Caterham School

Chemistry Department

Pre-A level

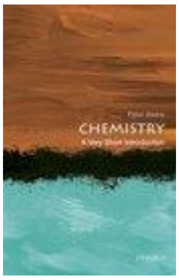
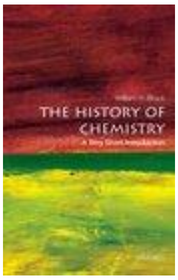
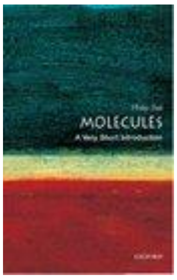
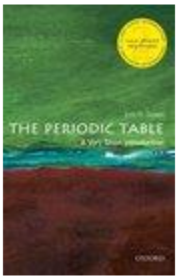
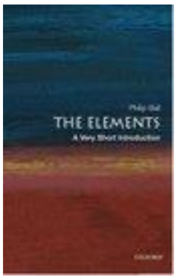
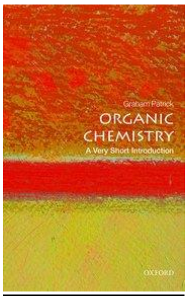
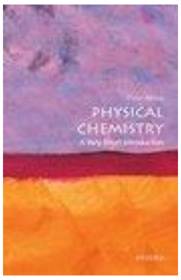
Essential preparation for A level Chemistry

Name:	

To be read and completed by the first lesson in September

Section 1

1. Buy and read at least one of the following books.

	**Chemistry: A Very Short Introduction** **Peter Atkins** **978-0199683970**		**The History of Chemistry: A Very Short Introduction** **William H. Brock** **978-0198716488**
	**Molecules: A Very Short Introduction** **Philip Ball** **978-0192854308**		**The Periodic Table: A Very Short Introduction** **Eric R. Scerri** **978-0198842323**
	**The Elements: A Very Short Introduction** **Philip Ball** **978-0192840998**		**Organic Chemistry: A Very Short Introduction** **Graham Patrick** **978-0198759775**
	**Physical Chemistry: A Very Short Introduction** **Peter Atkins** **978-0199689095**		**Materials: A Very Short Introduction** **Christopher Hall** **978-0199672677**

All of these books are also available as Apple Books for an iPad or as a kindle edition (you can download a free app from Amazon in order to read it on a non-kindle devise).

Many of the 'A very short introduction' series are also available as audiobooks through 'Audible' or other suppliers.

There are plenty of other chemistry books that you could/should also read, but one of these is a good start!

Make notes about why it was interesting.
What bits of it you particularly liked and why.
There is space on this page for you to make notes.

notes on ‘A Very Short Introduction’ to ……………………………………………

2. Watch this Khan Academy video – Introduction to chemistry

https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties/introduction-to-the-atom/v/introduction-to-chemistry

This is the first in a whole series of Khan Academy videos about chemistry – feel free to watch more (or them all) at your leisure.

3. You must watch some of the 'periodic videos'

These are a series of short chemistry videos made by the legend Sir Martyn Poliakoff, known as the professor, and his team at the University of Nottingham.

Watch this one first:
Who REALLY invented the periodic table?

https://www.youtube.com/watch?v=83RSwczyyRY

There are loads of great videos on this site – watch some for interest and fun.

4. Watch a TED Talk about the periodic Table

https://ed.ted.com/lessons/solving-the-puzzle-of-the-periodic-table-eric-rosado

5. What can you do with chemistry – career-wise?

The Royal Society of Chemistry aims to promote chemistry and its related disciplines as well as support chemists.
It is a huge organisation and has lots of great resources that can help you whatever stage you are at in your chemistry career!
On this page there are some 'stories' by young chemists and the varied and interesting jobs that they are doing. Read a few and get and overview of what job opportunities there are out there for graduate chemists:

https://edu.rsc.org/future-in-chemistry/career-options/job-profiles

6. Research an interesting molecule

You will research a molecule of interest to you. To find one you like you may need to look up a few until you find one that particularly appeals.
You will then need to present an A4 summary page on your chosen molecule.
This will need to address, at least, the following points:

> Systematic name, structure, function, discovery/synthesis date, name of person responsible, details of synthesis, why it is important and/or interesting to you, other interesting or pertinent information.

This is a 'scientific poster'!
They need to be academically informative and interesting – they will be used to 'decorate' the wall of the chemistry corridor in September when we return to school.

Here is a list of some molecules to give you a start with your research. Feel free to pick something not on my list.

