C3: Quantitative Chemistry

ANSWER KEY

8.1	**What is the law of conservation of mass?**	**Total mass of reactants = total mass of products**
8.2	When magnesium reacts with oxygen to form magnesium oxide, why does the mass increase?	Oxygen atoms have been joined to the magnesium (that had not been weighed beforehand as they came from the air)
8.3	**When calcium carbonate reacts with acid and makes carbon dioxide, why does the mass decrease?**	**Because carbon dioxide is a gas and escapes from the reaction**
8.4	What is relative formula mass, Mr?	The sum of the masses of each atom in a compound
8.5	**What are the four state symbols and what do they stand for?**	**(s) solid (l) liquid (g) gas (aq) aqueous - dissolved in water**
8.6	**What does excess mean?**	**We have some of this substance left over, unreacted, after the reaction (we had more than we needed)**
8.7	(HT) What is a limiting reactant?	A substance that is completely used up, or reacted, in a reaction
8.8	What is the unit for concentration?	g/dm^3
8.9	**Which formula relates concentration, mass and volume?**	**Concentration = $\frac{\text{mass (in g)}}{\text{volume (in dm}^3\text{)}}$**
8.10	What is the correct rearrangement of this formula to calculate mass?	Mass (in g) = concentration x volume (in dm^3)
8.11	**How many cm^3 are there in 1 dm^3?**	**1 dm^3 = 1000 cm^3**
8.12	**How do we convert 25 cm^3 into dm^3?**	**25 cm^3 = 0.025 dm^3 (divide by 1000)**
8.13	(HT) What is Avogadro's number?	6.02×10^{23}
8.14	**(HT) What formula relates moles, mass and Mr?**	**Moles = $\frac{\text{mass}}{\text{Mr}}$**
8.15	(HT) What is the correct rearrangement of this formula to calculate mass?	Mass = moles x Mr
8.16	How many mg is 0.34 g?	1 g = 1000 mg so 0.34 g = **340 mg** (x1000)
8.17	How many g is 0.75 kg?	1 kg = 1000 g so 0.75 kg = **750 g** (x1000)

C3: Simple Numerical Questions

ANSWER KEY

1	How many different **elements** are present in the formula H_2SO_4?	3 (count the capital letters) H = hydrogen, S = sulfur, O = oxygen
2	How many different **atoms** are present in the formula H_2SO_4?	7 (2 x H, 1 x S and 4 x O = 7)
3	What is the formula of sodium oxide, made from Na^+ and O^{2-} ions?	Na_2O
4	What is the formula of aluminium chloride, made from Al^{3+} and Cl^- ions?	$AlCl_3$
5	**iron + oxygen → iron oxide** 112 g 48 g ? **If 112 g of iron reacts with 48 g of oxygen, how much iron oxide should be formed?**	**112 + 48 = 160 g** **Total mass of reactants = total mass of products**
6	**nitrogen + hydrogen → ammonia** 28 g ? 34 g **34 g of ammonia is made from 28 g of nitrogen. How much hydrogen gas must have reacted?**	**34 - 28 = 6 g** **Total mass of reactants = total mass of products**
7	Balance the following equations: a) __Ca + O_2 → __CaO b) __Al + __Br_2 → __$AlBr_3$ c) __K + O_2 → __K_2O d) C_5H_{12} + __O_2 → __CO_2 + __H_2O	Must have same number of atoms on each side a) 2 Ca + O_2 → 2 CaO b) 2 Al + 3 Br_2 → 2 $AlBr_3$ c) 4 K + O_2 → 2 K_2O d) C_5H_{12} + 8 O_2 → 5 CO_2 + 6 H_2O
8	Use your periodic table to calculate the formula mass, Mr, of: a) CO_2 b) H_2SO_4 c) $Mg(NO_3)_2$	a) CO_2 = (1 x C) + (2 x O) = 12 + (2 x 16) = **44** b) H_2SO_4 = (2 x H) + (1 x S) + (4 x O) = (2 x 1) + 32 + (4 x 16) = **98** c) $Mg(NO_3)_2$ = (1 x Mg) + (2 x N) + (6 x O) = 24 + (2 x 14) + (6 x 16) = **148**
9	A solution has a concentration of 12 g/dm^3. Calculate the mass of solid dissolved in 25 cm^3 of this solution?	25 cm^3 = 0.025 dm^3 (divide by 1000) Mass = concentration x volume = 12 x 0.025 = **0.3 g**
10	0.35 g of solid is dissolved in 20 cm^3 of water. Calculate the concentration of the solution in g/dm^3	20 cm^3 = 0.02 dm^3 (divide by 1000) Concentration = mass/volume = 0.35/0.02 = **17.5 g/dm^3**

