Transition Pack for A Level Chemistry

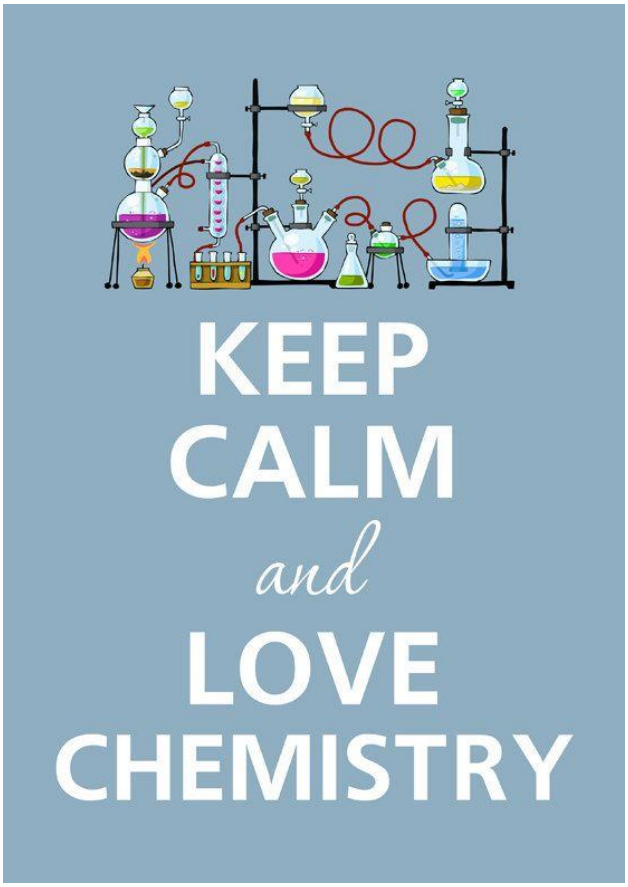
Tasks

1. Optional: Videos, recommended books and places to visit.
2. Use your online searching abilities to see if you can find out as much about the **5 topics** as you can. Remember it you are a prospective A level chemist, you should aim to push **your** knowledge. Answers to questions are at the end. **Make a 1-page summary for each one you research using Cornell notes (no more than a page for each!)**
3. Complete the GCSE basics sheets and self-mark. (Should be a quick one after the 5 topics)
4. Complete the final baseline assessment at the end of the booklet and self mark. Answers to questions are at the end.
5. FINALLY (yes there is a 'FINALLY'), you will be expected to read **AND** briefly review one of two books (or maybe even both, if you are an avid reader):

    - 'Bad Science', by Ben Goldacre, about the truth in science (Brilliant!)
    - 'A Short Story of Nearly Everything', by Bill Bryson (equally brilliant!)

    YOU CAN PICK A DIFFERENT SCIENCE BOOK IF YOU HAVE ALREADY READ THESE

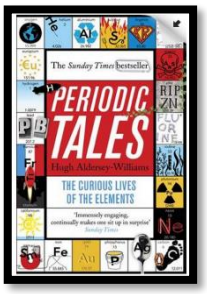
So you are considering A Level Chemistry?



This pack contains a programme of activities and resources to prepare you to start an A level in Chemistry in September. It is aimed to be used after you complete your GCSE, throughout the remainder of the summer term and over the Summer Holidays to ensure you are ready to start your course in September.

Book Recommendations Optional

Periodic Tales: The Curious Lives of the Elements (Paperback) Hugh Aldersey-Williams

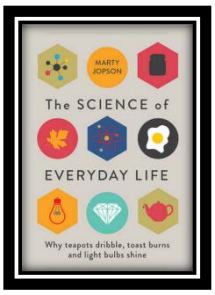


ISBN-10: 0141041455

http://bit.ly/pixlchembook1

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 (Hardback) Marty Jopson

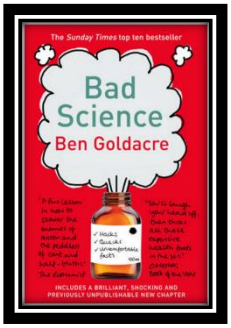


ISBN-10: 1782434186

http://bit.ly/pixlchembook2

The title says it all really, lots of interesting stuff about the things around you home!

Bad Science (Paperback) Ben Goldacre

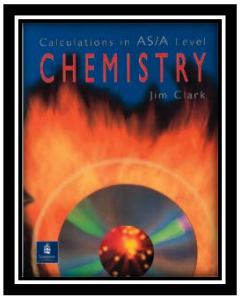


ISBN-10: 000728487X

http://bit.ly/pixlchembook3

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 'sciency'.

Calculations in AS/A Level Chemistry (Paperback) Jim Clark



ISBN-10: 0582411270

http://bit.ly/pixlchembook4

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.

Salters' Advanced Chemistry: Chemical Storylines

Do not feel you need to buy the latest edition (unless you are doing Salters chemistry!) You can pick up an old edition for a few pounds on ebay, gives you a real insight into how chemistry is used to solve everyday problems from global pollution through feeding to world to making new medicines to treat disease.

Videos to watch online Optional

Rough science – the Open University – 34 episodes available

Real scientists are 'stranded' on an island and are given scientific problems to solve using only what they can find on the island.

Great fun if you like to see how science is used in solving problems.

There are six series in total

http://bit.ly/pixlchemvid1a

http://www.dailymotion.com/playlist/x2igjq_Rough-Science_rough-science-full-series/1#video=xxw6pr

or

http://bit.ly/pixlchemvid1b

https://www.youtube.com/watch?v=lUoDWAt259I

A thread of quicksilver – The Open University

A brilliant history of the most mysterious of elements – mercury. This program shows you how a single substance led to empires and war, as well as showing you come of the cooler properties of mercury.

http://bit.ly/pixlchemvid2

https://www.youtube.com/watch?v=t46lvTxHHTA

10 weird and wonderful chemical reactions

10 good demonstration reactions, can you work out the chemistry of …. any… of them?

http://bit.ly/pixlchemvid3

https://www.youtube.com/watch?v=0Bt6RPP2ANI

Chemistry in the Movies

Dantes Peak 1997: Volcano disaster movie.

Use the link to look at the Science of acids and how this links to the movie.
http://www.open.edu/openlearn/science-maths-technology/science/chemistry/dantes-peak

http://www.flickclip.com/flicks/dantespeak1.html

http://www.flickclip.com/flicks/dantespeak5.html

Fantastic 4 2005 &2015: Superhero movie

Michio Kaku explains the "real" science behind fantastic four http://nerdist.com/michio-kaku-explains-the-real-science-behind-fantastic-four/

http://www.flickclip.com/flicks/fantastic4.html

Research activities

Use your online searching abilities to see if you can find out as much about the topic as you can. Remember it you are a prospective A level chemist, you should aim to push **your** knowledge.

You can make a 1-page summary for each one you research using Cornell notes:

http://coe.jmu.edu/learningtoolbox/cornellnotes.html

Task 1: The chemistry of fireworks

What are the component parts of fireworks? What chemical compounds cause fireworks to explode? What chemical compounds are responsible for the colour of fireworks?

Task 2: Why is copper sulfate blue?

Copper compounds like many of the transition metal compounds have got vivid and distinctive colours – but why?

Task 3: Aspirin

What was the history of the discovery of aspirin, how do we manufacture aspirin in a modern chemical process?

Task 4: The hole in the ozone layer

Why did we get a hole in the ozone layer? What chemicals were responsible for it? Why were we producing so many of these chemicals? What is the chemistry behind the ozone destruction?

Task 5: ITO and the future of touch screen devices

ITO – indium tin oxide is the main component of touch screen in phones and tablets. The element indium is a rare element and we are rapidly running out of it. Chemists are desperately trying to find a more readily available replacement for it. What advances have chemists made in finding a replacement for it?

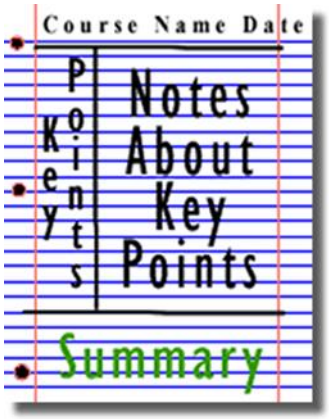


Figure 1: http://coe.jmu.edu/learningtoolbox/images/noteb4.gif

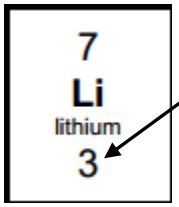
Pre-Knowledge Topics

Chemistry topic 1 – Electronic structure, how electrons are arranged around the nucleus

A periodic table can give you the proton / atomic number of an element, this also tells you how many electrons are in the ***atom***.

You will have used the rule of electrons shell filling, where:

The first shell holds up to 2 electrons, the second up to 8, the third up to 8 and the fourth up to 18 (or you may have been told 8).



Atomic number =3, electrons = 3, arrangement 2 in the first shell and 1 in the second or

Li = 2,1

At **A level** you will learn that the electron structure is more complex than this, and can be used to explain a lot of the chemical properties of elements.

The 'shells' can be broken down into 'orbitals', which are given letters:'s' orbitals, 'p' orbitals and 'd' orbitals.

You can read about orbitals here:

http://bit.ly/pixlchem1

http://www.chemguide.co.uk/atoms/properties/atomorbs.html#top

Now that you are familiar with s, p and d orbitals try these problems, write your answer in the format:

$1s^2$, $2s^2$, $2p^6$ etc.

Q1.1 Write out the electron configuration of:

a) Ca b) Al c) S d) Cl e) Ar f) Fe g) V h) Ni i) Cu j) Zn k) As

Q1.2 Extension question, can you write out the electron arrangement of the following ***ions***:

a) K^+ b) O^{2-} c) Zn^{2+} d) V^{5+} e) Co^{2+}

Chemistry topic 2 – Oxidation and reduction

At GCSE you know that oxidation is adding oxygen to an atom or molecule and that reduction is removing oxygen, or that oxidation is removing hydrogen and reduction is adding hydrogen. You may have also learned that oxidation is removing electrons and reduction is adding electrons.