Oxalic acid	Folic acid	Keratin	Theobromine
luminol	Aspirin	Chloroform	Asparagusic acid
Arachidonic acid	Caffeine	Lidocaine	Epinephrine
Atropine	DDT	Ibuprofen	Cholesterol
Thalidomide	Agent orange	Nicotinic acid	Capsaicin
Monosodium glutamate (MSG)	Lactic acid	Retinol	Heavy water
Ascorbic acid	Cisplatin	Benzene	Cytosine

7. Just love chemistry and develop a desire to want to know and understand more

Here are more books that you could buy and read:

The Chemistry Book: From Gunpowder to Graphene, 250 Milestones in the History of Chemistry
by Derek Lowe

Creations of Fire: Chemistry's Lively History from Alchemy to the Atomic Age
by Cathy Cobb

Stuff Matters: The Strange Stories of the Marvellous Materials that Shape Our Man-made World
by Mark Miodownik

The Disappearing Spoon...and other true tales from the Periodic Table
by Sam Kean

Periodic Tales: The Curious Lives of the Elements
by Hugh Aldersey-Williams

Napoleon's Buttons: How 17 Molecules Changed History
by Penny Le Couteur & Jay Burreson

Elemental: How the Periodic Table Can Now Explain (Nearly) Everything
by Tim James

The Elements of Murder: A History of Poison
by John Emsley

More Molecules of Murder
by John Emsley

Molecules At An Exhibition: Portraits of Intriguing Materials in Everyday Life
by John Emsley

The Periodic Kingdom: A Journey Into The Land Of The Chemical Elements
by Peter Atkins

Oxygen: The molecule that made the world
by Nick Lane

H_2O: A Biography of Water
by Philip Ball

this is not an exhaustive list; there are many more…

If you come across a good book that is not on the above list – please tell me about it.

Section 2

Do some research on the history of our understanding of ‘elements’ and ‘the atom’.
Make brief notes about key developments.

Section 3

Maths in Chemistry:

Within A Level Chemistry, 20% of the marks available in written exams will be for assessment of mathematics, in context, at a Level 2 standard, or higher.

Lower level mathematical skills will still be assessed within examination papers, but do not count within the 20%.

What Level 2 (or higher) means in the context of Chemistry:

- application and understanding requiring choice of data or equation to be used

- problem solving involving use of mathematics from different areas of maths and decisions about direction to proceed

- questions involving use of A Level mathematical content e.g. use of logarithmic equations.

Not counted as Level 2 but still assessed in chemistry:

- simple substitution with little choice of equation or data and/or structured question formats using GCSE mathematics.

Note: As lower level mathematical skills are assessed in addition to the 20% weighting for Level 2 and above, the overall assessment of mathematical skills will form greater than 20% of the assessment!

a. Units

you are required to

- give measurements and results of calculations in the correct units
- convert between different units
- determine the units for particular constants

A measured quantity without units is meaningless, although there are some derived quantities in chemistry that do not have units, notably relative mass and pH.

Unit prefixes indicate particular multiples and fractions of units.

A list of SI unit prefixes is given below, with the prefixes that are most likely to be used within the A Level Chemistry course highlighted.

Factor	Name	Symbol
10^{24}	yotta	Y
10^{21}	zeta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	terra	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

You will be expected to be able to convert between the commonly used multiples without help or prompting.

At A Level you are expected to be able to recognise and use compound units in the form mol dm^{-3}, rather than mol/dm^3. In fact, use of the latter unit style will cause you to fail the practical endorsement!

You are, in general, expected to use and recognise standard SI units.
For example, dm^3 is used rather than l (litre), although l and ml may be seen on glassware.

You should know that:
1 dm^3 = 1 l
1 cm^3 = 1 ml
1 dm^3 = 10^3 cm^3 = 1000 cm^3

The exception to use of SI units is the degree (°) for angles, which is used in preference to the radian.

Note that kelvin (K) and degree Celsius (°C) are both used for temperature. K = 273 + °C, and temperature differences are equivalent in both units.

While the pascal (Pa) is the SI, and therefore the preferred, unit of pressure, the atmosphere (atm) is still in common usage and learners should be comfortable with both. Questions involving pressure calculations would usually involve all quantities expressed in the same unit.

The *Data Sheet* gives the conversion for 1 tonne to grams. Any other conversion to or from non-standard units that may be required in assessment would be provided in the question.

b. decimal places and significant figures

It is very important in chemistry that you give answers to the correct number of significant figures or decimal places. The general rules are shown below.

Decimal places in calculations

Measurements should always be given to a number of decimal places appropriate to the apparatus.

When adding and subtracting measurements, the result should be quoted to the same number of decimal places.

For example:
25.50 °C – 8.30 °C = 17.20 °C;
answer given to the same number of decimal places (2), not lowest number of significant figures (3)

5.458 g + 6.349 g = 11.807 g;
answer given to the same number of decimal places (3), not lowest number of significant figures (4)

How many significant figures should be used?

The result of a calculation that involves measured quantities cannot be more certain than the *least* certain of the information that is used. So, the result should contain the same number of significant figures as the measurement that has the *smallest* number of significant figures.

