the hydrogen atoms are no longer balanced. A two must be placed in front of the H_2.

$2H_2 + O_2 \rightarrow 2H_2O$

The number of hydrogen and oxygen atoms is the same on both sides, so the equation is balanced.

Practice questions

1 Balance the following equations.

a $C + O_2 \rightarrow CO$

b $N_2 + H_2 \rightarrow NH_3$

c $C_2H_4 + O_2 \rightarrow H_2O + CO_2$

2.3 Balancing an equation with fractions

To balance the equation below:

$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

- Place a two before the CO_2 to balance the carbon atoms.
- Place a three in front of the H_2O to balance the hydrogen atoms.

  $C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$

There are now four oxygen atoms in the carbon dioxide molecules plus three oxygen atoms in the water molecules, giving a total of seven oxygen atoms on the product side.

- To balance the equation, place three and a half in front of the O_2.

  $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$

- Finally, multiply the equation by 2 to get whole numbers.

  $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

COMPULSORY QUESTIONS

Practice questions

2 Balance the equations below.

a $C_6H_{14} + O_2 \rightarrow CO_2 + H_2O$

b $NH_2CH_2COOH + O_2 \rightarrow CO_2 + H_2O + N_2$

2.4 Balancing an equation with brackets

$Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$

Here the brackets around the hydroxide (OH^-) group show that the $Ca(OH)_2$ unit contains one calcium atom, two oxygen atoms, and two hydrogen atoms.

To balance the equation, place a two before the HCl and another before the H_2O.

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

Practice questions

3 Balance the equations below.

a $Mg(OH)_2 + HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$

b $Fe(NO_3)_2 + Na_3PO_4 \rightarrow Fe_3(PO_4)_2 + NaNO_3$

3 Rearranging equations and calculating concentrations

3.1 Rearranging equations

In chemistry, you sometimes need to rearrange an equation to find the desired values.

For example, you may know the amount of a substance (*n*) and the mass of it you have (*m*), and need to find its molar mass (*M*).

The amount of substance (*n*) is equal to the mass you have (*m*) divided by the molar mass (*M*):

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

You need to rearrange the equation to make the molar mass (*M*) the subject.

Multiply both sides by the molar mass (*M*):

$$M \times n = m$$

Then divide both sides by the amount of substance (*n*):

$$m = \frac{m}{N}$$

Practice questions

1 Rearrange the equation $c = \frac{n}{V}$ to make:

a *n* the subject of the equation

b *V* the subject of the equation.

2 Rearrange the equation $PV = nRT$ to make:

a *n* the subject of the equation

b *T* the subject of the equation.

COMPULSORY QUESTIONS

3.2 Calculating concentration

The concentration of a solution (a solute dissolved in a solvent) is a way of saying how much solute, in moles, is dissolved in 1 dm^3 or 1 litre of solution.

Concentration is usually measured using units of mol dm^{-3}. (It can also be measured in g dm^3.)

The concentration of the amount of substance dissolved in a given volume of a solution is given by the equation:

$$c = \frac{n}{V}$$

where n is the amount of substance in moles, c is the concentration, and V is the volume in dm^3.

The equation can be rearranged to calculate:

- the amount of substance n, in moles, from a known volume and concentration of solution
- the volume V of a solution from a known amount of substance, in moles, and the concentration of the solution.

Practice questions

3 Calculate the concentration, in mol dm^{-3}, of a solution formed when 0.2 moles of a solute is dissolved in 50 cm^3 of solution.

4 Calculate the concentration, in mol dm^{-3}, of a solution formed when 0.05 moles of a solute is dissolved in 2.0 dm^3 of solution.

5 Calculate the number of moles of NaOH in an aqueous solution of 36 cm^3 of 0.1 mol dm^{-3}.

4 Molar calculations

4.1 Calculating masses and gas volumes

The balanced equation for a reaction shows how many moles of each reactant and product are involved in a chemical reaction.

If the amount, in moles, of one of the reactants or products is known, the number of moles of any other reactants or products can be calculated.

The number of moles (n), the mass of the substance (m), and the molar mass (M) are linked by:

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

Note: The molar mass of a substance is the mass per mole of the substance. For $CaCO_3$, for example, the atomic mass of calcium is 40.1, carbon is 12, and oxygen is 16. So the molar mass of $CaCO_3$ is:

40.1 + 12 + (16 × 3) = 100.1. The units are g mol^{-1}.

COMPULSORY QUESTIONS

Look at this worked example. A student heated 2.50 g of calcium carbonate, which decomposed as shown in the equation:

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

The molar mass of calcium carbonate is 100.1 g mol^{-1}.

a Calculate the amount, in moles, of calcium carbonate that decomposes.

$$n = \frac{m}{M} = 2.50/100.1 = 0.025 \text{ mol}$$

b Calculate the amount, in moles, of carbon dioxide that forms.

From the balanced equation, the number of moles of calcium carbonate = number of moles of carbon dioxide = 0.025 mol

Practice questions

1 In a reaction, 0.486 g of magnesium was added to oxygen to produce magnesium oxide.

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

a Calculate the amount, in moles, of magnesium that reacted.

b Calculate the amount, in moles, of magnesium oxide made.

c Calculate the mass, in grams, of magnesium oxide made.

2 Oscar heated 4.25 g of sodium nitrate. The equation for the decomposition of sodium nitrate is:

$2NaNO_3(s) \rightarrow 2NaNO_2(s) + O_2(g)$

a Calculate the amount, in moles, of sodium nitrate that reacted.

b Calculate the amount, in moles, of oxygen made.

3 0.500 kg of magnesium carbonate decomposes on heating to form magnesium oxide and carbon dioxide. Give your answers to 3 significant figures.

$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

a Calculate the amount, in moles, of magnesium carbonate used.

b Calculate the amount, in moles, of carbon dioxide produced.

5 Percentage yields and percentage errors

5.1 Calculating percentage yield

Chemists often find that an experiment makes a smaller amount of product than expected. They can predict the amount of product made in a reaction by calculating the percentage yield.

The percentage yield links the actual amount of product made, in moles, and the theoretical yield, in moles:

$$\text{percentage yield} = \frac{\text{actual amount (in moles) of product}}{\text{theoretical amount (in moles) of product}} \cdot 100$$

Look at this worked example. A student added ethanol to propanoic acid to make the ester, ethyl propanoate, and water.