At A level we use the idea of ***oxidation number*** a lot!

You know that the metals in group 1 react to form ions that are +1, i.e. Na^+ and that group 7, the halogens, form -1 ions, i.e. Br -.

We say that sodium, when it has reacted has an oxidation number of +1 and that bromide has an oxidation number of -1.

All atoms that are involved in a reaction can be given an oxidation number.

An element, Na or O_2 is always given an oxidation state of zero (0), any element that has reacted has an oxidation state of + or -.

As removing electrons is **reduction**, if, in a reaction the element becomes **more** negative it has been reduced, if it becomes more positive it has been oxidised.

You can read about the rules for assigning oxidation numbers here:

http://www.dummies.com/how-to/content/rules-for-assigning-oxidation-numbers-to-elements.html

Elements that you expect to have a specific oxidation state actually have different states, so for example you would expect chlorine to be -1, it can have many oxidation states: NaClO, in this compound it has an oxidation state of +1

There are a few simple rules to remember:

Metals have a + oxidation state when they react.

Oxygen is has an oxidation state of -2, unless its with fluorine +2 and hydrogen in H_2O_2 -1.

Hydrogen has an oxidation state of +1 (except metal hydrides)

The charges in a molecule must cancel.

Examples: Sodium nitrate, $NaNO_3$ sulfate ion, SO_4^{2-}

Na +1 3x O^{2-} 4xO^{2-} and 2- charges 'showing'

+1 -6 -8 -2

To cancel: N = +5 S = +6

Q2.1 Work out the oxidation state of the **underlined** atom in the following:

a) $Mg\underline{C}O_3$ b) $\underline{S}O_3$ c) $NaClO_3$ d) MnO_2 e) Fe_2O_3 f) V_2O_5

g) $KMnO_4$ h) $Cr_2O_7^{2-}$ i) Cl_2O_4

Chemistry topic 3 – Isotopes and mass

You will remember that an isotopes are elements that have differing numbers of neutrons. Hydrogen has 3 isotopes; H_1^1 H_1^2 H_1^3

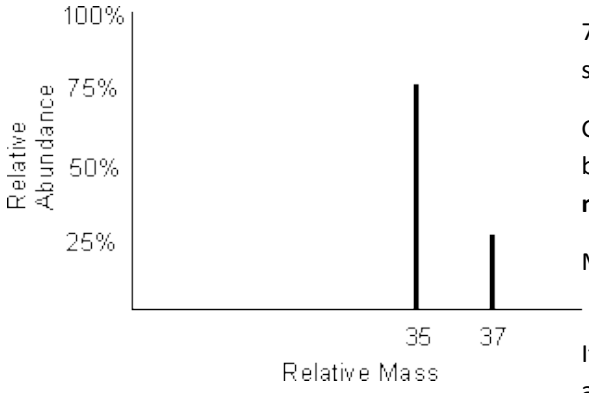
Isotopes occur naturally, so in a sample of an element you will have a mixture of these isotopes. We can accurately measure the amount of an isotope using a **mass spectrometer**. You will need to understand what a mass spectrometer is and how it works at A level. You can read about a mass spectrometer here:

http://bit.ly/pixlchem3
http://www.kore.co.uk/tutorial.htm
http://bit.ly/pixlchem4
http://filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-TN-MASS-SPECTROMETRY.PDF

Q3.1 What must happen to the atoms before they are accelerated in the mass spectrometer?

Q3.2 Explain why the different isotopes travel at different speeds in a mass spectrometer.

A mass spectrum for the element chlorine will give a spectrum like this:



75% of the sample consist of chlorine-35, and 25% of the sample is chlorine-37.

Given a sample of naturally occurring chlorine ¾ of it will be Cl-35 and ¼ of it is Cl-37. We can calculate what the **mean** mass of the sample will be:

Mean mass = $\frac{75}{100} \times 35 + \frac{25}{100} \times 37 = 35.5$

If you look at a periodic table this is why chlorine has an atomic mass of 35.5.

http://www.avogadro.co.uk/definitions/ar.htm

An A level periodic table has the masses of elements recorded much more accurately than at GCSE. Most elements have isotopes and these have been recorded using mass spectrometers.

GCSE

11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9
27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17

A level

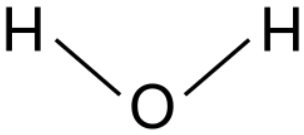
10.8 $^{5}_{}$**B** boron	12.0 $^{6}_{}$**C** carbon	14.0 $^{7}_{}$**N** nitrogen	16.0 $^{8}_{}$**O** oxygen	19.0 $^{9}_{}$**F** fluorine
27.0 $^{13}_{}$**Al** aluminium	28.1 $^{14}_{}$**Si** silicon	31.0 $^{15}_{}$**P** phosphorus	32.1 $^{16}_{}$**S** sulphur	35.5 $^{17}_{}$**Cl** chlorine

Given the percentage of each isotope you can calculate the mean mass which is the accurate atomic mass for that element.

Q3.3 Use the percentages of each isotope to calculate the accurate atomic mass of the following elements.

a) Antimony has 2 isotopes: Sb-121 57.25% and Sb-123 42.75%
b) Gallium has 2 isotopes: Ga-69 60.2% and Ga-71 39.8%
c) Silver has 2 isotopes: Ag-107 51.35% and Ag-109 48.65%
d) Thallium has 2 isotopes: Tl-203 29.5% and Tl-205 70.5%
e) Strontium has **4** isotopes: Sr-84 0.56%, Sr-86 9.86%, Sr-87 7.02% and Sr-88 82.56%

Chemistry topic 4 – The shapes of molecules and bonding.



Have you ever wondered why your teacher drew a water molecule like this?

The lines represent a covalent bond, but why draw them at an unusual angle?

If you are unsure about covalent bonding, read about it here:

http://bit.ly/pixlchem5

http://www.chemguide.co.uk/atoms/bonding/covalent.html#top

At A level you are also expected to know how molecules have certain shapes and why they are the shape they are.

You can read about shapes of molecules here:

http://bit.ly/pixlchem6

http://www.chemguide.co.uk/atoms/bonding/shapes.html#top

Q4.1 Draw a dot and cross diagram to show the bonding in a molecule of aluminium chloride ($AlCl_3$)

Q4.2 Draw a dot and cross diagram to show the bonding in a molecule of ammonia (NH_3)

Q4.3 What is the shape and the bond angles in a molecule of methane (CH_4)?

Chemistry topic 5 – Chemical equations

Balancing chemical equations is the stepping stone to using equations to calculate masses in chemistry.

There are loads of websites that give ways of balancing equations and lots of exercises in balancing.

Some of the equations to balance may involve strange chemical, don't worry about that, the key idea is to get balancing right.

http://bit.ly/pixlchem7

http://www.chemteam.info/Equations/Balance-Equation.html

This website has a download; it is safe to do so:

http://bit.ly/pixlchem8

https://phet.colorado.edu/en/simulation/balancing-chemical-equations

Q5.1 Balance the following equations

a. $H_2 + 0_2 \rightarrow H_20$

b. $S_8 + 02 \rightarrow SO_3$

c. $HgO \rightarrow Hg + 0_2$

d. $Zn + HCl \rightarrow ZnCl_2 + H_2$

e. $Na + H_20 \rightarrow NaOH + H_2$

f. $C_{10}H_{16} + Cl_2 \rightarrow C + HCl$

g. $Fe + 0_2 \rightarrow Fe_20_3$

h. $C_6H_{12}O_6 + 0_2 \rightarrow C0_2 + H_20$

i. $Fe_20_3 + H_2 \rightarrow Fe + H_20$

j. $Al + FeO \rightarrow Al_2O_3 + Fe$

Chemistry topic 6 – Measuring chemicals – the mole

From this point on you need to be using an A level periodic table, not a GCSE one you can view one here:

http://bit.ly/pixlpertab

https://secondaryscience4all.files.wordpress.com/2014/08/filestore_aqa_org_uk_subjects_aqa-2420-w-trb-ptds_pdf.png

Now that we have our chemical equations balanced, we need to be able to use them in order to work out masses of chemicals we need or we can produce.

The ***mole*** is the chemists equivalent of a dozen, atoms are so small that we cannot count them out individually, we weigh out chemicals.

For example: magnesium + sulfur → magnesium sulfide

Mg + S → MgS

We can see that one atom of magnesium will react with one atom of sulfur, if we had to weigh out the atoms we need to know how heavy each atom is.

From the periodic table: Mg = 24.3 and S = 32.1

If I weigh out exactly 24.3g of magnesium this will be 1 mole of magnesium, if we counted how many atoms were present in this mass it would be a huge number (6.02×10^{23}!!!!), if I weigh out 32.1g of sulfur then I would have 1 mole of sulfur atoms.

So 24.3g of Mg will react precisely with 32.1g of sulfur, and will make 56.4g of magnesium sulfide.

Here is a comprehensive page on measuring moles, there are a number of descriptions, videos and practice problems.

You will find the first 6 tutorials of most use here, and problem sets 1 to 3.

http://bit.ly/pixlchem9

http://www.chemteam.info/Mole/Mole.html

Q6.1 Answer the following questions on moles.

a) How many moles of phosphorus pentoxide (P_4O_{10}) are in 85.2g?
b) How many moles of potassium in 73.56g of potassium chlorate (V) ($KClO_3$)?

c) How many moles of water are in 249.6g of hydrated copper sulfate(VI) ($CuSO_4.5H_2O$)? For this one, you need to be aware the dot followed by $5H_2O$ means that the molecule comes with 5 water molecules so these have to be counted in as part of the molecules mass.
d) What is the mass of 0.125 moles of tin sulfate ($SnSO_4$)?
e) If I have 2.4g of magnesium, how many g of oxygen(O_2) will I need to react completely with the magnesium? $2Mg + O_2 \rightarrow MgO$

Chemistry topic 7 – Solutions and concentrations

In chemistry a lot of the reactions we carry out involve mixing solutions rather than solids, gases or liquids.