For example:

$3.0 \times 10^4 / 1.15 \times 10^4 = 2.6$; answer given to 2 significant figures

A common mistake is to simply copy down the final answer from the display of a calculator. This often has far more significant figures than the measurements justify.

Rounding off

When rounding off a number that has more significant figures than are justified, if the last figure is between 5 and 9 inclusive round up; if it is between 0 and 4 inclusive round down.

For example, the number 3.5099 rounded to:

4 sig figs is 3.510

3 sig figs is 3.51

2 sig figs is 3.5

1 sig fig is 4

Notice that when rounding you only look at the one figure beyond the number of figures to which you are rounding, *i.e.* to round to three sig fig you only look at the fourth figure.

How do we know the number of significant figures?

If the number 450.13 is rounded to 2 sig figs, the result is 450.

However, if seen in isolation, it would be impossible to know whether the final zero in 450 is significant (and the value to 3 sig figs) or insignificant (and the value to 2 sig figs).

In such cases, standard form should be used and is unambiguous:

- 4.5×10^2 is to 2 sig figs
- 4.50×10^2 is to 3 sig figs.

When to round off

It is important to be careful when rounding off in a calculation with two or more steps.

• Rounding off should be left until the very end of the calculation. Use 'calculator values' throughout the calculation until the final answer needs rounding.

• Rounding off after each step, and using this rounded figure as the starting figure for the next step, is likely to make a difference to the final answer. This introduces a **rounding error**.

Questions

complete the following questions writing your answer on the line:

Q1. Write the following numbers to the quoted number of significant figures.

a)	345789	4 sig figs	…………………………………
b)	297300	3 sig figs	…………………………………
c)	0.07896	3 sig figs	…………………………………

Q2. Write the following numbers to the quoted number of significant figures and in standard form.

a)	4590304	4 sig figs	…………………………………
b)	0.003715	3 sig figs	…………………………………
c)	10.4537	3 sig figs	…………………………………

Q3. Complete the following, giving the answer to the appropriate number of significant figures.

a)	$45.3 \times 10^{7} + 1035$	…………………………………
b)	102 / 51	…………………………………
c)	102.0 / 51.0	…………………………………
d)	$1.412 \times 10^{-3} \times 2.0$	…………………………………
e)	$1.412 \times 10^{-3} \times 2.00$	…………………………………
f)	1027 + 345.1	…………………………………
g)	907.4 - 1.32	…………………………………

Section 4

formula and equations

Formula

It is assumed that you have a good understanding of bonding in order to be able to work out the formula of relatively simple compounds.

Equations

Chemists record chemical reactions in the form of equations. They can be either 'word equations' or symbol equations' (sometimes called 'chemical equations'). Increasingly we only write symbol equations.

An equation has the basic structure:

reactants → products

There is a systematic to ensure that an equation is written correctly:

for example, for the complete combustion of ethane

1 write the word equation

ethane + oxygen →carbon dioxide + water

2 using knowledge of bonding work out the formula of each part of the equation

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

3 the equation must now be balanced by ensuring that the same number of atoms appear on either side of the arrow.

$$C_2H_6 + 3.5\ O_2 \rightarrow 2CO_2 + 3H_2O$$

4 state symbols are then added to show the state of matter of each part of the equation.

(g) denotes a gas | **(l)** denotes a liquid

(s) denotes a solid | **(aq)** denotes aqueous, i.e., dissolved in water

$$C_2H_{6\,(g)} + 3.5\ O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

another example:

1. **magnesium + hydrochloric acid → magnesium chloride + hydrogen**

2. $Mg + HCl \rightarrow MgCl_2 + H_2$

3. $Mg + 2HCl \rightarrow MgCl_2 + H_2$

4. $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

Questions

Q5. balance the following equations:

____ Fe_2O_3 + ____ C → ____ Fe + ____ CO

____ Mg + ____ HCl → ____ $MgCl_2$ + ____ H_2

____ S_8 + ____ O_2 → ____ SO_2

____ N_2 + ____ H_2 → ____ NH_3

____ NH_4NO_3 → ____ N_2O + ____ H_2O

____ C_2H_6 + ____ O_2 → ____ CO_2 + ____ H_2O

____ Al + ____ HCl → ____ $AlCl_3$ + ____ H_2

____ C_8H_{18} + ____ O_2 → ____ CO_2 + ____ H_2O

____ As_4S_6 + ____ O_2 → ____ As_4O_6 + ____ SO_2

Section 5

moles

The **mole** is the base unit of amount of substance (number) in the International System of Units (SI), defined as exactly $6.02214076 \times 10^{23}$ particles, e.g., atoms, molecules, ions or electrons.

Its symbol is **mol**.