C3: Further Quantitative (Triple Content)

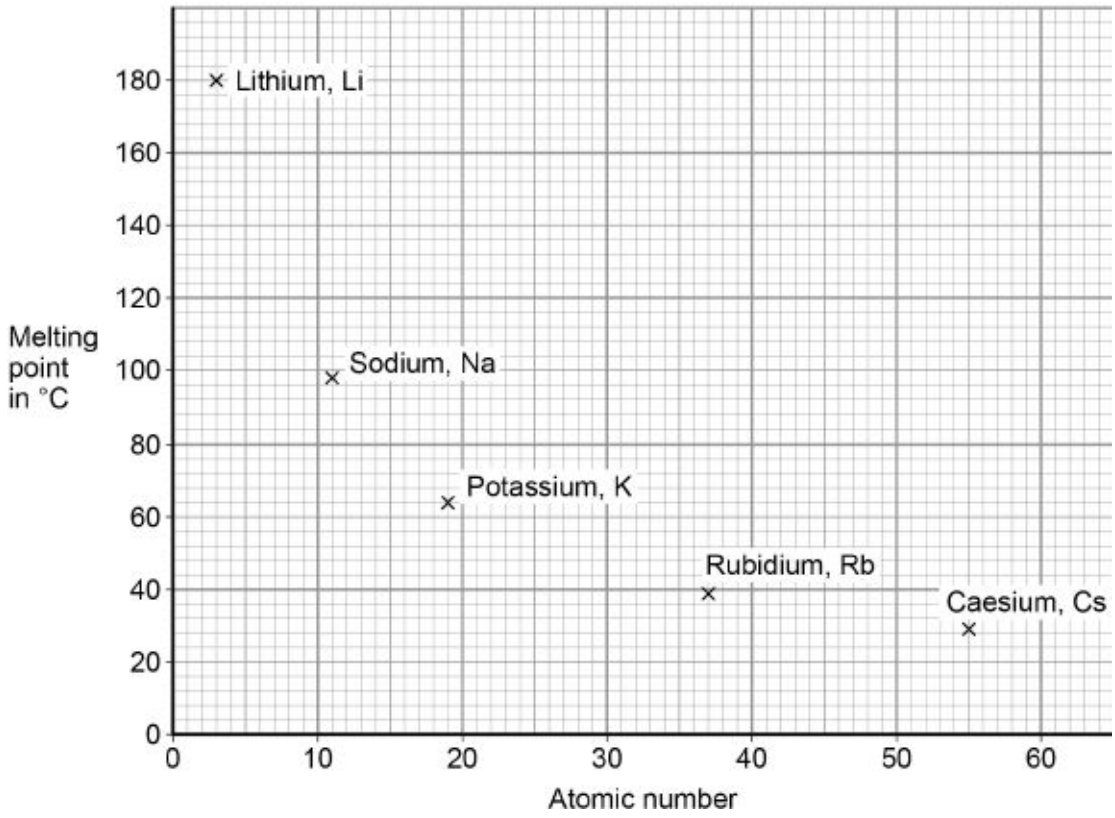
ANSWER KEY

1	What is the yield of a chemical reaction?	The amount of useful product
2	What is the theoretical yield of a chemical reaction?	The yield which you would expect to get in a reaction
3	**What is the equation for percentage yield?**	**% yield = actual yield x 100** **theoretical yield**
4	Why is the % yield almost never 100%?	• Loss of product on separation/purification • Unexpected side reactions • Impurities in reactants • Reversible reaction
5	What is atom economy?	The amount of starting material that ends up as useful product
6	**Why is a high atom economy important?**	**Avoids waste and is more sustainable**
7	**What is the equation for atom economy?**	**mass of desired product x 100** **total mass of all reactants**
8	(HT) What are the two units for concentration?	g/dm^3 and mol/dm^3
9	**(HT) Which formula relates concentration, moles and volume?**	**Concentration = moles** **volume (in dm^3)**
10	What is the purpose of titration?	Establish the concentration of an unknown solution
11	**Why is a pipette used in a titration?**	**To measure a fixed volume of solution accurately**
12	**Why is a burette used in a titration?**	**To measure a variable volume of solution accurately (it has a graduated scale)**
13	**What are concordant results?**	**Results that are within 0.10 cm^3 of each other in a titration**
14	(HT) What do the moles of gases and their volumes have in common?	Equal amounts of moles occupy the same volume (at a fixed temperature and pressure)
15	**(HT) What is the volume of one mole of any gas at room temperature and pressure?**	**24 dm^3**

FOUNDATION TIER

Q1. This question is about Group 1 metals.

The graph below shows the melting points of Group 1 metals plotted against their atomic number.



(a) Describe the trend shown by the melting points of Group 1 metals as the atomic number increases.

_____

_____

(1)

(b) Determine the atomic number and melting point of caesium. Use the graph above.

Atomic number of caesium = _____

Melting point of caesium = _____ °C

(1)

Lithium is a Group 1 metal.

(c) A lithium atom can be shown as $^{7}_{3}Li$

How many electrons does the **outer shell** of a lithium atom contain? _____

(1)

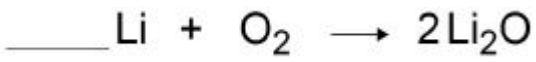
(d) Lithium reacts with oxygen to produce lithium oxide.

Draw **one** line from each substance to the correct description of the substance.

Substance	Description
	compound
Lithium oxide	element
	metal
Oxygen	mixture
	polymer

(2)

(e) Balance the equation for the reaction of lithium with oxygen.



(1)

(f) What type of bonding is present in lithium oxide?

Tick **one** box.

Covalent ☐

Ionic ☐

Metallic ☐

(1)

(g) Calculate the relative formula mass (M_r) of lithium oxide (Li_2O).

Relative atomic masses (A_r): Li = 7 O = 16

Relative formula mass = _____

(2)

(Total 9 marks)

Q2. A student investigated the law of conservation of mass.

The law of conservation of mass states that the mass of the products is equal to the mass of the reactants. This is the method used.

1. Pour lead nitrate solution into a beaker labelled **A**.
2. Pour potassium chromate solution into a beaker labelled **B**.
3. Measure the mass of both beakers and contents.
4. Pour the solution from beaker **B** into beaker **A**.
5. Measure the mass of both beakers and contents again.

When lead nitrate solution and potassium chromate solution are mixed, a reaction takes place.

This is the equation for the reaction:

$$Pb(NO_3)_2(aq) + K_2CrO_4(aq) \longrightarrow PbCrO_4(s) + 2KNO_3(aq)$$

(a) What would the student see when the reaction takes place?

_____

(1)

(b) The table shows the student's results.

	Mass in g
Beaker **A** and contents before mixing	128.71
Beaker **B** and contents before mixing	128.97
Beaker **A** and contents after mixing	154.10
Beaker **B** after mixing	103.58

Show that the law of conservation of mass is true.

Use the data from the table above.

_____

_____

_____

_____

(2)

(c) What is the resolution of the balance used to obtain the results in the table?

Tick (✓) **one** box.

0.01 g ☐ 0.1 g ☐ 1 g ☐ 100 g ☐

(1)

(d) Calculate the relative formula mass (M_r) of lead nitrate $Pb(NO_3)_2$

Relative atomic masses (A_r): N = 14 O = 16 Pb = 207

Relative formula mass = _____

(2)

(e) The solution of lead nitrate has a concentration of 6 g/dm^3

Calculate the mass of lead nitrate that is dissolved in 25 cm^3 of this solution

dissolved mass = _____

(2)

(f) Another student also tests the law of conservation of mass using the same method.

The student uses a different reaction.

This is the equation for the reaction.

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

Explain why this student's results would **not** appear to support the law of conservation of mass.

(3)

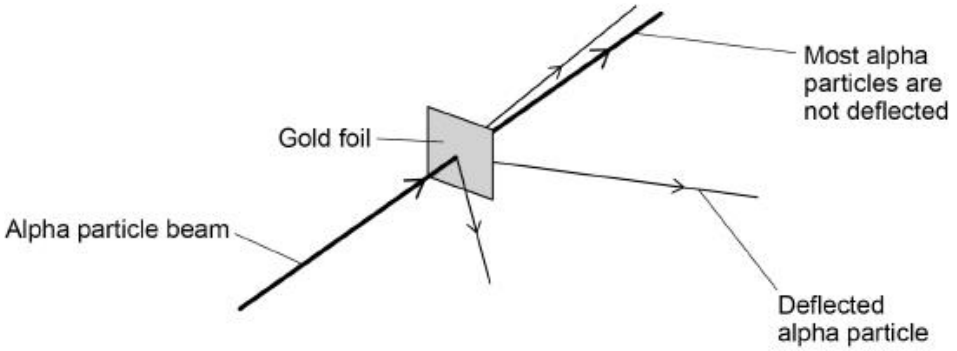
(Total 11 marks)

HIGHER TIER

Q3. This question is about gold and compounds of gold.

(a) In the alpha particle scattering experiment alpha particles are fired at gold foil.

Alpha particles are positively charged. The diagram below shows the results.



What **two** conclusions can be made from the results? Tick (✓) **two** boxes.

Atoms are balls of positive charge with embedded electrons.	☐
Atoms are tiny spheres that cannot be divided.	☐
Atoms have a positively charged nucleus.	☐
Mass is concentrated in the nucleus in the centre of atoms.	☐
Neutrons exist within the nucleus.	☐

(2)

(b) The gold foil is:

- 4.00×10^{-7} metres thick
- 2400 atoms thick.

What is the diameter of one gold atom in metres? Give your answer to 3 significant figures.

_____

_____

_____

_____

Diameter of one gold atom (3 significant figures) = _____ m

(3)

(c) Gold reacts with the elements in Group 7 of the periodic table.

0.175 g of gold reacts with chlorine.

The equation for the reaction is:

$$2\ Au + 3\ Cl_2 \rightarrow 2\ AuCl_3$$

Calculate the mass of chlorine needed to react with 0.175 g of gold.

Give your answer in mg. Relative atomic masses (A_r): Cl = 35.5 Au = 197

Mass of chlorine = _____ mg

(5)

(Total 10 marks)

Q4. This question is about fluorine.

(a) Calcium reacts with fluorine to produce calcium fluoride (CaF_2).

Explain how oxidation and reduction have taken place in this reaction.

Write about electron transfer in your answer.

(4)

(b) Explain why calcium fluoride has a high melting point.

(4)

(c) Fluorine reacts with sulfur to produce sulfur hexafluoride (SF_6).

$$S + 3F_2 \rightarrow SF_6$$

Relative formula masses, M_r: $F_2 = 38$ $SF_6 = 146$

Calculate the mass of sulfur hexafluoride produced when 0.950 g of fluorine is reacted with an excess of sulfur.

Give your answer to 3 significant figures.

Mass = _____ g

(5)

(Total 13 marks)

SEPARATE SCIENCE

Q5. A student investigated the reactions of copper carbonate and copper oxide with dilute hydrochloric acid.

In both reactions one of the products is copper chloride.

(a) Describe how a sample of copper chloride crystals could be made from copper carbonate and dilute hydrochloric acid.

_____

_____

_____

_____

_____

_____

(4)

(b) A student wanted to make 11.0 g of copper chloride.

The equation for the reaction is:

$$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5

Calculate the mass of copper carbonate the student should react with dilute hydrochloric acid to make 11.0 g of copper chloride.

_____

_____

_____

_____

Mass of copper carbonate = _____ g

(4)

(c) The percentage yield of copper chloride was 79.1 %.

Calculate the mass of copper chloride the student actually produced.

_____

_____

Actual mass of copper chloride produced = _____ g

(2)

(d) Look at the equations for the two reactions:

Reaction 1 $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$

Reaction 2 $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$

Reactive formula masses: CuO = 79.5; HCl = 36.5; $CuCl_2$ = 134.5; H_2O = 18

The percentage atom economy for a reaction is calculated using:

$$\frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula masses of all reactants from equation}} \times 100$$

Calculate the percentage atom economy for Reaction 2.

Percentage atom economy = _____ %

(3)

(e) The atom economy for Reaction 1 is 68.45 %.
Compare the atom economies of the two reactions for making copper chloride.

Give a reason for the difference.

(1)

(Total 14 marks)

Q1.

(a) melting points decrease (as the atomic number increases)

allow negative correlation

1

(b) 55
and
29 (°C)

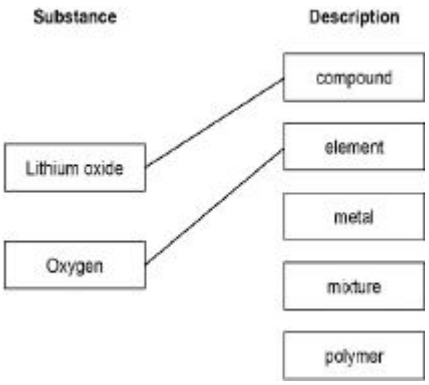
allow values in range 28−32 (°C)

1

(c) 1

1

(d)



1
1

(e) $4\ Li + O_2 \longrightarrow 2\ Li_2O$

allow correct multiples

1

(f) ionic

1

(g) $(M_r) = (2 \times 7) + 16$

1

$= 30$

1

*an answer of 30 scores **2** marks*

[9]

Q2.

(a) precipitate / solid formed

allow colour change

1

(b) total mass before = 257.68 g
total mass after = 257.68 g

1

so the mass of products equals the mass of the reactants

1

(c) 0.01 g

1

(d) 207 + (2 × 14) + (6 × 16)
or
207 + 2 × [14 + (3 × 16)]

1

= 331

1

*an answer of 331 scores **2** marks*

(e)

$\frac{25}{1000}$ = 0.025 dm^3

1

0.025 x 6 g = 0.15 (g)

1

(f) carbon dioxide is formed

allow a gas is produced

1

the gas escapes during the reaction

1

(so) the mass at the end is less than expected

1

[11]

Q3.

(a) atoms have a positively charged nucleus.

1

mass is concentrated in the nucleus in the centre of atoms.

1

(b)

$\frac{4 \times 10^{-7}}{2400}$

1

= 1.66666×10^{-10}

1

= 1.67×10^{-10} (m)

allow 0.000 000 000 167 (m)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses the values in the question

1

(c) moles Au = $\frac{0.175}{197}$ = 0.000888

1

moles Cl_2 = 0.000888 × $\frac{3}{2}$ = 0.00133

allow a correct calculation using an incorrectly calculated value of moles of gold

1

mass Cl_2 = 0.00133 × 71

allow a correct calculation using an incorrectly calculated value of moles of chlorine

1

= 0.0946 (g)

1

= 94.6 (mg)

allow a correct conversion using an incorrectly calculated mass of chlorine

1

alternative approach:

(from equation 2 moles of Au reacts with 3 moles of Cl_2)
(so) 394 g Au reacts with 213 g Cl_2 (1)

1 g Au reacts with ($\frac{213}{394}$ =)
0.54 g Cl_2 (1)

allow a correct calculation using an incorrectly calculated value of mass of gold and / or chlorine

0.175 g Au reacts with
0.54 × 0.175 g Cl_2 (1)

allow a correct calculation using an incorrectly calculated value of mass of gold and / or chlorine

= 0.0946 (g) (1)

= 94.6 (mg) (1)

allow a correct conversion using an incorrectly calculated mass of chlorine

[10]

Q4.

(a)

Level 2: Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	3-4
Level 1: Points are identified and stated simply, but their relevance is not clear and	1-2

there is no attempt at logical linking.	
No relevant content	0
Indicative content Ca / calcium (atom) loses two electrons / both outer electrons and is oxidised to Ca^{2+} ion F / fluorine (atom) gain one / an electron and is reduced to F^- ion **supporting points** • fluorine / F (atoms) gain electron(s) • negative ion produced • calcium (atoms) lose electron(s) • positive ion produced • reduction is gain of electrons • oxidation is loss of electrons	

4

(b) (because there are) strong electrostatic forces of attraction
or
ionic bonding

1

between Ca^{2+} and F^- ions / oppositely charged ions

1

(in a) giant structure / lattice

1

so a lot of energy is needed to overcome / break this attraction

1

(c) moles of F_2 = $\frac{0.95}{38}$ = 0.025 moles
mark is for ÷ 38

1

moles of SF_6 = $\frac{1}{3}$ × 0.25 = 0.008333 moles
mark is for ×1/3

1

mass of SF_6 = 0.008333 × 146
mark is for ×146

1

mass = 1.2166666

1

mass = 1.22 (g) 3 sig figs

1

[13]

Q5.

(a) add excess copper carbonate (to dilute hydrochloric acid)

accept alternatives to excess, such as 'until no more reacts'

1

filter (to remove excess copper carbonate)

reject heat until dry

1

heat filtrate to evaporate some water **or** heat to point of crystallisation

accept leave to evaporate or leave in evaporating basin

1

leave to cool (so crystals form)

until crystals form

1

*must be in correct order to gain **4** marks*

(b) M_r $CuCl_2$ = 134.5

*correct answer scores **4** marks*

1

moles copper chloride = (mass / M_r = 11 / 134.5) = 0.0817843866

1

M_r $CuCO_3$= 123.5

1

Mass $CuCO_3$ (=moles × M_2= 0.08178 × 123.5) = 10.1(00)

1

*accept 10.1 with no working shown for **4** marks*

(c) $\frac{79.1}{100} \times 11.0$ **or** 11.0 × 0.791

1

8.70 (g)

1

*accept 8.70(g) with no working shown for **2** marks*

(d) Total mass of reactants = 152.5

1

$\frac{134.5}{152.5}$ *allow ecf from step 1*

1

88.20 (%)

1

*allow 88.20 with no working shown for **3** marks*

(e) atom economy using carbonate lower because an additional product is made **or** carbon dioxide is made as well

allow ecf

1

[14]