You will have used bottles of acids in science that have labels saying 'Hydrochloric acid 1M', this is a solution of hydrochloric acid where 1 mole of HCl, hydrogen chloride (a gas) has been dissolved in $1dm^3$ of water.

The dm^3 is a cubic decimetre, it is actually 1 litre, but from this point on as an A level chemist you will use the dm^3 as your volume measurement.

http://bit.ly/pixlchem10

http://www.docbrown.info/page04/4_73calcs11msc.htm

Q7.1

a) What is the concentration (in mol dm^{-3}) of 9.53g of magnesium chloride ($MgCl_2$) dissolved in $100cm^3$ of water?
b) What is the concentration (in mol dm^{-3}) of 13.248g of lead nitrate ($Pb(NO_3)_2$) dissolved in $2dm^3$ of water?
c) If I add $100cm^3$ of 1.00 mol dm^3 HCl to $1.9dm^3$ of water, what is the molarity of the new solution?
d) What mass of silver is present in $100cm^3$ of 1moldm^{-3} silver nitrate ($AgNO_3$)?
e) The Dead Sea, between Jordan and Israel, contains 0.0526 moldm^{-3} of Bromide ions (Br^-), what mass of bromine is in $1dm^3$ of Dead Sea water?

Chemistry topic 8 – Titrations

One key skill in A level chemistry is the ability to carry out accurate titrations, you may well have carried out a titration at GCSE, at A level you will have to carry them out very precisely **and** be able to describe in detail how to carry out a titration - there will be questions on the exam paper about how to carry out practical procedures.

You can read about how to carry out a titration here, the next page in the series (page 5) describes how to work out the concentration of the unknown.

http://bit.ly/pixlchem11

http://www.bbc.co.uk/schools/gcsebitesize/science/triple_aqa/further_analysis/analysing_substances/revision/4/

Remember for any titration calculation you need to have a balanced symbol equation; this will tell you the ratio in which the chemicals react.

E.g. a titration of an unknown sample of sulfuric acid with sodium hydroxide.

A 25.00cm^3 sample of the unknown sulfuric acid was titrated with 0.100$moldm^{-3}$ sodium hydroxide and required exactly 27.40cm^3 for neutralisation. What is the concentration of the sulfuric acid?

Step 1: the equation $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Step 2; the ratios 2 : 1

Step 3: how many moles of sodium hydroxide $27.40cm^3 = 0.0274dm^3$

number of moles = c x v = 0.100 x 0.0274 = 0.00274 moles

step 4: Using the ratio, how many moles of sulfuric acid

for every 2 NaOH there are 1 H_2SO_4 so, we must have 0.00274/2 =0.00137 moles of H_2SO_4

Step 5: Calculate concentration. concentration = moles/volume ←in dm^3 = 0.00137/0.025 = ***0.0548 moldm^{-3}***

Here are some additional problems, which are harder, ignore the questions about colour changes of indicators.

http://bit.ly/pixlchem12

http://www.docbrown.info/page06/Mtestsnotes/ExtraVolCalcs1.htm

Use the steps on the last page to help you

Q8.1 A solution of barium nitrate will react with a solution of sodium sulfate to produce a precipitate of barium sulfate.

$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$

What volume of 0.25$moldm^{-3}$sodium sulfate solution would be needed to precipitate all of the barium from 12.5cm^3 of 0.15 $moldm^{-3}$ barium nitrate?

Chemistry topic 9 – Organic chemistry – functional groups

At GCSE you would have come across **hydrocarbons** such as alkanes (ethane etc) and alkenes (ethene etc). You may have come across molecules such as alcohols and carboxylic acids. At A level you will learn about a wide range of molecules that have had atoms added to the carbon chain. These are called functional groups, they give the molecule certain physical and chemical properties that can make them incredibly useful to us.

Here you are going to meet a selection of the functional groups, learn a little about their properties and how we give them logical names.

You will find a menu for organic compounds here:

http://bit.ly/pixlchem13

http://www.chemguide.co.uk/orgpropsmenu.html#top

And how to name organic compounds here:

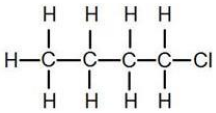
http://bit.ly/pixlchem14

http://www.chemguide.co.uk/basicorg/conventions/names.html#top

Using the two links see if you can answer the following questions:

Q9.1 Halogenoalkanes

What is the name of this halogenoalkane?



How could you make it from butan-1-ol?

Q9.2 Alcohols

How could you make ethanol from ethene?

How does ethanol react with sodium, in what ways is this a) similar to the reaction with water, b) different to the reaction with water?

Q9.3 Aldehydes and ketones

Draw the structures of a) propanal b) propanone

How are these two functional groups different?

Chemistry topic 10 – Acids, bases, pH

At GCSE you will know that an acid can dissolve in water to produce H^+ ions, at A level you will need a greater understanding of what an acid or a base is.

Read the following page and answer the questions

http://bit.ly/pixlchem15

http://www.chemguide.co.uk/physical/acidbaseeqia/theories.html#top

Q10.1 What is your new definition of what an acid is?

Q10.2 How does ammonia (NH_3) act as a base?

http://bit.ly/pixlchem16

http://www.chemguide.co.uk/physical/acidbaseeqia/acids.html#top

Q10.3 Ethanoic acid (vinegar) is a weak acid, what does this mean?

Q10.4 What is the pH of a solution of 0.01 $moldm^{-3}$ of the strong acid, hydrochloric acid?

Pre-Knowledge Topics Answers to problems

Q1.1a) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6 4s^2$ b) $1s^2\ 2s^2\ 2p^6 3s^2 3p^1$ c) $1s^2\ 2s^2\ 2p^6 3s^2 3p^4$ d) $1s^2\ 2s^2\ 2p^6 3s^2 3p^5$

e) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ f) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^6 4s^2$ g) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^3 4s^2$

h) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^8 4s^2$ i) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10}\ 4s^1$ j) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10} 4s^2$

k) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 4s^2\ 3d^{10}\ 4p^3$

Q1.2a) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ b) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ c) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10}$

d) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ e) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^7$

==========

Q2.1 a) +4 b) +6 c) +5 d) +4 e) +3 f) +5 g) +7 h) +6 i) +4

==========

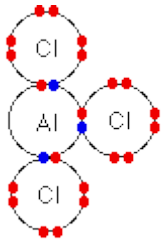
Q3.1 They must be ionised / turned into ions

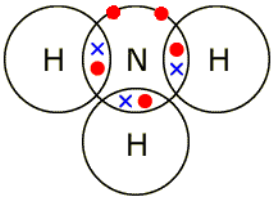
Q3.2 The ions are all given the same amount of kinetic energy, as KE = ½ mv^2 the lighter ions will have greater speed / heavier ions will have less speed.

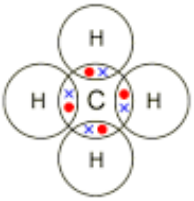
Q3.3 a) 121.855 b) 67.796 c) 107.973 d) 204.41 e) 87.710 / 87.7102

==========

Q4.1

a) 

120° b) 

107° c) 

109.5°

==========

Q5a. $2H_2 + 0_2 \rightarrow 2\ H_20$

b. $S_8 + 1202 \rightarrow 8SO_3$

c. $2HgO \rightarrow 2Hg + 0_2$

d. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

e. $2Na + 2H_20 \rightarrow 2NaOH + H_2$

f. $C_{10}H_{16} + 8Cl_2 \rightarrow 10C + 16HCl$

g. $2Fe + 30_2 \rightarrow 2Fe_2O_3$

h. $C_6H_{12}O_6 + 60_2 \rightarrow 6\ CO_2 + 6\ H_20$

i. $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_20$

j. $2Al + 3\ FeO \rightarrow Al_2O_3 + 3Fe$

Q6.1 a) 85.2/284 = 0.3 moles b) 73.56/122.6 = 0.6 moles c) 249.5/249.5 = 1.0 moles

d) 0.125 x 212.8 = 26.6g e) 2Mg : 2O or 1:1 ratio 2.4g of Mg = 0.1moles so we need 0.1 moles of oxygen (O_2): 0.1 x 32 = 3.2g

7.1 a) 9.53g/95.3 = 0.1 moles, in 100cm^3 or 0.1dm^3 in 1dm^3 0.1moles/0.1dm^3 = 1.0 mol dm^{-3}

b) 13.284g/331.2 = 0.04 moles, in 2dm^3 in 1dm^3 0.04moles /2dm^3 = 0.02 mol dm^{-3}

c) 100cm^3 of 0.1 mol dm^{-3} = 0.01 moles added to a total volume of 2 dm^3 = 0.01moles/2dm^3 = 0.005 mol dm^{-3}

d) in 1dm^3 of 1 mol dm^{-3} silver nitrate, 1 mole of Ag = 107.9g in 0.1dm^3 = 107.9 x 0.1 = 10.79g

e) 0.0526 x 79.7 = 42.0274g

==========

8.1

$Ba(NO_3)_2$: Na_2SO_4

1 : 1 ratio

12.5cm^3 of $Ba(NO_3)_2$ = 0.0125dm^3

0.15 moldm^{-3} x 0.0125dm^3 = 0.001875 moles

same number of moles of sodium sulfate needed, which has a concentration of 0.25 mol dm^{-3}

0.001875 moles / 0.25 mol dm^{-3} = 0.0075 dm^3 or 7.5cm^3

==========

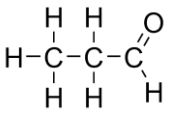
9.1 1-chlorobutane

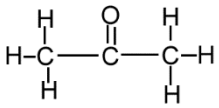
Add butan-1-ol to concentrated HCl and shake

9.2 react ethene with hydrogen gas at high temperature and pressure with a nickel catalyst

The reaction is similar in that it releases hydrogen but different as it proceeds much slower than in water

9.3 propanal propanone





The carbon atom joined to oxygen in propanal has a hydrogen attached to it, it does not in propanone.