$C_2H_5OH + C_2H_5COOH \rightarrow C_2H_5COOC_2H_5 + H_2O$

The experiment has a theoretical yield of 5.00 g.

The actual yield is 4.50 g.
The molar mass of $C_2H_5COOC_2H_5$ = 102.0 g mol^{-1}

Calculate the percentage yield of the reaction.

Actual amount of ethyl propanoate: $n = \frac{m}{M} = 4.5/102 = 0.0441 \text{ mol}$

COMPULSORY QUESTIONS

Theoretical amount of ethyl propanoate: $n = \frac{m}{M}$ = 5.0/102 = 0.0490 mol

percentage yield = (0.0441/0.0490) × 100% = 90%

Practice questions

1 Calculate the percentage yield of a reaction with a theoretical yield of 4.75 moles of product and an actual yield of 3.19 moles of product. Give your answer to 3 significant figures.

2 Calculate the percentage yield of a reaction with a theoretical yield of 12.00 moles of product and an actual yield of 6.25 moles of product. Give your answer to 3 significant figures.

5.2 Calculating percentage error in apparatus

The percentage error of a measurement is calculated from the maximum error for the piece of apparatus being used and the value measured:

$$\text{percentage error} = \frac{\text{maximum error}}{\text{measured value}} \times 100\%$$

Look at this worked example. In an experiment to measure temperature changes, an excess of zinc powder was added to 50 cm^3 of copper(II) sulfate solution to produce zinc sulfate and copper.

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

The measuring cylinder used to measure the copper(II) sulfate solution has a maximum error of ±2 cm^3.

a Calculate the percentage error.

percentage error = (2/50) × 100% = 4%

b A thermometer has a maximum error of ±0.05 °C.

Calculate the percentage error when the thermometer is used to record a temperature rise of 3.9 °C. Give your answer to 3 significant figures.

percentage error = (2 × 0.05)/3.9 × 100% = 2.56%

(Notice that two measurements of temperature are required to calculate the temperature change so the maximum error is doubled.)

Practice questions

3 A gas syringe has a maximum error of ±0.5 cm^3. Calculate the maximum percentage error when recording these values. Give your answers to 3 significant figures.

a 21.0 cm^3 **b** 43.0 cm^3

4 A thermometer has a maximum error of ±0.5 °C. Calculate the maximum percentage error when recording these temperature rises. Give your answers to 3 significant figures.

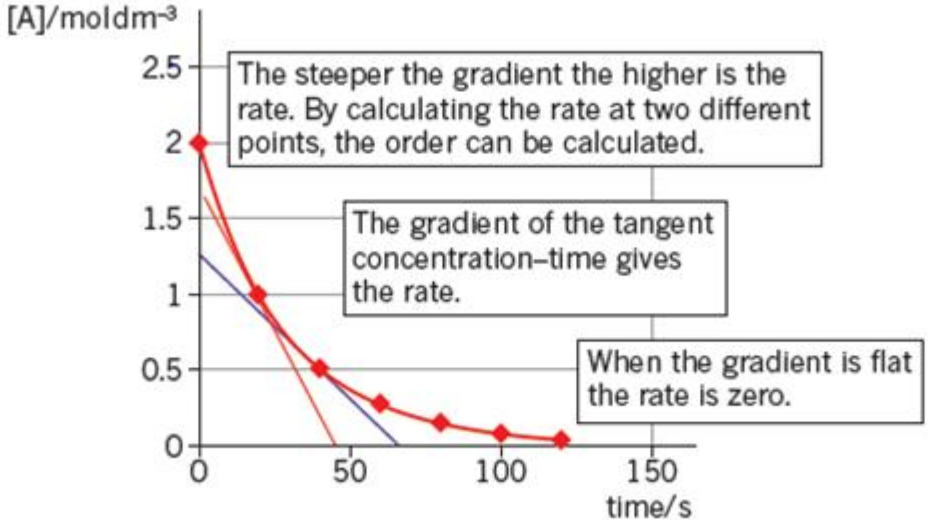
a 12.0 °C **b** 37.6 °C

COMPULSORY QUESTIONS

6 Graphs and tangents

6.1 Deducing reaction rates

To investigate the reaction rate during a reaction, you can measure the volume of the product formed, such as a gas, or the colour change to work out the concentration of a reactant during the experiment. By measuring this concentration at repeated intervals, you can plot a concentration–time graph.



Note: When a chemical is listed in square brackets, it just means 'the concentration of' that chemical. For example, [O_2] is just shorthand for the concentration of oxygen molecules.

By measuring the gradient (slope) of the graph, you can calculate the rate of the reaction. In the graph above, you can see that the gradient changes as the graph is a curve. If you want to know the rate of reaction when the graph is curved, you need to determine the gradient of the curve. So, you need to plot a tangent.

The tangent is the straight line that just touches the curve. The gradient of the tangent is the gradient of the curve at the point where it touches the curve.

Looking at the graph above. When the concentration of A has halved to 1.0 mol dm^{-3}, the tangent intercepts the *y*-axis at 1.75 and the *x*-axis at 48.

The gradient is $\frac{1.75}{48}$ = −0.0365 (3 s.f.).

So the rate is 0.0365 mol dm^{-3} s^{-1}.