This definition has been recently adopted (IUPAC November 2018) and replaces the previous definition based on the number of atoms in exactly 12g of carbon-12

This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in mol^{-1}, and is called the Avogadro number.

The number N_A was chosen so that the mass of one mole of a chemical compound, in grams, is numerically equal to the average mass of one molecule of the compound, in atomic mass units.

Hence the unit of Molar Mass is $gmol^{-1}$

So one mole of H atoms contains 6×10^{23} **atoms**

2 moles of O_2 gas contains 12×10^{23} **molecules** etc.

N.B. it is essential to have the qualifying particle description

To calculate the number of a particular particle present (be it an electron or an atom or a molecule etc…); first calculate the number of moles of that particle and then multiple by Avogadro's Number

There are 3 ways to calculate the amount of substance present.

1. from the mass of a solid or a pure liquid (or even a gas)

no. of moles (n) = mass (in grams) / molar mass (Mr)

mass = moles x Mr or **Mr = mass/moles**

N.B. If you know the volume and the density of a gas or liquid it is relatively simple to calculate its mass.

2. from the volume of a gas

1 mole of any gas occupies the same amount of space when in the same conditions.

At room temperature and pressure (rtp) 1 mole of any gas occupies **24dm^3** of space. (or **24,000cm^3**)

This is known as the 'molar gas volume', that is, the gas volume per mole.

N.B. rtp is 298 K (25°C) and 101.3 kPa (1 atm)

no. of moles (n) = volume of gas (in dm^3) / 24

N.B., you must be consistent with your units. If using cm^3 gas volumes then use 24,000!

3. solutions

A solution is a certain number of moles of a solute dissolved in a solvent to make up a certain volume.

the concentration of a solution is measured in 'moles per decimetre cubed', moldm^{-3}, of solute.

the unit is sometimes abbreviated to a **M**, as in 1M HCl (aq), where the M stands for Molar.

no. of moles = concentration x volume

the volume must be in dm^3.

As all of these mathematical expressions contain a mole value they are in turn all related to each other. You are expected to be able to work with more than one to get through a calculation!

Questions **use the periodic table at the end of this booklet for all calculations**

Q6. complete the following mole calculations:
show your working and write the answer in the box

a. How many atoms in 32g of sulfur?

b. How many atoms in 4g of helium?

c. The mass of one proton is 1.6725×10^{-24} g.

Calculate the mass of one mole of $^{1}H^{+}$ ions given that the Avogadro constant = 6.0225×10^{23}.

d. The mass of one mole of ^{127}I atoms is 126.9045 g.

Given that the Avogadro constant equals 6.0225×10^{23} and the mass of one electron equals 9.1091×10^{-28} g, calculate the mass of one mole of $^{127}I^{-}$ ions.

e. The percentage abundances for the isotopes of boron are 18.7% of ^{10}B and 81.3% of ^{11}B.

Calculate the relative atomic mass for boron.

f. Neon occurs as two isotopes of mass numbers 20 and 22.

Its relative atomic mass is 20.2.
What is the percentage of ^{20}Ne in naturally occurring neon?

Q7. What is the Molar Mass of the following:

Li_3N	
$Cu(OH)_2$	
CH_3COOH	
$Zn_3(PO_4)_2$	

Q8. Work out the number of moles of the following (show working)

32 g of $CuSO_4$	
2.35 g of K_2O	
113.75 g $FeCl_3$	
12.2 g of $AlPO_4$	

Q9. Work out the mass of the following; write the calculation out in full (watch your brackets):

0.2 moles of $AlCl_3$	
0.25 moles of NaOH	
0.033 moles of $BaCO_3$	
0.17 moles of $AgNO_3$	

Q10. What is the mass, in grams, of 2.60 mol of calcium carbonate?

Q11. What is the amount, in moles, in 2.50 g of sulfur dioxide?

Q12. What is the volume, in dm^3, occupied by 0.300 mol of argon gas at r.t.p.?
[Molar volume at r.t.p. = 24.0 dm^3/mol]

Q13. What is the amount, in mol, of oxygen at r.t.p. in 10,000 cm^3 of oxygen gas?

Section 6

stoichiometry

The term is derived from the Ancient Greek words στοιχεῖον *stoicheion* "element" and μέτρον *metron* "measure".

Although it is a rather awkward word, all it really means is that in chemical reactions the Laws of the Conservation of Matter must be obeyed. To do this we must be able to write and balance equations and then calculate the number of each particle being reacted or formed.

Knowing the balanced chemical equation enables us to calculate the quantities of all parts of the equation when we may know only one of them!

e.g., $\mathbf{2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}}$

The above balanced equation represents the combustion of magnesium gas in air (or oxygen) to produced magnesium oxide.

It is clear from the equation that 2 moles of magnesium metal react with 1 mole of oxygen gas to produce 2 moles of magnesium oxide.