==========

10.1 An acid is a proton donor

10.2 Ammonia can accept a proton, to become NH_4^+

10.3 ethanoic acid has not fully dissociated, it has not released all of its hydrogen ions into the solution.

$CH_3COOH \leftrightharpoons CH_3COO^- + H^+$
Mostly this Very few of these

10.4 pH = -log [0.01] = 2 The pH = 2

Places to visit Optional

1. Go outdoors!
   Have you actually spent any time observing the geology of the area you live in? What rocks or minerals are found in your area? Does your area have a history of extracting minerals? If so what were they, what were they used for, how did they obtain them? Are there any working or remains of mineral extraction industries?

2. Are there any chemical or chemistry based businesses in your area? A big ask, but one that could be really beneficial to you, write them a letter explaining that you are taking A level chemistry and you want to see how chemistry is used in industry and you would like to visit / have some work experience. You never know this could lead to great things!!!!

3. You could also try writing to / searching for your nearest university to see if they are running any summer schools for chemistry – they are usually free and give you the opportunity to experience the laboratories in a university.

4. Science museums.
   You could visit your nearest science museum. They often have special exhibitions that may be of interest to you.
   https://en.wikipedia.org/wiki/List_of_science_museums#United_Kingdom

5. Somerset Earth Science Centre:

   http://www.earthsciencecentre.org.uk

6. The UK Association for Science and Discovery Centres (ASDC)

   This association brings together over 60 major science engagement organisations in the UK.

   http://sciencecentres.org.uk/centres/weblinks.php

Chemistry A level transition - baseline assessment. 40 marks

All data is given on this paper, you will not need a periodic table

Answer all questions.

1. Here is part of a periodic table, use it to answer the following questions

10.8 $_{5}$B boron	12.0 $_{6}$C carbon	14.0 $_{7}$N nitrogen	16.0 $_{8}$O oxygen	19.0 $_{9}$F fluorine	20.2 $_{10}$Ne neon
27.0 $_{13}$Al aluminium	28.1 $_{14}$Si silicon	31.0 $_{15}$P phosphorus	32.1 $_{16}$S sulphur	35.5 $_{17}$Cl chlorine	39.9 $_{18}$Ar argon

   a. Which is the correct electron configuration for a nitrogen atom, circle the correct answer [1]

   $1s^2 2p^5$ $1s^1 2p^6$ $1s^2 2s^2 2p^3$ $1s^2 2s^5$ $1s^2 2s^2 2p^6 3s^2 3p^2$

   b. Which is the correct electron configuration for a chlorine atom, circle the correct answer [1]

   $1s^2 2s^8 2p^7$ $1s^2 2s^2 2p^8 2d^5$ $1s^2 2s^2 2p^6 3d^7$ $1s^2 2s^2 2p^6 3p^7$ $1s^2 2s^2 2p^6 3s^2 3p^5$

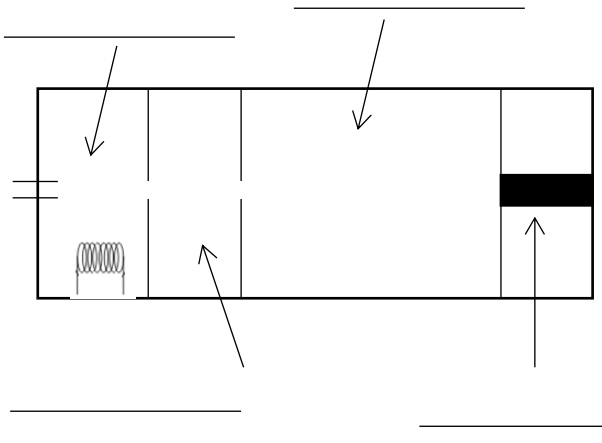
   c. Which is the correct electron configuration for an aluminium **ion**, Al^{3+}? Circle the correct answer [1]

   $1s^2 2s^2 2p^6$ $1s^2 2s^2 2p^6 3s^2 3p^3$ $1s^2 2s^2 2p^6 3s^2$ $1s^2 2s^2 2p^6 2d^1$

2. Draw a dot and cross diagram to show the bonding in a molecule of water, H_2O. [2]
   Atomic numbers: H =1, O =8

3. A time of flight mass spectrometer has 4 main stages. put the correct stage in the diagram below:

   Drift region **Ionisation** **Detector** **Acceleration**



[4]

4. A mass spectrometer was used to analyse a sample of chlorine; the results of the analysis are as follows:

isotope mass	% of sample
Cl-35	75.53
Cl-37	24.47

Calculate the accurate atomic mass of chlorine. Give your answer to **3 decimal places**. [3]

mass: _____

5. Give the oxidation state of the underlined atom in the following chemicals.
Useful information: H = +1, K = +1, Na = +1, Mg = +2, O = -2, Cl = -1 [7]

a) $\underline{C}O_2$ b) $\underline{S}O_3$ c) $H_2\underline{S}O_4$ d) $\underline{Al}Cl_3$

e) $\underline{Cr}_2O_3$ f) $Na\underline{N}O_3$ g) $\underline{V}Cl_4$

6. Balance the following chemical equations:

a) C_3H_8 + ___ O_2 → ___ CO_2 + ___ H_2O [3]

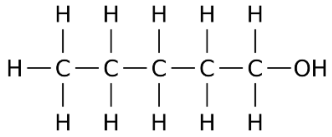
b) ___ HCl + $Mg(OH)_2$ → $MgCl_2$ + ___ H_2O [2]

c) Na_2CO_3 + ___ HCl → ___ NaCl + ___ H_2O + CO_2 [3]

7. Calculate the relative formula masses of the following:
Atomic masses: H = 1, O = 16, S = 32.1, C = 12, Ca = 40.1, Na = 23, Cl = 35.5, Zn = 65.4

a) $CaCl_2$ b) H_2CO_3 c) Na_2SO_4 d) C_3H_7OH e) $Zn(NO_3)_2$ [5]

8. A student carried out a reaction with this molecule:



a. What is the name of this molecule? _____ [2]

9. Vinegar is a solution of ethanoic acid (CH_3COOH) in water. A student carried out a titration of a sample of vinegar.
He used a pipette to measure exactly 25.0cm^3 of vinegar into a flask, added an indicator and titrated it with a 1.00 mol dm^{-3} solution of sodium hydroxide (NaOH).
The reaction is:

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

The student found that his average titration was 27.50cm^3

c = n/v c = concentration (mol dm^{-3}), n = number of moles, v = volume (dm^3)

n = m/Rfm n = number of moles, m = mass in grams, Rfm = formula mass

1dm^3 = 1000 cm^3

a. Using the chemical equation, how many moles of sodium hydroxide will react with 1 mole of ethanoic acid?

_____moles [1]

b. How many moles of sodium hydroxide are in 27.50cm^3 of 1.00 moldm^{-3} sodium hydroxide?

_____moles [2]

c. How many moles of ethanoic acid are in 25.0cm^3 of the vinegar sample?

_____moles [1]

d. How many moles of ethanoic acid are in 1dm^3 of vinegar?

_____moles [1]

e. Ethanoic acid has a formula mass of 48. What mass of ethanoic acid is present in 1dm^3 of vinegar?

_____g [2]

Chemistry A level transition - baseline assessment. - Answers

1. .

   a. Which is the correct electron configuration for a nitrogen atom, circle the correct answer [1]

   $1s^2 2p^5$ $1s^1 2p^6$ $1s^2 2s^2 2p^3$ $1s^2 2s^5$ $1s^2 2s^2 2p^6 3s^2 3p^2$

   b. Which is the correct electron configuration for a chlorine atom, circle the correct answer [1]

   $1s^2 2s^8 2p^7$ $1s^2 2s^2 2p^8 2d^5$ $1s^2 2s^2 2p^6 3d^7$ $1s^2 2s^2 2p^6 3p^7$ $1s^2 2s^2 2p^6 3s^2 3p^5$

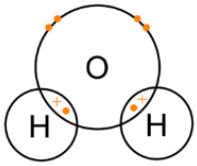
   c. Which is the correct electron configuration for an aluminium **ion**, Al^{3+}? Circle the correct answer [1]

   $1s^2 2s^2 2p^6$ $1s^2 2s^2 2p^6 3s^2 3p^3$ $1s^2 2s^2 2p^6 3s^2$ $1s^2 2s^2 2p^6 2d^1$

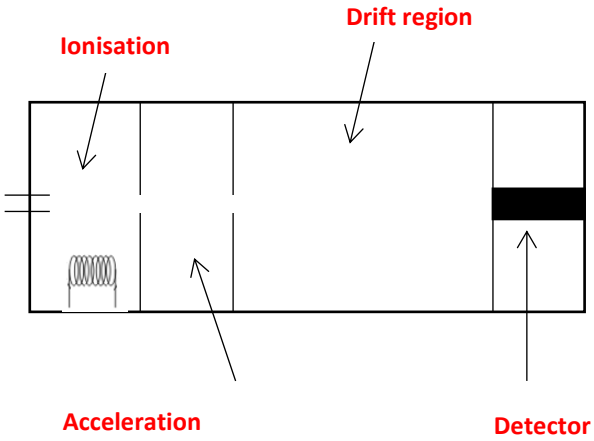
2. Draw a dot and cross diagram to show the bonding in a molecule of water, H_2O. [2]
   Atomic numbers: H =1, O =8