Practice questions

1 Using the graph above, calculate the rate of reaction when the concentration of A halves again to 0.5 mol dm^{-3}.

Answers to maths skills practice questions

1 Core mathematics

1 **a** 1.413×10^3 °C **b** 1.0×10^{-7} m
c 1.806×10^{21} atoms

2 **a** 0.000 0055 **b** 290
c 11150 **d** 0.001 412
e 72

3 **a** 36.9 **b** 260
c 0.043 **d** 8 000 000

4 Number of molecules = 0.5 moles × 6.022×10^{23} = 3.011×10^{23} = 3.01×10^{23}

5 **a** 4.8 **c** 1.01

6 **a** 0.0003 m
c 1×10^7 kW

b 0.54 **d** 2.000
b 5×10^9 mJ

2 Balancing chemical equations

1 **a** $2C + O_2 \rightarrow 2CO$ **b** $N_2 + 3H_2 \rightarrow 2NH_3$

c $C_2H_4 + 3O_2 \rightarrow 2H_2O + 2CO_2$

2 **a** $C_6H_{14} + 9\frac{1}{2}O_2 \rightarrow 6CO_2 + 7H_2O$ **or** $2C_6H_{14} + 19O_2 \rightarrow 12CO_2 + 14H_2O$

b $2NH_2CH_2COOH + 4\frac{1}{2}O_2 \rightarrow 4CO_2 + 5H_2O + N_2$

or $4NH_2CH_2COOH + 9O_2 \rightarrow 8CO_2 + 10H_2O + 2N_2$

3 **a** $Mg(OH)_2 + 2HNO_3 \rightarrow Mg(NO_3)_2 + 2H_2O$

b $3Fe(NO_3)_2 + 2Na_3PO_4 \rightarrow Fe_3(PO_4)_2 + 6NaNO_3$

3 Rearranging equations and calculating concentrations

1 **a** $n = cv$ **b** $v = \frac{n}{c}$

2 **a** $n = \frac{PV}{RT}$ **b** $T = \frac{PV}{nR}$

3 $\frac{0.2}{0.050} = 4.0 \text{ mol dm}^{-3}$

4 $\frac{0.05}{2} = 0.025 \text{ mol dm}^{-3}$

5 $\frac{36}{1000} \cdot 0.1 = 3.6 \times 10^{-3} \text{ mol}$

$$\frac{362}{2} \quad \frac{}{RT} \quad \frac{1}{2} \quad \frac{1}{2} \quad \frac{nR}{c}$$

4 Molar calculations

1 **a** $\frac{0.486}{24.3}$ = 0.02 mol

b 0.02 mol

c 0.02 × 40.3 = 0.806 g

2 **a** $\frac{4.25}{}$ = 0.05 mol **b** $\frac{0.05}{}$ = 0.025 mol

3 **a** $\frac{500}{84.3}$ = 5.93 mol **b** 5.93 mol

5 Percentage yields and percentage errors

1 3.19/4.75 × 100 = 67.2%

2 6.25/12.00 × 100 = 52.1%

3 **a** 0.5/21 × 100 = 2.38% **b** 0.5/43 × 100 = 1.16%

4 **a** 0.5 × (2/12) × 100 = 8.33% **b** 0.5 × (2/37.6) × 100 = 2.66

6 Graphs and tangents

1 $\frac{-1.25}{65}$ = −0.0192

CHALLENGE TASK

EXTENSION TASK

Moles and Formulae

To succeed with this topic you need to:

- be able to find A_r (atomic mass number) values from the Periodic Table
- use a calculator to do basic arithmetic

After working through this Factsheet you will be able to:

- calculate M_r (molecular mass number) from A_r values
- calculate percentage composition by mass for a compound
- calculate moles from grams and grams from moles of a substance
- calculate empirical formulae using a variety of different methods
- convert empirical formulae into molecular formulae

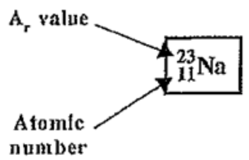
Examination guide

The calculations covered by this Factsheet can appear in nearly every module of the AS and A2 specification. The concepts and methods introduced are the basis of all quantitative chemistry and it is vital you can handle them.

1. Finding M_r (relative molecular mass or formula mass)

The M_r of a compound is found by adding up the relative atomic masses (A_r) of the elements in the compound's formula.

Remember: The A_r value is found from the Periodic Table.



Hint: A_r is always the larger of the two number in the boxes

Example 1: What is the M_r of C_2H_6?

C_2H_6 includes 2 C atoms and 6 H atoms.
So $M_r(C_2H_6) = 2 \times A_r(C) + 6 \times A_r(H)$
(A_r = 12 for C and 1 for H)

$$\therefore\ M_r = (2 \times 12) + (6 \times 1) = 30$$

Example 2: What is the M_r of $Ca(NO_3)_2$?

NB: The small 2 outside the brackets multiplies everything inside the bracket - just like in maths.

So $Ca(NO_3)_2$ includes 1 Ca atom, 2 N atoms and 6 O atoms.
So $M_r(Ca(NO_3)_2) = A_r(Ca) + 2 \times A_r(N) + 6 \times A_r(O)$
(A_r = 40 for Ca, 14 for N and 16 for O)

$$\therefore\ M_r = 40 + (2 \times 14) + (6 \times 16) = 164$$

2. The percentage composition of a compound

You may be asked to find (for example) the percentage of sodium nitrate that is nitrogen. N.B this is a commonly asked examination question!

Method
Step 1:- find M_r (by totalling A_r values)

Step 2:- find % of an element using:

$$\frac{\text{no. of atoms of element} \times A_r}{M_r} \times 100\%$$

Example: What is the percentage by mass of each of the elements present in C_2H_5Br?

$$M_r\ (C_2H_5Br) = (12 \times 2) + (1 \times 5) + (80 \times 1) = 109$$

$$\%\ C = \frac{12 \times 2}{109} \times 100 = 22.02\ \%$$

$$\%\ H = \frac{1 \times 5}{109} \times 100 = 4.59\ \%$$

$$\%\ Br = \frac{80 \times 1}{109} \times 100 = 73.39\ \%$$

Check! these should add up to 100%

3. Moles

What is a mole?

A mole of something is just 6.023×10^{23} of it. A mole of hydrogen atoms is 6.023×10^{23} hydrogen atoms, a mole of water molecules is 6.023×10^{23} water molecules - you could even imagine a mole of people or a mole of cars! The number 6.023×10^{23} is called the Avagadro Number - you do NOT have to learn it!

Exam Hint: - Be careful what it's a mole of! A mole of hydrogen atoms (H) is not the same as a mole of hydrogen molecules (H_2). A mole of hydrogen molecules contains 2 moles of hydrogen atoms! If a question refers to a mole of an element, it means a mole of molecules of that element.

Why that particular number?

Avagadro's number is chosen to "fiddle" it so that one mole of a substance has mass (in grams) equal to the A_r or M_r of that substance. So as hydrogen atoms have $A_r = 1$, one mole of hydrogen atoms will have mass one gram. Similarly, as C_2H_6 has $M_r = 30$, one mole of C_2H_6 will have mass 30 grams. This makes moles easier to work with!

Definition of a mole

The definition of a mole given below probably seems a bit odd, but it is the one that must be given in an exam!

Definition: One mole is the amount of substance which contains the same number of particles (atoms, molecules or ions) as there are atoms in 12.00g of ^{12}C

Calculating with Moles

The important thing is to be able to use the mole in calculations. The basic equation is:

$$\text{Number of moles} = \frac{\text{mass (g)}}{A_r \text{ or } M_r}$$

or rearranged

$$\text{Mass (g)} = \text{moles} \times A_r \text{ or } M_r$$

$$A_r \text{ or } M_r = \frac{\text{mass (g)}}{\text{moles}}$$

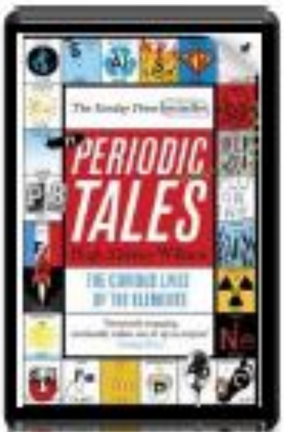
COMPULSORY TASK

Work through the MaChemGuy "Prep for A-level" playlist.
https://tinyurl.com/wzljngt

WIDER READING AND PREPARATION FOR A LEVEL

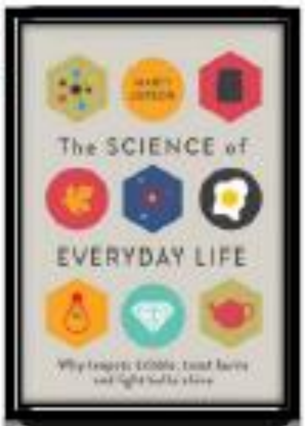
Book Recommendations

Kick back this summer with a good read. The books below are all popular science books and great for extending your understanding of chemistry



Periodic Tales: The Curious Lives of the Elements
This book covers the chemical elements, where they come from and how they are used. There are loads of fascinating insights into uses for chemicals you would have never even thought about.

The Science of Everyday Life: Why Teapots Dribble, Toast Burns and Light Bulbs Shine
The title says it all really, lots of interesting stuff about the things around your home!



Bad Science
Here Ben Goldacre takes apart anyone who published bad / misleading or dodgy science – this book will make you think about everything the advertising industry tries to sell you by making it sound 'sciencey'.

Calculations in AS/A Level Chemistry
If you struggle with the calculations side of chemistry, this is the book for you. Covers all the possible calculations you are ever likely to come across. Brought to you by the same guy who wrote the excellent chemguide.co.uk website.

One of our crowning scientific achievements is also a treasure trove of passion, adventure, betrayal and obsession. The **Disappearing Spoon** follows the elements, their parts in human history, finance, mythology, conflict, the arts, medicine and the lives of the (frequently) mad scientists who discovered them.

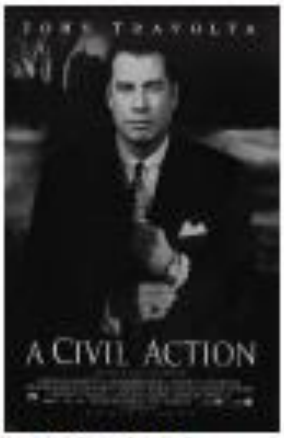
Movie Recommendations

Everyone loves a good story and everyone loves some great science. Here are some of the picks of the best films based on real life scientists and discoveries. You wont find Jurassic Park on this list! We've looked back over the last 50 years to give you our top 5 films you might not have seen before. Great watching for a rainy day.

The Human Experiment (2013)
A documentary that explores chemicals found in everyday household products.

An Inconvenient Truth (2006)
Al Gore, former presidential candidate campaigns to raise public awareness of the dangers of global warming and calls for immediate action to curb its destructive effects on the environment.
(See also: An Inconvenient Sequel, 2017)

A Civil Action (1998)
A tenacious lawyer takes on a case involving a major company responsible for causing several people to be diagnosed with leukemia due to the town's water supply being contaminated, at the risk of bankrupting his firm and career.



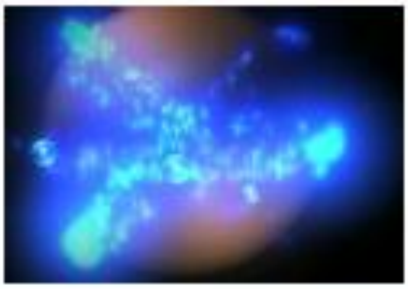
Erin Brokovich (2000)
Based on a true story. An unemployed single mother becomes a legal assistant and almost single-handedly brings down a California power company accused of polluting a city's water supply.

The Insider (1999)
A research chemist comes under personal and professional attack when he decides to appear in a "60 Minutes" expose on Big Tobacco.

Movie Recommendations

If you have 30 minutes to spare, here are some great presentations (and free!) from world leading scientists and researchers on a variety of topics. They provide some interesting answers and ask some thought-provoking questions. Use the link or scan the QR code to view:

Play with Smart Materials
Available at :
https://www.ted.com/talks/catarina_mota_play_with_smart_materials Ink that conducts electricity; a window that turns from clear to opaque at the flip of a switch; a jelly that makes music. All this stuff exists, it's time to play with it. A tour of surprising and cool new materials.



Just how small is an atom?
Available at :
https://www.ted.com/talks/just_how_small_is_an_atom
Just how small are atoms? Really, really, really small. This fast-paced animation from TED-Ed uses metaphors (imagine a blueberry the size of a football stadium!) to give a visceral sense of just how small atoms are.

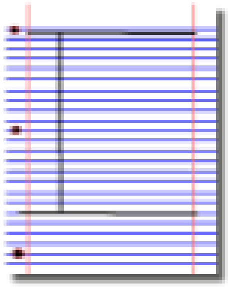
Battling Bad Science
Available at :
https://www.ted.com/talks/ben_goldacre_battling_bad_science#t-44279
Every day there are news reports of new health advice, but how can you know if they're right? Doctor and epidemiologist Ben Goldacre shows us, at high speed, the ways evidence can be distorted, from the blindingly obvious nutrition claims to the very subtle tricks of the pharmaceutical industry.

How Spectroscopy Could Reveal Alien Life
Available at :
https://www.ted.com/talks/garik_israelian_what_s_inside_a_star
Garik Israelian is a spectroscopist, studying the spectrum emitted by a star to figure out what it's made of and how it might behave. It's a rare and accessible look at this discipline, which may be coming close to finding a planet friendly to life.

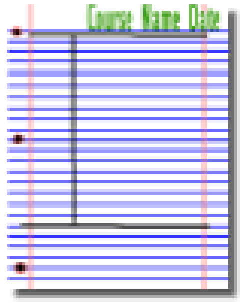
Research Activities

Research, reading and note making are essential skills for A level chemistry study. For the following task you are going to produce 'Cornell Notes' to summarise your reading.

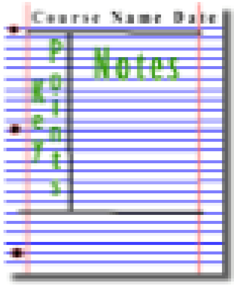
1. Divide your page into three sections like this



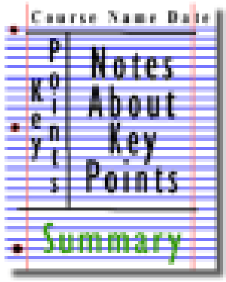
2. Write the name, date and topic at the top of the page



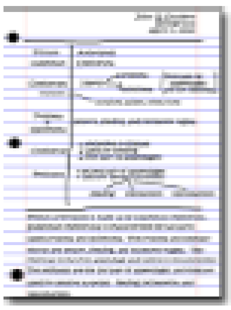
3. Use the large box to make notes. Leave a space between separate idea. Abbreviate where possible.



4. Review and identify the key points in the left hand box



5. Write a summary of the main ideas in the bottom space



Images taken from http://coe.jmu.edu/learningtoolbox/cornellnotes.html

Research Activities

Aimed at students aged 14-19, Catalyst magazine is packed with interesting articles on cutting-edge science, interviews and new research written by leading academics. It also includes a booklet of teacher's notes, full of ideas and lesson plans to bring the articles to life in the classroom.
For each of the following topics you are going to use the resources to produce one page of Cornell style notes.
Use the links of scan the QR code to take you to the resources.

CATALYST

Topic 1: Using Plastics in the Body
Available at:
https://www.stem.org.uk/resources/elibrary/resource/382317/using-plastics-body
This Catalyst article looks at how scientists are learning to use polymers for many medical applications, including implants, bone repairs and reduction in infections.

Topic 2: Catching a Cheat
Available at:
https://www.stem.org.uk/system/files/elibrary-resources/2017/03/Catching%20a%20cheat.pdf
This Catalyst article looks at analytical chemists who are involved in many kinds of testing, including drug testing to catch cheats in sport.

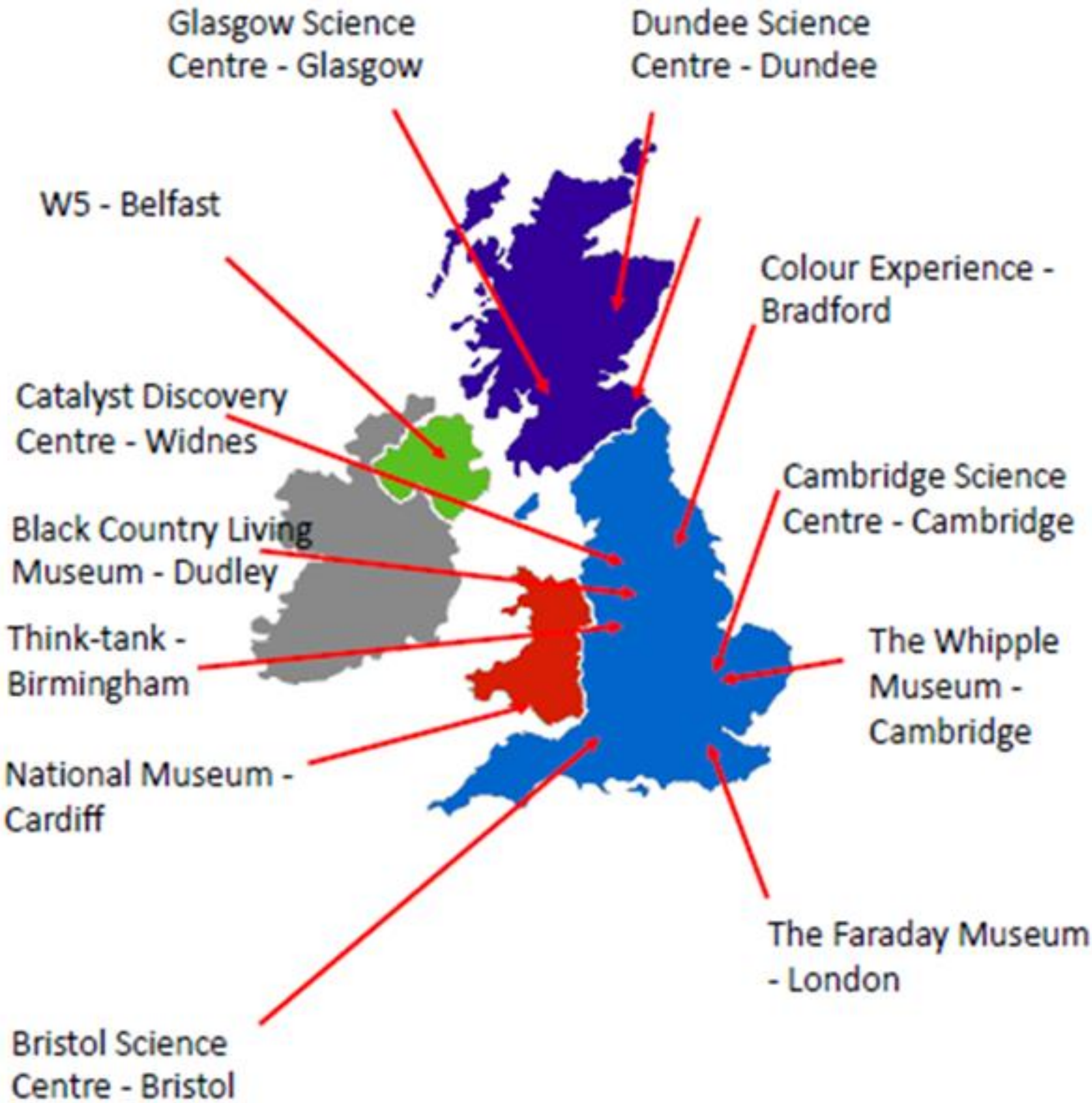
Topic 3: Diamond: More than just a gemstone
Available at:
https://www.stem.org.uk/system/files/elibrary-resources/2017/02/Diamond%20more%20than%20just%20a%20gemstone.pdf
This Catalyst article looks at diamond and graphite which are allotropes of carbon. Their properties, which depend on the bonding between the carbon atoms, are also examined.

Topic 4: The Bizarre World of High Pressure Chemistry
Available at:
https://www.stem.org.uk/system/files/elibrary-resources/2016/11/Catalyst27_1_the_bizarre_world_of_high_pressure_chemistry.pdf
This Catalyst article investigates high pressure chemistry and discovers that, when put under extreme pressure, the properties of a material may change dramatically.

Topic 5: Microplastics and the Oceans
Available at:
https://www.stem.org.uk/system/files/elibrary-resources/2016/11/Catalyst27_1_microplastics_%20and_the_oceans.pdf
This Catalyst article looks at microplastics. Microplastics are tiny particles of polymer used in many products. They have been found to be an environmental pollutant especially in oceans.

Ideas for Day Trips

If you are on holiday in the UK, or on a staycation at home, why not plan a day trip to one of these :



Science on Social Media

Science communication is essential in the modern world and all the big scientific companies, researchers and institutions have their own social media accounts. Here are some of our top tips to keep up to date with developing news or interesting stories:

Follow on Twitter:
Salters' Institute - Our activities include Festivals of Chemistry; Chemistry Camps; Curricula; Awards for Technicians, Graduates, A Level Students; and Seminars
@salters_inst

Daily A Level Chemistry Facts – Daily Chemistry Facts (Based on the A-Level AQA spec but most facts work with all)
@chemAlevels

Chemistry News –The latest chemistry news from only the best sources
@chemistrynews

Compound Interest– Graphics exploring everyday #chemistry. Winner of @absw 2018 science blog award
@compoundchem

Chemistry World – Chemistry magazine bringing you the latest chemistry news and research every day. Published by the Royal Society of Chemistry.
@ChemistryWorld

Royal Society of Chemistry - Promote, support and celebrate chemistry. Follow for updates on latest activities
@RoySocChem

Periodic Videos– Chemistry video series by @BradyHaran & profs at the Uni of Nottingham - also see @sixtysymbols & @numberphile
@periodicvideos

Find on Facebook:
Science Now - Science Now is a dedicated community that helps spread science news in all fields, from physics to biology, medicine to nanotechnology, space and beyond!

National Science Foundation – As an independent federal agency, NSF fund a significant proportion of basic research. For official source information about NSF, visit www.nsf.gov

Science News Magazine - Science covers important and emerging research in all fields of science

BBC Science News - The latest BBC Science and Environment News: breaking news, analysis and debate on science and nature around the world

Scientific American - Scientific American is the authority on science and technology for a general audience, with coverage that explains how research changes our understanding of the world and shapes our lives.

These are some textbooks which you may find interesting and useful before and during your AS-Level Chemistry course.

*Essential Maths Skills for AS/A-Level Chemistry
By Nora Henry
Published by Philip Allan for Hodder Education
ISBN 978 1 4718 6349 3

*A-Level Year 1, Chemistry, OCR A
Complete Revision and Practice
Published by CGP
ISBN 9781782943402

*A-Level Year 1, Chemistry, OCR A
Complete Revision and Practice
Published by CGP
ISBN 978 1 78294 340 2

*Aspirin. The Story of a Wonder Drug
By D.Jeffreys
Published by Bloomsbury
ISBN 9781582346007

*Periodic Tales, The Curious Lives of the Elements
By Hugh Aldersey-Williams
Published by Penguin
ISBN 978-0141041452

USEFUL WEBSITES

Chemguide	www.chemguide.co.uk
Rod's pages	http://rod.beavon.org.uk/index.htm
Knockhardy	http://www.knockhardy.org.uk/sci.htm
Amazing grades	www.amazing-grades.com
Memrise	https://www.memrise.com/
Doc Brown	http://www.docbrown.info/
S-cool Revision	https://www.s-cool.co.uk/a-level/chemistry
Chemrevise	https://chemrevise.org/
Crash course	https://www.youtube.com/user/crashcourse/featured

Science: Things to do!

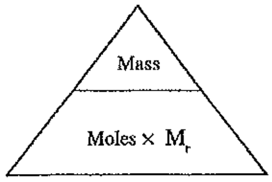
Day 4 of the holidays and boredom has set in?
There are loads of citizen science projects you can take part in either from the comfort of your bedroom, out and about, or when on holiday. Wikipedia does a comprehensive list of all the current projects taking place. Google "citizen science project"

MOOC

Want to stand above the rest when it comes to UCAS? Now is the time to act.
MOOCs are online courses run by nearly all universities. They are short FREE courses that you take part in. They are usually quite specialist, but aimed at the public, not the genius!
There are lots of websites that help you find a course, such as edX and Future learn.
You can take part in any course, but there are usually start and finish dates.
They mostly involve taking part in web chats, watching videos and interactives.

Completing a MOOC will look great on your Personal statement and they are dead easy to take part in!

Some students find the 'triangle method' useful in remembering and rearranging equations.



You cover up the thing in the triangle you want to find. Then, what you can see tells you the calculation to do. For example, if you want to find moles, cover it up and you are left with mass/M_r

This method can be used for ANY equation that has a fraction on one side and just one thing on the other side. Whatever is on the top of the fraction goes in the top of the triangle.

Here are some examples:

Example 1: How many moles are there in 6g of C?

$$\text{moles} = \frac{\text{mass(g)}}{A_r} \quad (A_r = 12 \text{ for C})$$

$$\therefore \text{ moles} = \frac{6}{12} = 0.5 \text{ moles}$$

Example 2: How many moles are there in 36g of H_2O?

Since M_r is in the formula, we must calculate this first

$$M_r(H_2O) = (1 \times 2) + (16 \times 1) = 18$$

$$\text{moles} = \frac{\text{mass(g)}}{M_r} = \frac{36}{18} = 2 \text{ moles}$$

Example 3: What is the mass of 0.5 moles of H_2S?

$$M_r(H_2S) = (1 \times 2) + (32 \times 1) = 34$$

$$\text{mass(g)} = \text{moles} \times M_r = 0.5 \times 34 = 17 \text{ g}$$

Example 4: 0.2 moles of a metal have a mass of 4.6g.

i) Calculate the element's atomic mass

ii) Suggest an identity for the metal.

$$\text{i) } A_r = \frac{\text{mass(g)}}{\text{moles}} = \frac{4.6}{0.2} = 23$$

ii) Looking at the Periodic Table, we see that sodium has an atomic mass of 23, and it is a metal.

***Challenge Question:** Does the metal HAVE to be sodium?*

Answer: No. It is the most likely answer, but isotopes of other metals could have atomic mass 23.

4. Empirical and Molecular Formulas

For <u>calculation</u> purposes there are 2 types of formulae you need to know:

- The **empirical formula (ef)** shows the ratio of the atoms present in their lowest terms i.e. cancelled down to smallest whole numbers.
- The **molecular formula (mf)** shows the actual number of each type of atom present in one molecule.

Finding Empirical Formulae

There are several ways to calculate empirical formulae, and these are shown below in order of increasing difficulty:-

1. Calculating EF from Moles

What is the EF of the compound formed when 6 moles of potassium atoms react with 3 moles of oxygen atoms?

	K:O	
Moles	6:3	
Simplest ratio	2:1	(divided by 3)
EF =	K_2O	

2. Calculating EF from Mass

What is the EF of the compound formed when 6g of carbon reacts with 32g of sulphur?

First find moles:

$$\text{moles C} = \frac{6}{12} = 0.5 \quad \text{Moles S} = \frac{32}{32} = 1$$

	C:S	
moles	0.5:1	(now divide by 0.5 - the smaller number)
Simplest ratio	1:2	
EF = CS_2		

3. Calculating EF from Percentage Composition

NB. This is the most commonly examined method of finding EF. The approach is exactly the same as calculating from mass; you treat the percentages as if they are masses. One method of approaching these is using a table, as shown below - but you must use whichever style of presentation you are most comfortable with.

What is the empirical formula for the compound which contains the following elements by percentage composition of mass?

C = 66.67%, H = 11.11%, O = 22.22%

Element	%	A_r	% ÷ A_r	Ratio *
C	66.67	12	5.56	5.56 ÷ 1.39 = 4
H	11.11	1	11.11	11.11 ÷ 1.39 = 8
O	22.22	16	1.39	1.39 ÷ 1.39 = 1

EF = C_4H_8O

*To find the ratio column, take the smallest of the %÷A_r values (which is 1.39 here) and divide all the %÷A_r values by it.

4. Calculating EF from Combustion Data

This method is one step up in difficulty from the last example because you have to calculate the masses of the elements first. The combustion products are always oxides. CO_2 and H_2O are the commonest and the following example uses these, although the method can be adapted for others.

Method

Step1:- find mass of the carbon and hydrogen using

$$\text{mass of oxide} \times \frac{\text{no. of atoms of element} \times A_r}{M_r \text{ for oxide}}$$

Find the mass of any other element in the compound by subtraction.

Step 2:- convert mass to moles for each element by dividing by A_r

Step 3:- find the simplest ratio by dividing all the values from step 2 by the smallest of them.

Example: 1g of a compound undergoes complete combustion and produces 2.38g of CO_2 and 1.215g of H_2O. The compound contains only C, H and O. What is its empirical formula?

Step 1: M_r for CO_2 = 44

$$\text{So mass of C} = 2.38 \times \frac{12}{44} = 0.65\text{g}$$

M_r for H_2O = 18

$$\text{So mass of H} = 1.215 \times \frac{2 \times 1}{18} = 0.135\text{g}$$

Mass of O = 1 - 0.65 - 0.135 = 0.215g

Step 2: Moles of C = 0.65 ÷ 12 = 0.054167
Moles of H = 0.135 ÷ 1 = 0.135
Moles of O = 0.215 ÷ 16 = 0.0134375

Step 3: Ratio is:
C : 0.054167 ÷ 0.0134375 = 4
H : 0.135 ÷ 0.0134375 = 10
O : 0.0134375 ÷ 0.0134375 = 1
So the empirical formula is $C_4H_{10}O$

Finding Molecular Formulae

To do this, you need to know (or be able to find) the empirical formula and M_r for the compound.

> Method
> Step 1:- divide M_r by EF formula mass to get scale factor
> Step 2:- multiply EF by scale factor to give MF

Example 1: If the EF = CH_2 and M_r = 42, what is the MF?

$$EF = CH_2 \quad M_r(CH_2) = (12) + (1 \times 2) = 14$$

$$\frac{42}{14} = 3$$

$$\therefore MF = (CH_2) \times 3 = C_3H_6$$

Example 2: 0.24 moles of a compound, containing carbon and hydrogen only, have mass 18.72 grams. On complete combustion, this amount of the compound yields 63.36g of carbon dioxide and 12.96g of water. Find the molecular formula of this compound.

First find the EF. We use the combustion data for this:

$$\text{Mass of C} = 63.36 \times \frac{12}{44} = 17.28\text{g}$$

$$\text{Mass of H} = 12.96 \times \frac{2 \times 1}{18} = 1.44\text{g}$$

Moles of C = 17.28 ÷ 12 = 1.44
Moles of H = 1.44 ÷ 1 = 1.44
So ratio is 1:1 and EF is CH

Now we need M_r in order to find the molecular formula.
We must use the other information in the question:
M_r = mass ÷ moles = 18.72 ÷ 0.24 = 78
M_r (CH) = 13.
78 ÷ 13 = 6
So MF = (CH) × 6 = C_6H_6

Practice Questions

Mole calculations (except for volumetric analysis) make up parts of 'A' level questions. The 13 questions below are designed to give you practice in the different types covered by this Factsheet.

1. Calculating moles of elements (using A_r values)
How many moles are there in each of the following?

(a) 46g Na (b) 12g Mg
(c) 44g Sr (d) 21g Li
(e) 64g S (f) 127g I_2
(g) 64g O_2 (h) 7g Si
(i) 7g N_2 (j) 142g Cl_2
(k) 12.5g of bromine gas (l) 0.787g of neon
(m) 37.9g of fluorine gas (n) 1.89g of potassium
(o) 7.14g of oxygen gas

2. Calculating the mass of element (using A_r values)
What is the mass (in g) of each of the following?

(a) 4 moles A_r (b) 0.5 moles Ca
(c) 0.75 moles Mg (d) 1.5 moles Li
(e) 2 moles Fe (f) 0.5 moles Br_2
(g) 7 moles I_2 (h) 2.5 moles O_2
(i) 3 moles Cu (j) 0.25 moles C
(k) 0.18 moles of fluorine gas (l) 1.75 moles of argon
(m) 0.102 moles of silver (n) 12.5 moles of lead
(n) 3.9 moles of sodium

3. Calculating A_r values from mass and moles
What is the A_r value of the following elements?

(a) 0.27 moles of Pl has a mass of 55.89g
(b) 18g of O_2 contains 0.563 moles
(c) 0.40 moles of S has a mass of 12.8g
(d) 240g of Ca contains 6 moles
(e) 14.80g of Mg contains 0.617 moles

4. Finding relative molecular mass (M_r) from relative atomic masses (A_r)
What is the relative molecular mass of the following?

(a) CO_2 (b) H_2O (c) H_2SO_4
(d) SO_3 (e) CH_4 (f) $(CH_3)_2CO$
(g) C_2H_5OH (h) $MgCO_3$ (i) $Cu(NO_3)_2$
(j) $SiCl_4$ (k) $Na_2CO_3.10\ H_2O$
(l) $CuSO_4.5H_2O$ (m) $CH_3\ (CH_2)_5\ Br$
(n) $Na_2S_2O_3.5H_2O$ (o) Cl_2O_7

5. Calculating moles of compounds (using M_r values)
How many moles are there in each of the following?
(a) 32g SO_2 (b) 90g C_2H_6 (c) 160g SO_3
(d) 22g CO_2 (e) 8g CH_4 (f) 8g MgO
(g) 100g Ca CO_3 (h) 2g CO (i) 14g SiO_2
(j) 80g NO_2 (k) 30.5g $LiNO_3$ (l) 0.87g C_2H_5OH
(m) 6.9g HNO_3 (n) 18g $Na_2CO_3.10H_2O$
(o) 21.55g $CaCl_2$

6. Calculating the mass of compounds (using M_r values)
What is the mass (in g) of each of the following?
(a) 2 moles C_4H_8 (b) 0.33 moles CO
(c) 5 moles CaO (d) 1.5 moles NO
(e) 0.1 moles C_3H_7OH (f) 0.2 moles Na_2O
(g) 0.5 moles $CaCO_3$ (h) 2.7 moles H Cl
(i) 0.7 moles Na Cl (j) 8 moles C_4H_9Br
(k) 4.6 moles H_2SO_4 (l) 0.012 moles C_2H_6
(m) 4 moles ClO_4 (n) 0.25 moles $(CH_3)_2$ I
(o) 0.56 moles $MgCl_2$

7. Calculating M_r values from mass and moles
   What is the M_r value for each of the following compounds?
   (a) 1.0g of compound A contains 0.0208 moles
   (b) 1.5 moles of compound B has a mass of 105g
   (c) 14.8g of compound C contains 0.117 moles
   (d) 7.0g of compound D contains 0.219 moles
   (e) 0.24 moles of compound E has a mass of 13.92g

8. Find the percentage composition by mass of elements in a compound
   What is the percentage composition by mass of each element in the following compounds?
   (a) $SiCl_4$ (b) C_2H_6 (c) Na_2CO_3
   (d) $CaBr_2$ (e) $CuSO_4.5H_2O$

9. Calculating empirical formula from moles
   What is the empirical formula of compounds with the following composition?
   (a) 2 moles Na with 2 moles I
   (b) 0.1 moles K with 0.05 moles O
   (c) 0.5 moles N with 1.5 moles H
   (d) 0.2 moles Mg with 0.4 moles Cl
   (e) 1.2 moles of a carbon oxide contains 0.4 moles of carbon

10. Calculating empirical formula from mass
    What is the empirical formula of compounds with the following composition by mass?
    (a) 12g C with 16g O
    (b) 6g Mg with 4g O
    (c) 46g Na with 80g Br
    (d) 14g N reacting with H to form 17g of compound
    (e) 22g Sr reacting with O to form 26g of compound

11. Calculating empirical formula from percentage composition
    What is the empirical formula of each of the following compounds?
    (a) 80% C, 20%H
    (b) 52.2% C, 13.1% H, 34.7% O
    (c) 40.4% C, 7.9% H, 15.7% N, 36.0% O
    (d) 38.7% C, 9.7% H, 51.6% S
    (e) 40.2% K, 26.9% Cr, 32.9% O
    (f) 85.25% $BaCl_2$, 14.75% water of crystallisation

12. Calculating empirical formula from combustion data
    What is the empirical formula of each of the following compounds?
    (a) Complete combustion of 1.0g of a compound produced 2.99g CO_2 and 1.64g H_2O
    (b) 1.0g of a compound underwent complete combustion and produced 3.035g CO_2 and 1.55g H_2O
    (c) 2.0g of a compound produced 5.86g CO_2 and 3.6g H_2O on complete combustion
    (d) A compound made of carbon, hydrogen and oxygen produced 2.2g CO_2 and 1.2g H_2O when 1.0g of it underwent complete combustion

13. Finding molecular formula from empirical formula and M_r
    What is the molecular formula of the following?
    (a) E.F. = CH $M_r = 72$
    (b) E.F. = C_2H_2O $M_r = 42$
    (c) E.F. = C_2H_3Br $M_r = 214$
    (d) E.F. = CH_2O $M_r = 120$
    (e) E.F. = NaO $M_r = 78$