This 2:1:2 ratio is true no matter what mass of magnesium you start with.

so if you took 12 grams of magnesium; that would be 12/24 = 0.5 moles of Mg

half as many moles of oxygen gas is needed to react with it so you would need 0.5/2 = 0.25 moles of oxygen (which, incidentally, is 0.25 x 24000 cm^3 = 6000cm^3 (or 6dm^3)

but the same number of moles of magnesium oxide would be produced as moles of magnesium used, i.e., 0.5 moles

the mass of MgO produced = 0.5 x (24 + 16) = 20g

Questions **use the periodic table at the end of this booklet for all calculations**

Q14. complete the following calculations

show all your working

a. Copper oxide can be reduced to copper using methane. What mass of copper oxide would be needed to make 19.2g of copper?

$$4CuO + CH_4 \rightarrow 4Cu + CO_2 + 2H_2O$$

b. What mass of water is produced by completely burning 15kg of butane?

$$2C_4H_{10} + 13\ O_2 \rightarrow 8CO_2 + 10\ H_2O$$

c. Sodium sulfate can be made by neutralising sodium hydroxide with sulfuric acid:

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

Calculate the mass of sodium sulfate that can be made from 80 g of sodium hydroxide using an excess of sulfuric acid.

You will need to write balanced equations before you can do the next questions.

d. What mass of copper(II) oxide, CuO, is formed when 127 g of copper is reacts with oxygen?

e**.** Mercury(II) oxide, HgO, decomposes to give mercury and oxygen when heated. What mass of mercury is obtained from 54 g of mercury(II) oxide?

f. What mass of carbon dioxide can be made by decomposing 200 g of calcium carbonate?

g. When hydrochloric acid neutralises potassium hydroxide, the products are potassium chloride and water.

Find the mass of potassium chloride that is formed when 14 g of potassium hydroxide are completely neutralised by hydrochloric acid.

Section 7

Percentage Yield

When we do experiments and mole calculation, we assume that the stoichiometry of the equation actually works in practice.

Not all the reactant that is put in ever reacts! That is why in questions they use phrases such as:

" ..calculate the maximum mass of XXX that could be produced…."

or

"…calculate the minimum mass of XXX needed to ……"

The maximum possible amount of product is known as the 'theoretical yield'. It is rarely achieved!

Reasons include:

- the reaction does not go to completion
  - reactions are reversible so the forward/desired reaction may not complete
  - as the concentration of reactants decreases the rate of reaction slows – it may slow so much that the product is collected before the reaction has actually finished
- other side-reactions happening within the reaction mixture – we tend to ignore these but they do account for impurities within the final mixture.
- when collecting and purifying product in order to measure it, some may be lost

The actual yield obtained will be lower that the theoretical yield.

The % conversation of starting material into desired product is known as percentage yield:

$$\textbf{\% yield} = \frac{\textbf{actual number of moles of product formed}}{\textbf{theoretical number of moles of product formed}} \times 100$$

Questions **use the periodic table at the end of this booklet for all calculations**

Q15

Calculate the percentage yield of a reaction that has a theoretical yield of 4.75 moles of product and an actual yield of 3.19 moles of product.

Give you answer to an appropriate number of significant figures.

Q16

An excess of zinc is added to 25.0 cm^3 of 1.0 mol dm^{-3} iron (II) sulfate solution

$$Zn\ (s) + FeSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Fe\ (s)$$

1.116g of iron is produced

calculate the percentage yield.

Q17

A student added 2.254g of ethanol to an excess of propanoic acid to make the ester, ethyl propanoate, and water.

$$C_2H_5OH + C_2H_5COOH \rightarrow C_2H_5COOC_2H_5 + H_2O$$

4.5g of the ester was obtained.

Calculate the percentage yield

Section 8

Atom Economy

This is a measure of how economically all the atoms of the reactants have been used to create he desired product.

Atom economy was developed as a way of looking at the use of finite resources and the environmental concerns about harmful waste from the chemical industry.

Atom economy is a measure of the proportion of desired products compared with all the other products formed.

Atom economy is calculated using the following formula:

$$\textbf{atom economy} = \frac{\textbf{molecular mass of the desired product}}{\textbf{sum of molecular masses of all products}} \times 100$$

Using atom economy, it is possible to gain a measure of the proportion of waste materials produced and thus the environmental impact of a chemical process.

Addition reaction, where two reactants produce one product, produce only desired product and therefore have an atom economy of 100%. There are no waste products.

Substitution reactions produce the desired product as well as unwanted by-products. They will have an atom economy of less than 100%.

Chemical companies are trying to find other uses for the ‘waste products’ / by-products. They will turn them into ‘desired products’ and therefore increase the atom economy.

It is possible for a reaction to have a high percentage yield but a low atom economy, and vice versa.