1 mark for 2 x shared electrons

1 mark for lone pairs



3. A time of flight mass spectrometer has 4 main stages. put the correct stage in the diagram below:



[4]

4. A mass spectrometer was used to analyse a sample of chlorine, the results of the analysis are as follows:

isotope mass	% of sample
Cl-35	75.53
Cl-37	24.47

(35x75.53) + (37x24.47)/100 [1]

= 35.4894 [1]

To 3dp = 35.489 [1] [2 marks if above line is missing]

[3]

5. Give the oxidation state of the underlined atom in the following chemicals.
Useful information: H = +1, K = +1, Na = +1, Mg = +2, O = -2, Cl = -1 [7]

a) $\underline{C}O_2$ +4 b) $\underline{S}O_3$ +6 c) $H_2\underline{S}O_4$ +6 d) $\underline{Al}Cl_3$ +3

e) $\underline{Cr}_2O_3$ +3 f) $NaNO_3$ +5 g) $\underline{V}Cl_4$ +4

6. Balance the following chemical equations:

a) C_3H_8 + _5_ O_2 → _3_ CO_2 + _4_ H_2O [3]

b) _2_ HCl + $Mg(OH)_2$ → $MgCl_2$ + _2_ H_2O [2]

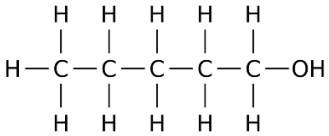
c) Na_2CO_3 + _2_ HCl → _2_ NaCl + _1_ H_2O + CO_2 [3]

7. Calculate the relative formula masses of the following:
Atomic masses: H = 1, O = 16, S = 32.1, C = 12, Ca = 40.1, Na = 23, Cl = 35.5

a) $CaCl_2$ b) H_2CO_3 c) Na_2SO_4 d) C_3H_7OH e) $Zn(NO_3)_2$ [5]

111.1 62 142.3 60 189.4

8. A student carried out a reaction with this molecule:



a. What is the name of this molecule? pentan-1-ol [2]

Pentanol = 1 mark pentan-1-ol = 2 marks

9.

a. Using the chemical equation, how many moles of sodium hydroxide will react with 1 mole of ethanoic acid?

_____1_____moles [1]

b. How many moles of sodium hydroxide are in 27.50cm^3 of 1.00 $moldm^{-3}$ sodium hydroxide?

27.5/1000 [1] x 1.00 = 0.0275 [1]

0.0275 [2] moles [2]

c. How many moles of ethanoic acid are in 25.0cm^3 of the vinegar sample?

___0.0275 __moles [1]

d. How many moles of ethanoic acid are in $1dm^3$ of vinegar?

0.0275 x 1000/25 = 1.10

___1.10____moles [1]

e. Ethanoic acid has a formula mass of 48. What mass of ethanoic acid is present in $1dm^3$ of vinegar?

1.1 x 48 = 52.8g

___52.8g ___g [1]

1 Complete the table to show the formula and structure type (use ✓s) of the following substances. (10)

Substance	Formula	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
silver(I) nitrate						
bromine						
potassium bromide						
calcium						
aluminium sulfate						
argon						
ammonia						
ammonium chloride						
hydrogen sulfide						
graphene						

2 a) Explain what the Avogadro constant is. ……

……

……

…… (1)

b) Calculate the number of molecules of water in 90.0 g of water. (Avogadro constant, L = 6.022 x 10^{23} mol^{-1})

……

……

……

……

…… (2)

3 Calculate the relative formula mass (M_r) of the following substances.

a) O_2 …… (1)

b) K_2SO_4 …… (1)

c) $Mg(NO_3)_2$ …… (1)

d) $CuSO_4.5H_2O$ …… (1)

4 Calculate the mass of each of the following.

a) 5.00 moles of Fe_2O_3 ……

…… (1)

b) 0.250 moles of hydrogen ……

…… (1)

c) 1.50×10^{-4} moles of aluminium iodide ……

…… (1)

5 Calculate the number of moles of each of the following.

a) 23.6 g of Cu……

…… (1)

b) 43.8 mg of fluorine ……

…… (1)

c) 1.25 tonnes of vanadium(V) oxide ……

…… (1)

6 Convert these quantities into the units shown.

a) 18 mmol to mol …… (1)

b) 20 MPa to Pa …… (1)

c) 65 mg to g …… (1)

d) 20°C to K …… (1)

e) 125 pm to m …… (1)

f) 50 cm^3 to dm^3 …… (1)

g) 200 cm^3 to m^3 …… (1)

7 250 cm^3 of aqueous solution contains 2.0 g of dissolved sodium hydroxide. Calculate the concentration of the solution in mol dm^{-3}

……

……

…… (2)

8 What mass of oxygen reacts with 2.30 g of sodium? $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

……

……

……

……

…… (3)

9 Which is the limiting reagent and what mass of aluminium chloride is formed when 1.35 g of aluminium is heated with 4.26 g of chlorine?

$$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$$

……

……

……

……

…… (4)

10 In a titration, it was found that 25.0 cm^3 of 0.150 mol dm^{-3} sulfuric acid reacts with 23.58 cm^3 of sodium hydroxide solution. Calculate the concentration of the sodium hydroxide solution in mol dm^{-3}.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

……

……

……

……

……

……

…… (3)

11 Write a balanced equation for each of these reactions. (6)

a) calcium + water

……

b) ethanethiol (C_2H_5SH) + oxygen

……

c) zinc + hydrochloric acid

……

d) potassium carbonate + nitric acid

……

e) ammonia + sulfuric acid

……

f) copper(II) oxide + nitric acid

……

12 Write an ionic equation for each of these reactions. (3)

a) precipitation of iron(III) hydroxide when solutions of sodium hydroxide and iron(III) nitrate are mixed

……

b) redox reaction between solution of silver(I) nitrate and magnesium metal

……

c) acid-base reaction between sulfuric acid and potassium hydroxide

……

13 Complete the table about these atoms and ions. (4)

atom / ion	atomic number	mass number	protons	neutrons	electrons
$^{37}_{17}Cl$					
$^{37}_{17}Cl^-$					
			12	14	10
	8	18			10

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Find moles from mass (and vice versa)		
Good SPG			Write formulae (other)			Can do reacting mass calculations		
Shows full working			Write balanced equations			Understands limiting reagents		
Explanations are clear			Write ionic equations			Can do solution calculations		
Convert units			Identify structure type of substances			Can work out PNE numbers in atoms/ions		
Work to appropriate sig figs			Understands Avogadro constant					
Gives units when appropriate			Can work out formula mass					

1 Complete the table to show the formula and structure type (use ✓s) of the following substances. (10)

Substance	Formula	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
silver(I) nitrate	$AgNO_3$				✓	
bromine	Br_2		✓			
potassium bromide	KBr				✓	
calcium	Ca					✓
aluminium sulfate	$Al_2(SO_4)_3$				✓	
argon	Ar	✓				
ammonia	NH_3		✓			
ammonium chloride	NH_4Cl				✓	
hydrogen sulfide	H_2S		✓			
graphene	C			✓		

2 a) Explain what the Avogadro constant is.

✓ **6.022×10^{23} of something** (1)

b) Calculate the number of molecules of water in 90.0 g of water. (Avogadro constant, L = 6.022×10^{23} mol^{-1})

✓ **moles H_2O = $\frac{90.0}{18.0}$ = 5.00**

✓ **molecules H_2O = $5.00 \times 6.022 \times 10^{23}$ = 3.01×10^{24}** (2)

3 Calculate the relative formula mass (M_r) of the following substances.

a) O_2 ✓ **M_r = 32.0** (1)

b) K_2SO_4 ✓ **M_r = 174.3** (1)

c) $Mg(NO_3)_2$ ✓ **M_r = 148.3** (1)

d) $CuSO_4.5H_2O$ ✓ **M_r = 249.6** (1)

4 Calculate the mass of each of the following.

a) 5.00 moles of Fe_2O_3 ✓ **$5.00 \times 159.6 = 798$ g** (1)

b) 0.250 moles of hydrogen ✓ **H_2 $0.250 \times 2.0 = 798$ g** (1)

c) 1.50×10^{-4} moles of aluminium iodide ✓ **AlI_3 $1.50 \times 10^{-4} \times 407.7 = 0.0612$ g** (1)

5 Calculate the number of moles of each of the following.

a) 23.6 g of Cu ✓ **moles Cu = $\frac{23.6}{63.5}$ = 0.372** (1)

b) 43.8 mg of fluorine ✓ **moles F_2 = $\frac{0.0438}{38.0}$ = 0.00115** (1)

c) 1.25 tonnes of vanadium(V) oxide ✓ **moles V_2O_5 = $\frac{1.25 \times 10^6}{181.8}$ = 6880** (1)

6 Convert these quantities into the units shown.

a) 18 mmol to mol ✓ **18×10^{-3} = 0.018 mol** (1)

b) 20 MPa to Pa ✓ **20×10^6 = 2.0×10^7 Pa** (1)

c) 65 mg to g ✓ **65×10^{-3} = 0.065 g** (1)

d) 20°C to K ✓ **20 + 273 = 293 K** (1)

e) 125 pm to m ✓ **125×10^{-12} = 1.25×10^{-10} m** (1)

f) 50 cm^3 to dm^3 ✓ **50×10^{-3} = 0.050 dm^3** (1)

g) 200 cm^3 to m^3 ✓ **200×10^{-6} = 2.00×10^{-4} m^3** (1)

7 250 cm^3 of aqueous solution contains 2.0 g of dissolved sodium hydroxide. Calculate the concentration of the solution in mol dm^{-3}

✓ **moles NaOH = $\frac{2.0}{40.0}$ = 0.0500**

✓ **concentration = $\frac{0.0500}{\frac{250}{1000}}$ = 0.200 mol dm^{-3}** (2)

8 What mass of oxygen reacts with 2.30 g of sodium? $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

✓ **moles Na = $\frac{2.30}{23.0}$ = 0.100**

✓ **moles O_2 = $\frac{0.100}{4}$ = 0.0250**

✓ **mass O_2 = 0.025 x 32 = 0.800 g** (3)

9 Which is the limiting reagent and what mass of aluminium chloride is formed when 1.35 g of aluminium is heated with 4.26 g of chlorine?

$$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$$

✓ **moles Al = $\frac{1.35}{27.0}$ = 0.0500** **moles Cl_2 = $\frac{4.26}{71.0}$ = 0.0600**

✓ **limiting reagent is Cl_2 as 0.0500 mol of Al would need 0.0750 mol of Cl_2, but there is only 0.0600 mol**

✓ **moles $AlCl_3$ = 0.0600 x $\frac{2}{3}$ = 0.0400**

✓ **mass $AlCl_3$ = 0.0400 x 133.5 = 5.34 g** (4)

10 In a titration, it was found that 25.0 cm^3 of 0.150 mol dm^{-3} sulfuric acid reacts with 23.58 cm^3 of sodium hydroxide solution. Calculate the concentration of the sodium hydroxide solution in mol dm^{-3}.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

✓ **moles H_2SO_4 = $\frac{25.0}{1000}$ x 0.150 = 0.00375**

✓ **moles NaOH = 2 x 0.00375 = 0.00750**

✓ **concentration NaOH = $\frac{0.00750}{\frac{23.58}{1000}}$ = 0.318 mol dm^{-3}** (3)

11 Write a balanced equation for each of these reactions. ✓ **correct formulas** & ✓ **balanced** (6)

a) calcium + water

✓✓ **$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$**

b) ethanethiol (C_2H_5SH) + oxygen

✓✓ **$C_2H_5SH + 4.5O_2 \rightarrow 2CO_2 + 3H_2O + SO_2$**

c) zinc + hydrochloric acid

✓✓ **$Zn + 2HCl \rightarrow ZnCl_2 + H_2$**

d) potassium carbonate + nitric acid

✓✓ **$K_2CO_3 + 2HNO_3 \rightarrow 2KNO_3 + CO_2 + H_2O$**

e) ammonia + sulfuric acid

✓✓ **$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$**

f) copper(II) oxide + nitric acid

✓✓ **$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$**

12 Write an ionic equation for each of these reactions. (3)

a) precipitation of iron(III) hydroxide when solutions of sodium hydroxide and iron(III) nitrate are mixed

✓ **$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$**

b) redox reaction between solution of silver(I) nitrate and magnesium metal

✓ **$2Ag^+ + Mg \rightarrow 2Ag + Mg^{2+}$**

c) acid-base reaction between sulfuric acid and potassium hydroxide

✓ **$H^+ + OH^- \rightarrow H_2O$**

13 Complete the table about these atoms and ions. ✓ **correct row** (4)

atom / ion	atomic number	mass number	protons	neutrons	electrons
$^{37}_{17}Cl$	**17**	**37**	**17**	**18**	**17**
$^{37}_{17}Cl^-$	**17**	**37**	**17**	**18**	**18**
$^{26}_{12}Mg^{2+}$	**17**	**37**	12	14	10
$^{18}_{8}O^{2-}$	8	18	**8**	**10**	10

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Find moles from mass (and vice versa)		
Good SPG			Write formulae (other)			Can do reacting mass calculations		
Shows full working			Write balanced equations			Understands limiting reagents		
Explanations are clear			Write ionic equations			Can do solution calculations		
Convert units			Identify structure type of substances			Can work out PNE numbers in atoms/ions		
Work to appropriate sig figs			Understands Avogadro constant					
Gives units when appropriate			Can work out formula mass					

1 Complete the table to show the formula and structure type (use ✓s) of the following substances. (8)

Substance	Formula	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
ammonia						
iodine						
lithium bromide						
potassium						
aluminium hydroxide						
diamond						
buckminsterfullerene						
helium						

2 Convert these quantities into the units shown.

a) 25 cm^3 to dm^3 …… (1)

b) 500 cm^3 to m^3 …… (1)

c) 100 kPa to Pa …… (1)

d) 89 mg to g …… (1)

e) –196°C to K …… (1)

f) 0.102 nm to m …… (1)

3 Write a balanced equation for each of these reactions. (8)

a) copper(II) carbonate + nitric acid

……

b) magnesium oxide + hydrochloric acid

……

c) silane (SiH_4) + oxygen

……

d) calcium + hydrochloric acid

……

4 Write an ionic equation for each of these reactions. (6)

a) precipitation of lead(II) iodide when solutions of potassium iodide and lead(II) nitrate are mixed

……

b) acid-base reaction between sulfuric acid and lithium hydroxide

……

c) redox reaction between solution of iron(II) nitrate and zinc metal

……

5 Complete the table about these atoms and ions. (2)

atom / ion	atomic number	mass number	protons	neutrons	electrons
$^{31}_{15}P^{3-}$					
			35	46	36

6 Which is the limiting reagent and what mass of lithium oxide is formed when 1.0 g of lithium is heated with 1.3 g of oxygen?

$$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$$

……

……

……

……

…… (4)

7 Calculate the percentage atom economy to form chlorine in this reaction.

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$$

……

……

……

……

…… (2)

8 Calculate the mass of one atom of $^{7}_{3}Li$. (Avogadro constant, L = 6.022 x 10^{23} mol^{-1})

……

……

……

…… (1)

9 In a reaction, 115 g of tungsten was formed from 200 g of tungsten oxide. Calculate the percentage yield.

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

……

……

……

……

……

……

……

…… (4)

10 In a titration, it was found that 25.00 cm^3 of 0.100 mol dm^{-3} sodium hydroxide reacts with 26.38 cm^3 of nitric acid. Calculate the concentration of the nitric acid solution in mol dm^{-3}.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

……

……

……

……

……

……

……

…… (3)

11 Draw stick diagrams and dot-cross diagrams for each of these molecules. (8)

	NH_3	CO_2	HBr	N_2
stick diagram				
dot-cross diagram				

12 Explain each of the following.

a) Magnesium chloride has a high melting point. ……

……

……

……

…… (3)

b) Copper conducts electricity. ……

……

……

……

…… (3)

c) Methane has a low boiling point. ……

……

……

……

…… (3)

d) Aluminium oxide conducts electricity when molten but not as a solid. ……

……

……

……

…… (3)

e) Helium has a very low boiling point. ……

……

……

……

…… (3)

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Can do solution calculations		
Good SPG			Write formulae (other)			Can find % atom economy		
Shows full working			Write balanced equations			Can find % yield		
Explanations are clear			Write ionic equations			Can work out PNE numbers in atoms/Ions		
Convert units			Identify structure type of substances			Can draw stick diagrams		
Work to appropriate sig figs			Understands Avogadro constant			Can draw dot-cross diagrams		
Gives units when appropriate			Can work out formula mass			Good understand of structure & bonding		
			Find moles from mass (and vice versa)			Use of terms: atoms / molecules / ions / e^-		
			Can do reacting mass calculations			Use of terms: bonds / forces		
			Understands limiting reagents					

1 Complete the table to show the formula and structure type (use ✓s) of the following substances. (8)

Substance	Formula	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
ammonia	NH_3		✓			
iodine	I_2		✓			
lithium bromide	LiBr				✓	
potassium	K					✓
aluminium hydroxide	$Al(OH)_3$				✓	
diamond	C			✓		
buckminsterfullerene	C_{60}		✓			
helium	He	✓				

2 Convert these quantities into the units shown.

a) 25 cm^3 to dm^3 ✓ $25 \times 10^{-3} = 0.025\ dm^3$ (1)

b) 500 cm^3 to m^3 ✓ $500 \times 10^{-6} = 5.00 \times 10^{-4}\ m^3$ (1)

c) 100 kPa to Pa ✓ $100 \times 10^3 = 1.0 \times 10^5\ Pa$ (1)

d) 89 mg to g ✓ $89 \times 10^{-3} = 0.089\ g$ (1)

e) –196°C to K ✓ $-196 + 273 = 77\ K$ (1)

f) 0.102 nm to m ✓ $0.102 \times 10^{-9} = 1.02 \times 10^{-10}\ m$ (1)

3 Write a balanced equation for each of these reactions. ✓ correct formulas & ✓ balanced (8)

a) copper(II) carbonate + nitric acid

✓✓ $CuCO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + CO_2 + H_2O$

b) magnesium oxide + hydrochloric acid

✓✓ $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

c) silane (SiH_4) + oxygen

✓✓ $SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O$

d) calcium + hydrochloric acid

✓✓ $Ca + 2HCl \rightarrow CaCl_2 + H_2$

4 Write an ionic equation for each of these reactions. (6)

a) precipitation of lead(II) iodide when solutions of potassium iodide and lead(II) nitrate are mixed

✓ $Pb^{2+} + 2I^- \rightarrow PbI_2$

b) acid-base reaction between sulfuric acid and lithium hydroxide

✓ $H^+ + OH^- \rightarrow H_2O$

c) redox reaction between solution of iron(II) nitrate and zinc metal

✓ $Fe^{2+} + Zn \rightarrow Fe + Zn^{2+}$

5 Complete the table about these atoms and ions. ✓ **correct row** (2)

atom / ion	atomic number	mass number	protons	neutrons	electrons
$^{31}_{15}P^{3-}$	**15**	**31**	**15**	**16**	**18**
$^{81}_{35}Br^-$	**17**	**37**	35	46	36

6 Which is the limiting reagent and what mass of lithium oxide is formed when 1.0 g of lithium is heated with 1.3 g of oxygen?