Questions **use the periodic table at the end of this booklet for all calculations**

Q18

The following displacement reaction could be used as a method to obtain the desired product, iron metal.

$$Zn\ (s) + FeSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Fe\ (s)$$

Determine the atom economy for this reaction.

Q19

The following reaction could be used to make the desired ester.

$$C_2H_5OH + C_2H_5COOH \rightarrow C_2H_5COOC_2H_5 + H_2O$$

Determine the atom economy for this reaction.

Q20

A chemist prepares a sample of propan-1-ol by reacting 1-chloropropane with potassium hydroxide solution.

$$CH_3CH_2CH_2Cl + KOH = CH_3CH_2CH_2OH + KCl$$

Determine the atom economy for this reaction.

Suggest a way the atom economy for this method of production of propan-1-ol can be improved.

Further Questions **use the periodic table at the end of this booklet for all calculations**

Q1. Empirical Formula:

Find the empirical formulae for the ten compounds (a)–(j) from the data given.

No compound contains more than 15 atoms in total in its formula.

Show all your working in neat, clearly-presented answers. All compositions are by mass.

a) 35.0% Nitrogen, 5.0% Hydrogen, 60.0% Oxygen

b) 90.7% Lead, 9.3% Oxygen

c) 26.6% Potassium, 35.3% Chromium, 38.1% Oxygen

d) 40.3% Potassium, 26.8% Chromium, 32.9% Oxygen

e) 29.4% Vanadium, 9.2% Oxygen, 61.4% Chlorine

f) 81.8% Carbon, 18.2% Hydrogen

g) 38.7% Carbon, 9.7% Hydrogen, 51.6% Oxygen

h) 77.4% Carbon, 7.5% Hydrogen, 15.1% Nitrogen

i) 25.9% Nitrogen, 74.1% Oxygen

j) 29.7% Carbon, 5.8% Hydrogen, 26.5% Sulphur, 11.6% Nitrogen, 26.4% Oxygen

k) Complete combustion of 6.4 g of compound K produced 8.8 g of carbon dioxide and 7.2 g of water.

Calculate the empirical formula of K.

l) Complete combustion of 1.8 g of compound L produced 2.64 g of carbon dioxide, 1.08 g of water and 1.92 g of sulfur dioxide.

Calculate the empirical formula of L.

Q2. Ar & Mr and molecular formula

Assume that the mass of an isotope in amu to 3 s.f. is equal to its mass number.

1 Atomic mass unit (u) = 1.66054×10^{-27} kg

a) Which isotope is used as the standard against which relative atomic masses are calculated?

b) Fluorine only occurs naturally in one isotope, ^{19}F, and has a relative atomic mass of 19.0 amu.

Calculate the mass of a fluorine atom in kg.

c) Magnesium has the following natural isotopes: ^{24}Mg 78.6%; ^{25}Mg 10.1%; ^{26}Mg 11.3%. Calculate the relative atomic mass of magnesium.

d) The relative atomic mass of boron is 10.8 amu. Boron exists in two isotopes, ^{10}B and ^{11}B. Calculate the percentage abundance of ^{10}B.

e) Complete the table below but finding the values that should replace the ?:

ELEMENT	Ar	Isotope 1	Isotope 2	Isotope 3	Isotope 4
Bromine	?	^{79}Br 50.5%	^{81}Br 49.5%		
Silver	107.9	^{107}Ag...?...%	^{109}Ag...?....%		
Cerium	140.2	^{136}Ce 0.2%	^{138}Ce 0.2%	^{140}Ce 88.5%	$^{?}Ce$ 11.1%

f) The relative molecular mass of compound M is 135 amu.

M contains 3.7% hydrogen, 44.4% carbon and 51.9% nitrogen by mass.

Find the molecular formula of M.

g) Complete combustion of compound N occurs in a stoichiometric ratio of 1:6 with oxygen gas.

Complete combustion of 4.2 g of compound N produces 13.2 g of carbon dioxide and 5.4 g of water.

Find the molecular formula of N.

Q3 Standard form

Complete the following calculations, giving the answers in standard form to the appropriate number of significant figures.

a) 120×70

b) $5600 + 800 + 12 + 1100 + 320$

c) $95.0 / 19000$

d) $12000 + 84000 + (3.00 \times 10^3) + 29000$

e) $(4.0 \times 10^2) \times 100 \times 300$

f) $1.6 \times 10^{-8} / 6.4 \times 10^{-3}$

g) $3.00 \times 10^8 / 5.2 \times 10^{-7}$

h) $2.12 \times 10^{12} \times 5.4 \times 10^6$

i) $1.4 \times 10^{-10} \times 1.4 \times 10^{-10} \times 2.2 \times 10^{-10}$

j) $1.6 \times 10^{-19} \times 6.0 \times 10^{23}$

k) $1.3 \times 10^{17} / 3.0 \times 10^{8}$

l) $(1.4 \times 10^{-6})^{3}$

m) $\sqrt{(2.5 \times 10^{14})}$

n) $2.0 \times 10^{4} \times 1.2 \times 10^{4} / (3.2 \times 10^{6})^{2}$

o) $1.1 \times 10^{-5} \times (-2) \times 3 / (9.6 \times 10^{-11} + 1.2 \times 10^{-10})$

Q4. Unit conversions

Use standard form where answers are outside the range 0.01 to 1000 units.