$$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$$

✓ **moles Li = $\frac{1.0}{6.9}$ = 0.145** **moles O_2 = $\frac{1.3}{32.0}$ = 0.0406**

✓ **limiting reagent is Li as 0.0406 mol of O_2 would need 0.162 mol of Li but there is only 0.145 mol**

✓ **moles Li_2O = 0.145 x $\frac{1}{2}$ = 0.00725**

✓ **mass Li_2O = 0.00725 x 29.8 = 2.2 g** (4)

7 Calculate the percentage atom economy to form chlorine in this reaction.

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$$

✓ **% atom economy = $\frac{71.0}{2(58.5)+2(18.0)}$ x 100**

✓ **= 46.4%** (2)

8 Calculate the mass of one atom of ^7_3Li. (Avogadro constant, L = 6.022 x 10^{23} mol^{-1})

✓ **mass = $\frac{7}{6.022 \times 10^{23}}$ = 1.162 x 10^{-23} g** **(1)**

9 In a reaction, 115 g of tungsten was formed from 200 g of tungsten oxide. Calculate the percentage yield.

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

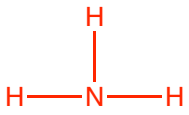
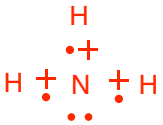
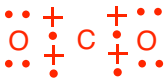
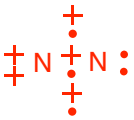
- ✓ **moles WO_3 = $\frac{200}{231.8}$ = 0.863**
- ✓ **moles W = 0.863**
- ✓ **mass W = 0.863 x 183.8 = 158.6 g**
- ✓ **% yield = $\frac{115}{158.6}$ x 100 = 72.5%** (4)

10 In a titration, it was found that 25.00 cm^3 of 0.100 mol dm^{-3} sodium hydroxide reacts with 26.38 cm^3 of nitric acid. Calculate the concentration of the nitric acid solution in mol dm^{-3}.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

- ✓ **moles NaOH = $\frac{25.0}{1000}$ x 0.100 = 0.00250**
- ✓ **moles HNO_3 = 0.00250**
- ✓ **concentration HNO_3 = $\frac{0.00250}{\frac{26.38}{1000}}$ = 0.0945 mol dm^{-3}** (3)

11 Draw stick diagrams and dot-cross diagrams for each of these molecules. (8)

	NH_3	**CO_2**	**HBr**	**N_2**
stick diagram				
dot-cross diagram				

12 Explain each of the following.

a) Magnesium chloride has a high melting point.

- ✓ **ionic structure**
- ✓ **strong attraction between positive and negative ions**
- ✓ **takes a lot of energy to overcome attraction** (3)

b) Copper conducts electricity.

- ✓ **outer shell**
- ✓ **electrons are delocalised**
- ✓ **and carry charge through structure / metal** (3)

c) Methane has a low boiling point.

- ✓ **simple molecular**
- ✓ **weak forces between molecules**
- ✓ **does not need much energy to overcome attraction** (3)

d) Aluminium oxide conducts electricity when molten but not as a solid.

- ✓ **ions cannot move as solid**
- ✓ **ions can move as liquid**
- ✓ **and carry charge through structure** (3)

e) Helium has a very low boiling point.

- ✓ **monatomic**
- ✓ **weak forces between atoms**
- ✓ **does not need much energy to overcome attraction** (3)

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Can do solution calculations		
Good SPG			Write formulae (other)			Can find % atom economy		
Shows full working			Write balanced equations			Can find % yield		
Explanations are clear			Write ionic equations			Can work out PNE numbers in atoms/Ions		
Convert units			Identify structure type of substances			Can draw stick diagrams		
Work to appropriate sig figs			Understands Avogadro constant			Can draw dot-cross diagrams		
Gives units when appropriate			Can work out formula mass			Good understand of structure & bonding		
			Find moles from mass (and vice versa)			Use of terms: atoms / molecules / ions / e^-		
			Can do reacting mass calculations			Use of terms: bonds / forces		
			Understands limiting reagents					

1 Complete the table using ✓s to show which type of structure the following substances have. (8)

Substance	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
helium (He)					
nitrogen fluoride (NF_3)					
silicon chloride ($SiCl_4$)					
strontium chloride ($SrCl_2$)					
iron oxide (Fe_2O_3)					
phosphorus (P_4)					
silicon dioxide (SiO_2)					
iridium (Ir)					

2 Give the formula of each of the following ionic substances. (8)

a) potassium bromide ……

b) aluminium sulfide ……

c) magnesium hydroxide ……

d) iron(III) nitrate ……

e) cobalt(II) carbonate ……

f) ammonium nitrate ……

g) titanium(IV) oxide ……

h) rubidium sulfate ……

3 Write a balanced equation for each of these reactions. (10)

a) potassium oxide + hydrochloric acid

……

b) barium + water

……

c) propane (C_3H_8) + oxygen

……

d) magnesium + nitric acid

……

e) zinc(II) carbonate + sulfuric acid

……

4 Write an ionic equation for each of these reactions. (3)

a) redox reaction between solution of copper(II) sulfate and magnesium metal

……

b) acid-base reaction between nitric acid and calcium hydroxide

……

c) precipitation of silver(I) bromide when solutions of potassium bromide and silver(I) nitrate are mixed

……

5 Convert these quantities into the units shown.

a) 25 cm^3 to m^3 …… (1)

b) 150 cm^3 to dm^3 …… (1)

c) 40 MPa to Pa …… (1)

d) 7.5 mg to g …… (1)

6 6.15 g of hydrated magnesium sulfate, $MgSO_4.xH_2O$ decompose to form 3.00 g of anhydrous magnesium sulfate on heating. Calculate the formula mass of hydrated magnesium sulfate and the value of *x*.

……

……

……

……

……

……

……

……

……

…… (4)

7 Determine the limiting reagent and then calculate the mass of titanium produced when 10.00 g of titanium chloride react with with 2.00 g of magnesium.

$$TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$$

……

……

……

……

……

……

…… (4)

8 Describe what each of the following formulae tells you about the substance shown.

a) Ammonia has the molecular formula NH_3 ……

……

……

…… (2)

b) Silicon dioxide has the formula SiO_2 ……

……

……

…… (2)

c) Aluminium oxide has the formula Al_2O_3. ……

……

……

…… (2)

d) Sulfur has the molecular formula S_8. ……

……

……

…… (2)

9 The element carbon exists in several different forms (allotropes), including diamond, graphite and graphene.

a) Explain why these forms of carbon all have high melting points.

……

……

……

……

……

……

…… (3)

b) Explain why graphite and graphene are electrical conductors but diamond is not.

……

……

……

……

……

…… (3)

c) Buckminsterfullerene is another form of carbon with the formula C_{60}. Explain how the formula C_{60} tells us that this is a molecular substance and not a giant covalent substance.

……

……

……

……

……

…… (2)

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Understands limiting reagents		
Good SPG			Write formulae (other)			What formulas mean		
Shows full working			Write balanced equations			Link structure types to properties		
Explanations are clear			Write ionic equations			Identify structure types of substances		
Convert units			Can work out formula mass					
Work to appropriate sig figs			Find moles from mass (and vice versa)					
Gives units when appropriate			Can do reacting mass calculations					

1 Complete the table using ✓s to show which type of structure the following substances have. (8)

Substance	Monatomic	Simple molecular	Giant covalent	Ionic	Metallic
helium (He)	✓				
nitrogen fluoride (NF_3)		✓			
silicon chloride ($SiCl_4$)		✓			
strontium chloride ($SrCl_2$)				✓	
iron oxide (Fe_2O_3)				✓	
phosphorus (P_4)		✓			
silicon dioxide (SiO_2)			✓		
iridium (Ir)					✓

2 Give the formula of each of the following ionic substances. (8)

a) potassium bromide ✓ **KBr**

b) aluminium sulfide ✓ **Al_2S_3**

c) magnesium hydroxide ✓ **$Mg(OH)_2$**

d) iron(III) nitrate ✓ **$Fe(NO_3)_3$**

e) cobalt(II) carbonate ✓ **$CoCO_3$**

f) ammonium nitrate ✓ **NH_4NO_3**

g) titanium(IV) oxide ✓ **TiO_2**

h) rubidium sulfate ✓ **Rb_2SO_4**

3 Write a balanced equation for each of these reactions. ✓ **correct formulas** & ✓ **balanced** (10)

a) potassium oxide + hydrochloric acid

✓✓ **$K_2O + 2HCl \rightarrow 2KCl_2 + H_2O$**

b) barium + water

✓✓ **$Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$**

c) propane (C_3H_8) + oxygen

✓✓ **$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$**

d) magnesium + nitric acid

✓✓ **$Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$**

e) zinc(II) carbonate + sulfuric acid

✓✓ **$CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + CO_2 + H_2O$**

4 Write an ionic equation for each of these reactions. (3)

a) redox reaction between solution of copper(II) sulfate and magnesium metal

✓ $Cu^{2+} + Mg \rightarrow Cu + Mg^{2+}$

b) acid-base reaction between nitric acid and calcium hydroxide

✓ $H^+ + OH^- \rightarrow H_2O$

c) precipitation of silver(I) bromide when solutions of potassium bromide and silver(I) nitrate are mixed

✓ $Ag^+ + Br^- \rightarrow AgBr$

5 Convert these quantities into the units shown.

a) 25 cm^3 to m^3 ✓ $25 \times 10^{-6} = 2.5 \times 10^{-5}\ m^3$ (1)

b) 150 cm^3 to dm^3 ✓ $150 \times 10^{-3} = 0.150\ dm^3$ (1)

c) 40 MPa to Pa ✓ $40 \times 10^6 = 4.0 \times 10^5$ Pa (1)

d) 7.5 mg to g ✓ $7.5 \times 10^{-3} = 0.0075$ g (1)

6 6.15 g of hydrated magnesium sulfate, $MgSO_4.xH_2O$ decompose to form 3.00 g of anhydrous magnesium sulfate on heating. Calculate the formula mass of hydrated magnesium sulfate and the value of *x*.

✓ moles $MgSO_4 = \frac{3.00}{120.4} = 0.0249$

✓ moles $MgSO_4.xH_2O = 0.0249$

✓ $M_r\ MgSO_4.xH_2O = \frac{6.15}{0.0249} = 246.8$

✓ $M_r\ xH_2O = 246.8 - 120.4 = 126.4$ $\quad x = \frac{126.4}{18.0} = 7.02 = 7$ (nearest integer) (4)

7 Determine the limiting reagent and then calculate the mass of titanium produced when 10.00 g of titanium chloride react with with 2.00 g of magnesium.

$$TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$$

✓ moles $TiCl_4 = \frac{10.00}{189.9} = 0.0527$ $\quad$ moles $Mg = \frac{2.00}{24.3} = 0.0823$

✓ limiting reagent is Mg as 0.0527 mol of $TiCl_4$ would need 0.1054 mol Mg but there is only 0.0823 mol

✓ moles Ti = $0.0823 \times \frac{1}{2} = 0.04115$

✓ mass Ti = $0.04115 \times 47.9 = 1.97$ g (4)

8 Describe what each of the following formulae tells you about the substance shown.

a) Ammonia has the molecular formula NH_3

✓ **in each molecule**
✓ **1 N atom and 3 H atoms** (2)

b) Silicon dioxide has the formula SiO_2

✓ **ratio through structure**
✓ **is 1 Si atom : 2 O atoms** (2)

c) Aluminium oxide has the formula Al_2O_3.

✓ **ratio through structure**
✓ **is 2 Al^{3+} : 3 O^{2-} ions** (2)

d) Sulfur has the molecular formula S_8.

✓ **in each molecule**
✓ **8 S atoms** (2)

9 The element carbon exists in several different forms (allotropes), including diamond, graphite and graphene.

a) Explain why these forms of carbon all have high melting points.

✓ **giant covalent structure**
✓ **need to break covalent bonds**
✓ **takes a lot of energy to overcome** (3)

b) Explain why graphite and graphene are electrical conductors but diamond is not.

✓ **graphite has delocalised electrons**
✓ **and carry charge through structure**
✓ **diamond has no delocalised electrons** (3)

c) Buckminsterfullerene is another form of carbon with the formula C_{60}. Explain how the formula C_{60} tells us that this is a molecular substance and not a giant covalent substance.

✓ **there are 60 C atoms in each molecule**
✓ **if it was giant covalebt the formula would be C as it is an empirical formula** (2)

Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Write formulae (ionic)			Understands limiting reagents		
Good SPG			Write formulae (other)			What formulas mean		
Shows full working			Write balanced equations			Link structure types to properties		
Explanations are clear			Write ionic equations			Identify structure types of substances		
Convert units			Can work out formula mass					
Work to appropriate sig figs			Find moles from mass (and vice versa)					
Gives units when appropriate			Can do reacting mass calculations					

Transition from GCSE to A Level

Moving from GCSE Science to A Level can be a daunting leap. You'll be expected to remember a lot more facts, equations, and definitions, and you will need to learn new maths skills and develop confidence in applying what you already know to unfamiliar situations.

This worksheet aims to give you a head start by helping you:

- to pre-learn some useful knowledge from the first chapters of your A Level course
- understand and practice of some of the maths skills you'll need.

Learning objectives

After completing the worksheet you should be able to:

- define practical science key terms
- recall the answers to the retrieval questions
- perform maths skills including:
    - converting between units and standard form and decimals
    - balancing chemical equations
    - rearranging equations
    - calculating moles and masses
    - calculating percentage yield and percentage error
    - interpreting graphs of reactions.

Retrieval questions

You need to be confident about the definitions of terms that describe measurements and results in A Level Chemistry.

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

Practical science key terms

When is a measurement valid?	
When is a result accurate?	
What are precise results?	
What is repeatability?	
What is reproducibility?	
What is the uncertainty of a measurement?	
Define measurement error	
What type of error is caused by results varying around the true value in an unpredictable way?	
What is a systematic error?	
What does zero error mean?	
Which variable is changed or selected by the investigator?	
What is a dependent variable?	
Define a fair test	
What are control variables?	

Atomic structure

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

What does an atom consist of?	
What are the relative masses of a proton, neutron, and electron?	
What are the relative charges of a proton, neutron, and electron?	
How do the number of protons and electrons differ in an atom?	
What force holds an atomic nucleus together?	
What is the atomic number of an element?	
What is the mass number of an element?	
What is an isotope?	
What is an ion?	
What is the function of a mass spectrometer?	
What is a mass spectrum?	
What is the total number of electrons that each electron shell (main energy level) can contain?	
How many electrons can the first three electron shells hold each?	
What are the first four electron sub-shells (orbitals) called?	
How many electrons can each orbital hold?	
Define the term ionisation energy, and give its unit	
What is the equation for relative atomic mass (A_r)?	
What is the equation for relative molecular mass (M_r)?	

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 × 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.

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 question

6 Calculate the following unit conversions.
a 300 μm to m
b 5 MJ to mJ
c 10 GW to kW

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 question

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

Practice question

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 question

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.

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}.

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:

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

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 mol

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.

5.3 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

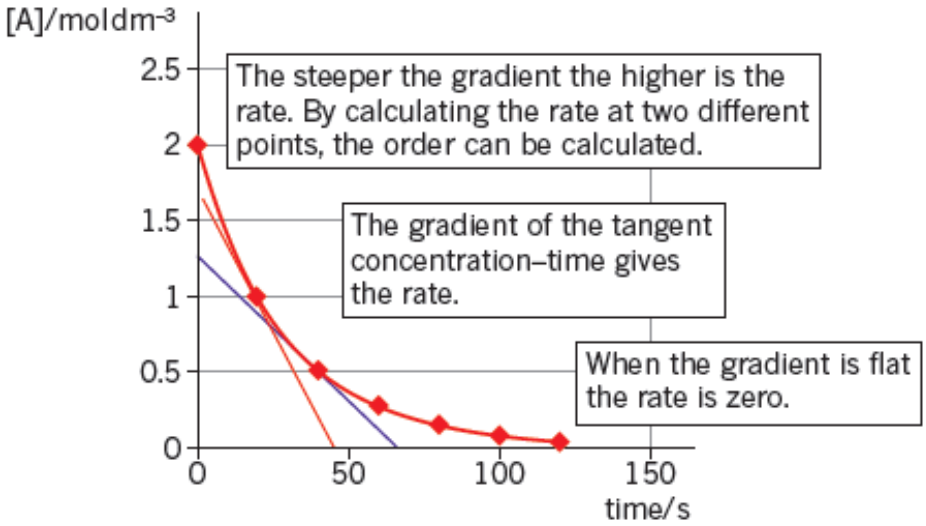
4 A thermometer has a maximum error of ±0.5 °C. Calculate the maximum percentage error when recording these temperature rises. Give your answers to 3 significant figures.

a 12.0 °C **b** 37.6 °C

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 question

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

6.2 Deducing the half-life of a reactant

In chemistry, half-life can also be used to describe the decrease in concentration of a reactant in a reaction. In other words, the half-life of a reactant is the time taken for the concentration of the reactant to fall by half.

Practice question

2 The table below shows the change in concentration of bromine during the course of a reaction.

Time / s	$[Br_2]$ / mol dm^{-3}
0	0.0100
60	0.0090
120	0.0066
180	0.0053
240	0.0044
360	0.0028

a Plot a concentration–time graph for the data in the table.

b Calculate the rate of decrease of Br_2 concentration by drawing tangents.

c Find the half-life at two points and deduce the order of the reaction.

Maths skills

1 Core mathematics

Practice questions

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 × $6.022 \times 10^{23} = 3.011 \times 10^{23} = 3.01 \times 10^{23}$

5 **a** 4.8 **b** 0.54
c 1.01 **d** 2.000

6 **a** 0.0003 m **b** 5×10^9 mJ
c 1×10^7 kW

2 Balancing chemical equations

Practice questions

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

Practice questions

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

4 Molar calculations

Practice questions

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

c 0.02 × 40.3 = 0.806 g

2 **a** $\frac{4.25}{85}$ = 0.05 mol **b** $\frac{0.05}{2}$ = 0.025 mol

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

5 Percentage yields and percentage errors

Practice questions

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%

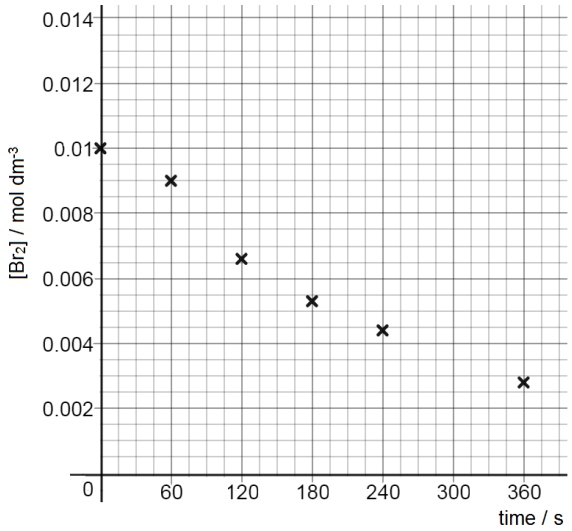
4 **a** 0.5 × (2/12) × 100 = 8.33% **b** 0.5 × (2/37.6) × 100 = 2.66%

6 Graphs and tangents

Practice questions

1 $\frac{-1.25}{65} = -0.0192$

2 **a**



b Half-life is approximately 180 seconds **c** The reaction is first order