1 Å = 10^{-10} m (although the angstrom is not an SI unit it is metric and sometimes used!)

(i) Convert the following volumes into dm^3

a) 0.86 m^3

b) 200 cm^3

c) 45 ml

d) 120 m^3

e) 0.064 nm^3

f) 70 cl

g) 1.6 mm^3

h) 1100 cc

i) 2.2 km^3

j) 42.5 $Å^3$

(ii) Converts the following masses into g:

a) 16.0 kg

b) 120 mg

c) 0.004 kg

d) 12 tonne

e) 54 µg

(iii) Convert the following into standard SI units:

a) 68 km h^{-1}

b) 500 g

c) 24 dm^3

d) 20 mbar

e) $-77\,^\circ C$

f) 5.0 h

g) 740 nm

h) 72 mN cm^{-1}

i) 1014 mbar

j) 13.8 g cm^{-3}

(iv) Give the results of the following calculations in standard SI units:

a) Density = 250 g / 400 cm^3

b) Speed = 96 km / 80 min

c) Concentration = 2.50 mmol / 40.0 cm^3 (use mol dm^{-3})

d) Momentum = 4.0×10^{-23} g × 900 m s^{-1}

e) Pressure = 590 fN / 10 nm^2

f) Volume = 240 pm × 240 pm × 320 pm

g) Amount = 2.0 µmol dm^{-3} × 75 μm^3

h) Energy = 3.2×10^{-19} C × 2.4 kV

Q.5 Gases

RTP = room temperature and pressure.

Any gas occupies 24 dm^3 per mole at RTP.

Avogadro's number, $N_A = 6.02 \times 10^{23}$.

(i) Calculate the volume occupied by:

a) 4.0 moles of gas at RTP

b) 0.030 moles of gas at RTP

c) 5.0×10^{18} atoms of helium gas at RTP

d) 1.2×10^{24} molecules of ozone at RTP

e) 8.0 g of O_2 at RTP

f) 1.1 kg of carbon dioxide at RTP

(ii) Calculate the amount of gas (at RTP) in:

a) 4.8 dm^3

b) 12 m^3

c) 400 cm^3

d) 18 ml

(iii) Calculate the number of molecules of gas (at RTP) in:

a) 36 dm^3

b) 300 cm^3

(iv) Calculate the number of atoms (at RTP) in:

a) 60 cm^3 of argon

b) 1.2 dm^3 of N_2

c) 8.0 m^3 of carbon dioxide

d) 420 cm^3 of ethane

(v) Calculate the mass of:

a) 1.0 m^3 of neon at RTP

b) 20 cm^3 of $(CH_3)_2O$ at RTP

c) 420 cm^3 of ammonia at RTP

Q. 6 Solids

(i) Find the molar masses in amu of the following compounds:

a) $CaCO_3$

b) Na_2CO_3

c) NaOH

d) HCl

e) H_2SO_4

f) $FeSO_4$

g) $KMnO_4$

h) $Fe_2O_3 \cdot 5\,H_2O$

i) Calcium hydroxide

j) Butane

(ii) Calculate the mass of:

a) 0.25 moles of H_2O_2 (l)

b) 6.0 moles of C_2H_6 (g)

c) 0.40 moles of H_2O(l)

d) 20.0 moles of Sr(s)

e) 1.20 moles of aluminium oxide

f) 7.4 moles of ammonium sulfate

(iii) Calculate the amount of:

a) 1.001 g of $CaCO_3$ (s)

b) 197 kg of Au(s)

c) 1.4 g of CO(g)

d) 2.006 kg of Hg(l)

e) 11.1 g of lithium carbonate

f) 10.0 mg of lead(II) iodide

Q.7 Solutions

(i) Calculate the concentration in mol dm^{-3} of the following solutions:

a) 0.40 g NaOH in 100 ml water

b) 7.3 g HCl in 1000 ml water

c) 2.5 g H_2 SO_4 in 50 ml water

d) 15 g $FeSO_4$ in 500 ml water

e) 0.16 g $KMnO_4$ in 200 ml water

(ii) Calculate the mass of solute in each of the following:

a) 500 ml of 0.010 mol dm^{-3} $NaOH$

b) 150 ml of 4.0 mol dm^{-3} HCl

c) 1.00 ml of 10.0 mol dm^{-3} H_2SO_4

d) 25.0 ml of 0.50 mol dm^{-3} $FeSO_4$

e) 21.8 ml of 0.0050 mol dm^{-3} $KMnO_4$

f) 2.0 dm^3 of 0.10 mol dm^{-3} $NaCl$

g) 100 ml of limewater with a concentration of 0.00020 mol dm^{-3}

Q.8 Reactions

(i) Calculate the amount of oxygen needed, and amount of carbon dioxide produced, in each of the following cases:

a) $C_3H_8 + 5\ O_2 \longrightarrow 3\ CO_2 + 4\ H_2O$, using 1.0 mole of C_3H_8

b) $C_2H_6O + 3\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$, using 0.2 moles of C_2H_6O

c) $2\ CO + O_2 \longrightarrow 2\ CO_2$, using 4.0 moles of CO

d) $C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$, using 0.040 moles of $C_6H_{12}O_6$

e) $C_2H_4O_2 + 2\ O_2 \longrightarrow 2\ CO_2 + 2\ H_2O$, using 0.10 moles of $C_2H_4O_2$

(ii) Calculate the amount of water produced by complete combustion of the following in oxygen (you will need to write a balanced equation each time):

a) 1.0 mole of pentane, C_5H_{12}

b) 2.5 moles of heptane, C_7H_{16}

c) 200 moles of hydrogen, H_2

d) 4.0 moles of butane

e) 0.0030 moles of methane

(iii) Write the equation for each reaction and hence calculate the amount of acid required for complete reaction in each of the following cases:

a) 0.10 mol NaOH reacting with H_2SO_4

b) HCl reacting with 20 g of $CaCO_3$

c) 24 g CuO reacting with HNO_3

d) 5.6 g Fe reacting with HCl

e) 14.8 g of calcium hydroxide reacting with H_2SO_4

f) 10 g of magnesium oxide reacting with nitric acid

(iv) Calculate the volume of 0.50 mol dm^{-3} H_2SO_4 required to neutralize each of the following:

a) 25.0 cm^3 of 1.0 mol dm^{-3} NaOH

b) 3.0 g $CaCO_3$

c) 1.25 g $ZnCO_3$

d) 4.03 kg MgO

e) 100 cm^3 of 0.2 mol dm^{-3} NH_3 (aq)

Qu. 9 Parts per million

We use this unit rarely in chemistry but it comes up a lot in medicine and other applied sciences so it is helpful to understand it. When communicating science to the public the unit ppm is often used as it makes concentration units like *moldm*$^{-3}$ a little more friendly and understandable to non-scientists. So it is important to know how to perform a basic ppm calculation if you're going to communicate with other scientists or the public.

It is basically what it sounds like – how many (the number) of parts of the thing you are interested in 1 million parts of the solution.

It is a bit like a percentage but smaller. Percentage just means the number of units per one hundred and could be abbreviated to *pph* (parts per hundred) but instead we use the % symbol.

PPM calculations are just the same as % calculations really but you times by a million rather than 100:

$$\text{Concentration in ppm} = \frac{\text{Amount of substance}}{\text{Amount of whole solution}} \times 1{,}000{,}000$$

The first thing that needs to be done, though, is to ensure that the solute and the solvent are in the same units to start with. This may need some unit conversions before you apply the formula above.

(i) Calculate the ppm by volume of:

a) 20 cm^3 of CO per 40 m^3 of air

b) 0.10 ml of alcohol per 100 ml of blood

c) 5.0 cm^3 of O_3 per 20 m^3 of air

d) $0.0040\ cm^3$ of C_2H_4 per 1 dm^3 of air

(ii) Calculate the ppm by mass of:

a) 10 mg of Hg per tonne of water

b) 0.020 g of Mg per kg of $CaCO_3$

c) 50 mg of iron per kg of blood

d) 4.0×10^{-4} moles of arsenic per 1 kg of iron ore

(iii) Calculate the ppm by number of particles of:

a) 23 mg of sodium in 2 kg of mercury

b) 60 µmol of albumen in 36 cm^3 of water

c) 12 µg of magnesium hydrogen phosphate in 90 µl of water

d) 84 µg of carbon monoxide in 12 dm^3 of air

(iv) Convert the following concentrations from parts per million (ppm) by mass to mol kg^{-1} .

a) 2500 ppm $CaCO_3$

b) 32.0 ppm NH_3

c) 120 ppm H_2O_2

d) 0.25 ppm Hg

e) 6.0 ppm $CH_3CH_2CH_2COOH$

The Periodic Table of the Elements

Key
atomic number
Symbol
name
relative atomic mass

1 (1)	2 (2)	3	4	5	6	7	8	9	10	11	12	13 (3)	14 (4)	15 (5)	16 (6)	17 (7)	18 (0)
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.2	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium	92 **U** uranium 238.1	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium