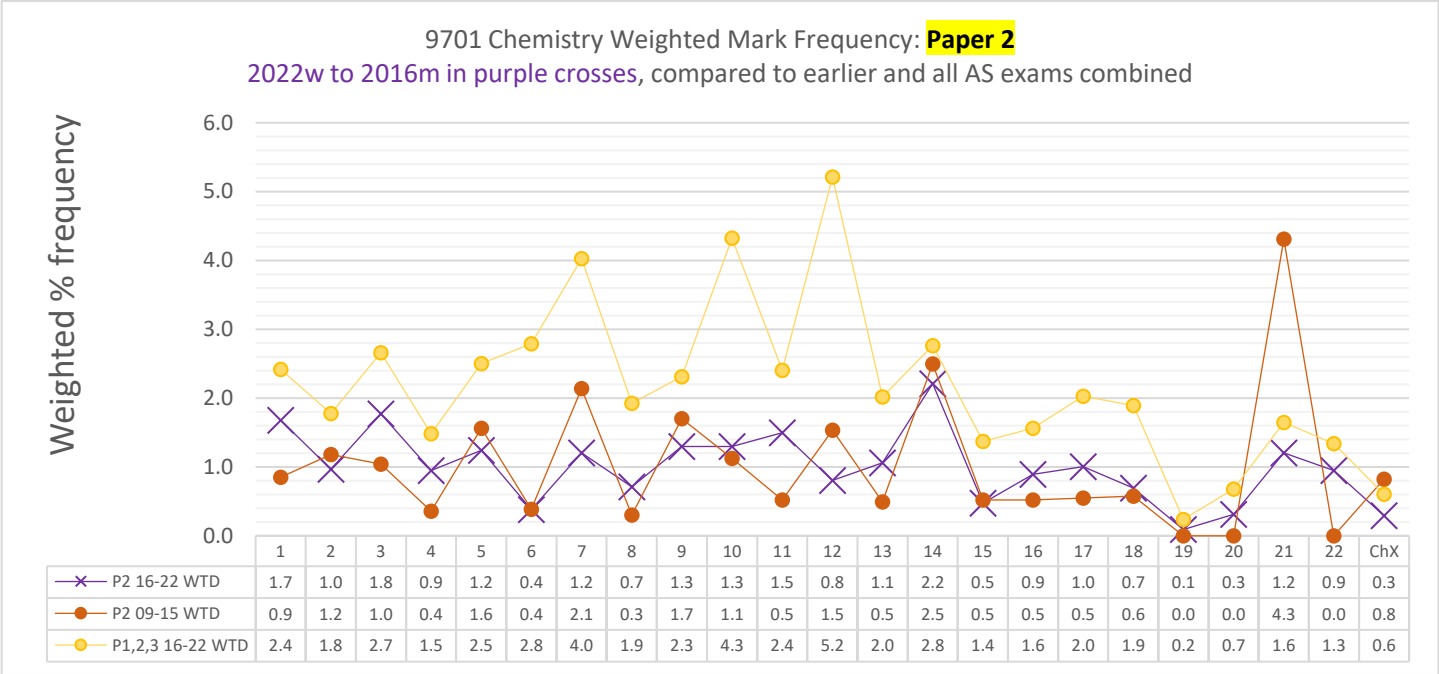
Name: Class: Date:

ALvl Chem 2 EQ P2 22w to 09s Paper 2 Atoms, molecules and stoichiometry 96marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper 2 Topic 2 Checklist Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	96		4	10	24	38	48	72	96
Time @75s/mark (minutes)									



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	ChX
P2 16-22 WTD	1.7	1.0	1.8	0.9	1.2	0.4	1.2	0.7	1.3	1.3	1.5	0.8	1.1	2.2	0.5	0.9	1.0	0.7	0.1	0.3	1.2	0.9	0.3
P2 09-15 WTD	0.9	1.2	1.0	0.4	1.6	0.4	2.1	0.3	1.7	1.1	0.5	1.5	0.5	2.5	0.5	0.5	0.5	0.6	0.0	0.0	4.3	0.0	0.8
P1,2,3 16-22 WTD	2.4	1.8	2.7	1.5	2.5	2.8	4.0	1.9	2.3	4.3	2.4	5.2	2.0	2.8	1.4	1.6	2.0	1.9	0.2	0.7	1.6	1.3	0.6

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Silver**" (25%) in the same topic in **Paper 1**, which tend also to be easier questions, as well as ""**Silver**" (25%) in the same topic, if it exists, in Paper 3.

2 Atoms, molecules and stoichiometry

2.1 Relative masses of atoms and molecules

Learning outcomes

Candidates should be able to:

1 define the unified atomic mass unit as one twelfth of the mass of a carbon-12 atom

2 define relative atomic mass, A_r, relative isotopic mass, relative molecular mass, M_r, and relative formula mass in terms of the unified atomic mass unit

2.2 The mole and the Avogadro constant

Learning outcomes

Candidates should be able to:

1 define and use the term mole in terms of the Avogadro constant

2.3 Formulae

Learning outcomes

Candidates should be able to:

1 write formulae of ionic compounds from ionic charges and oxidation numbers (shown by a Roman numeral), including:

(a) the prediction of ionic charge from the position of an element in the Periodic Table

(b) recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+}, Ag^+, HCO_3^-, PO_4^{3-}

2 (a) write and construct equations (which should be balanced), including ionic equations (which should not include spectator ions)

(b) use appropriate state symbols in equations

3 define and use the terms empirical and molecular formula

4 understand and use the terms anhydrous, hydrated and water of crystallisation

5 calculate empirical and molecular formulae, using given data

2.4 Reacting masses and volumes (of solutions and gases)

Learning outcomes

Candidates should be able to:

1 perform calculations including use of the mole concept, involving:

(a) reacting masses (from formulae and equations) including percentage yield calculations

(b) volumes of gases (e.g. in the burning of hydrocarbons)

(c) volumes and concentrations of solutions

(d) limiting reagent and excess reagent

(When performing calculations, candidates' answers should reflect the number of significant figures given or asked for in the question. When rounding up or down, candidates should ensure that significant figures are neither lost unnecessarily nor used beyond what is justified (see also Mathematical requirements section).)

(e) deduce stoichiometric relationships from calculations such as those in 2.4.1 (a)–(d)

1 Atoms with nuclei containing an odd number of protons tend to have fewer isotopes than those with an even number of protons.

(a) Gallium has two stable isotopes, ^{69}Ga and ^{71}Ga.

(i) Complete Table 1.1 to show the numbers of protons, neutrons and electrons in the two stable isotopes of gallium.

Table 1.1

isotope	number of protons	number of neutrons	number of electrons
^{69}Ga			
^{71}Ga			

[2]

(ii) Define relative atomic mass.

.....

.....

..... [2]

(iii) The relative atomic mass of gallium, A_r, is 69.723.
The relative isotopic masses of ^{69}Ga and ^{71}Ga are:

^{69}Ga, 68.926; ^{71}Ga, 70.925.

Use this information to calculate the percentage abundance of ^{69}Ga in elemental gallium.
Show your working.
Assume that the element contains only the ^{69}Ga and ^{71}Ga isotopes.
Give your answer to **four** significant figures.

percentage abundance of ^{69}Ga = ... %
[2]

Q# 27/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 Compound **V** is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(a) Calculate the molecular formula of **V**. Show your working.

molecular formula of **V** = ... [3]

(ii) A 3.196 g sample of Br_2 reacts completely with 2.800 g of **V**.

Calculate how many alkene functional groups are present in one molecule of **V**. Show your working.

number of alkene functional groups in **V** = ... [1]

Q# 28/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Calcium, magnesium and radium are Group 2 elements. Radium follows the same trends as the other members of Group 2.

(e) A sample of magnesium contains three isotopes, ^{25}Mg, ^{26}Mg and **X**.

The percentage abundance of the three isotopes is shown in Table 1.1.

Table 1.1

isotope of Mg	mass/a.m.u.	percentage abundance/%
X		78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

(i) The relative atomic mass, A_r, is calculated by comparing the average mass of the isotopes of an element to the unified atomic mass unit.

Define the unified atomic mass unit.

..... [1]

(ii) Calculate the mass of **X**. Use data from Table 1.1 and A_r (magnesium) = 24.31 in your calculation. Show your working.

mass of **X** = ...
[2]

Q# 29/ ALvl Chemistry/2022/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2 Some oxides of elements in Period 3 are shown.

Na_2O Al_2O_3 P_4O_6 P_4O_{10} SO_2 SO_3

(a) Na reacts with O_2 to form Na_2O. Na is the reducing agent in this reaction.

(i) Define reducing agent.

.....

..... [1]

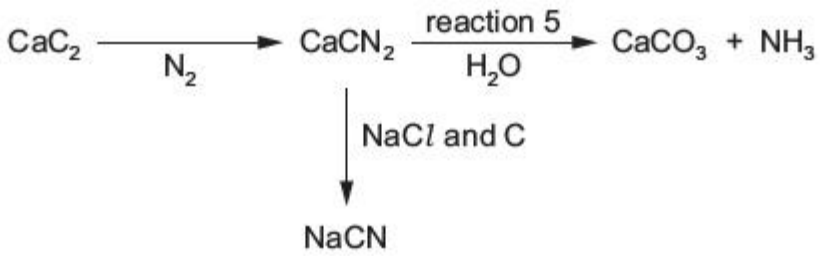
(c)

(ii) Determine the oxidation number of P in H_3PO_3.

..... [1]

Q# 30/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(d) The flowchart shows some reactions of CaC_2.



(i) Reaction 5 can be used to prepare NH_3.

$$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$$

Calculate the minimum mass, in tonnes, of calcium cyanamide, $CaCN_2$, that is required to produce 1.50×10^6 tonnes of NH_3.

Show your working.

1 tonne = 1.00×10^6 g

minimum mass of $CaCN_2$ = ... tonnes
[2]

Q# 31/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) The compound As_2S_3 is a common mineral.

When As_2S_3 is heated strongly in air, it forms a mixture of products, as shown.

$$2As_2S_3(s) + 9O_2(g) \rightarrow As_4O_6(s) + 6SO_2(g)$$

(i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm^3 of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in dm^3, of gas present at the end of the experiment.

The molar volume of gas is 24.0 $dm^3 mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ... dm^3
[4]

Q# 32/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Ethanedioic acid, HO_2CCO_2H, has a relative molecular mass of 90.0.

(a) (i) Explain what is meant by the term *relative molecular mass*.

.....

.....

..... [2]

(ii) State the empirical formula of ethanedioic acid.

..... [1]

(iii) Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid, HO_2CCO_2H.

Show your working.

atoms of carbon present = ... [3]

Q# 33/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(b) In the reaction described in **(a)(i)**, a student uses 17.43 g of $CuSO_4 \cdot yH_2O$. By further titration of the reaction products the student concludes that the total amount of $CuSO_4$ in the sample is 0.0982 mol.

Use the *Data Booklet* to complete the table to calculate the value of **y**, where **y** is an integer. Show your working.

mass of 0.0982 mol $CuSO_4$	..... g
amount of H_2O in 17.43 g of $CuSO_4 \cdot yH_2O$	..... mol H_2O
value of **y**	**y** = ...

[4]

[Total: 9]

Q# 34/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Gallium is a metal in Group 13 of the Periodic Table.

(a) There are two stable isotopes of gallium, ^{69}Ga and ^{71}Ga.

(ii) State what further information is needed to calculate the relative atomic mass of gallium.

..... [1]

Q# 35/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(d) Chlorine exists as a diatomic gas, $Cl_2(g)$. A sample of $Cl_2(g)$ was made during a chemical reaction. When measured at 404 kPa and 25 °C the sample occupied a volume of 20.0 cm^3.

(i) Calculate the mass, in grams, of $Cl_2(g)$ formed.

For this calculation, assume that chlorine behaves as an ideal gas under these conditions.

mass of $Cl_2(g)$ = ... g [3]

(ii) Calculate the number of chlorine atoms in this sample of $Cl_2(g)$. You may find it helpful to use your answer to **(d)(i)**.

If you are unable to calculate an answer to **(d)(i)**, use 0.36 g of Cl_2. This is **not** the correct answer.

number of chlorine atoms = ... [2]

Q# 36/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(b) When solid Mg_2Si is added to water, silane gas, SiH_4, and a solution of magnesium hydroxide are produced.

Construct the equation for this reaction. Include state symbols.

..... [2]

Q# 37/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 Nitrogen, N_2, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(b) Magnesium and lithium both form nitrides with N_2. These compounds both contain the N^{3-} ion.

(i) Write an equation for the reaction of magnesium with N_2 to form magnesium nitride.

..... [1]

(ii) Solid lithium nitride, Li_3N, reacts with water according to the following equation.

$$Li_3N(s) + 3H_2O(l) \rightarrow 3LiOH(aq) + NH_3(aq)$$

State **one** observation you would make during this reaction.

..... [1]

Q# 38/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3 Calcium and its compounds have a large variety of applications.

(a) Calcium metal reacts readily with most acids.

(i) Write an equation for the reaction of calcium with dilute nitric acid. State symbols are **not** required.

..... [1]

Q# 39/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

(iii) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

Include state symbols.

..... [2]

(v) SiH_4 reacts spontaneously with oxygen to produce a white solid and a colourless liquid that turns anhydrous copper(II) sulfate blue. No other products are formed.

Write an equation for the reaction of SiH_4 with oxygen.

State symbols are **not** required.

..... [1]

[Total: 22]

Q# 40/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds.

(a) Define the term *relative molecular mass*.

.....

.....

.....

..... [2]

Q# 41/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

(iii) A naturally occurring sample of cerium contains only **four** isotopes. Data for **three** of the isotopes are shown in the table.

isotope	^{136}Ce	^{138}Ce	^{140}Ce	^{142}Ce
relative isotopic mass	135.907	137.906	139.905	to be calculated
percentage abundance	0.185	0.251	88.450	to be calculated

The A_r of the sample is 140.116.

Use these data to calculate the **relative isotopic mass** of the fourth isotope in this sample of cerium.

Give your answer to **three** decimal places.

relative isotopic mass = ... [3]

[Total: 17]

Q# 42/ ALvl Chemistry/2016/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) A sample of strontium exists as a mixture of four isotopes. Information about three of these isotopes is given in the table.

mass number	86	87	88
abundance	9.86%	7.00%	82.58%

(i) Calculate the abundance of the fourth isotope.

abundance = ... % [1]

(ii) The relative atomic mass of this sample of strontium is 87.71.

Calculate the mass number of the fourth isotope.

mass number = ... [2]

[Total: 16]

Q# 43/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) Aluminium reacts with chlorine to form a white, solid chloride that contains 79.7% chlorine and sublimes (changes straight from a solid to a gas) at 180 °C.

(ii) Calculate the empirical formula of the chloride. You must show your working.

empirical formula = ... [2]

At 200 °C and 100 kPa, a 1.36 g sample of this chloride occupied a volume of 200 cm^3.

(iii) Calculate the relative molecular mass, M_r, of the chloride. Give your answer to **three** significant figures.

M_r = ... [2]

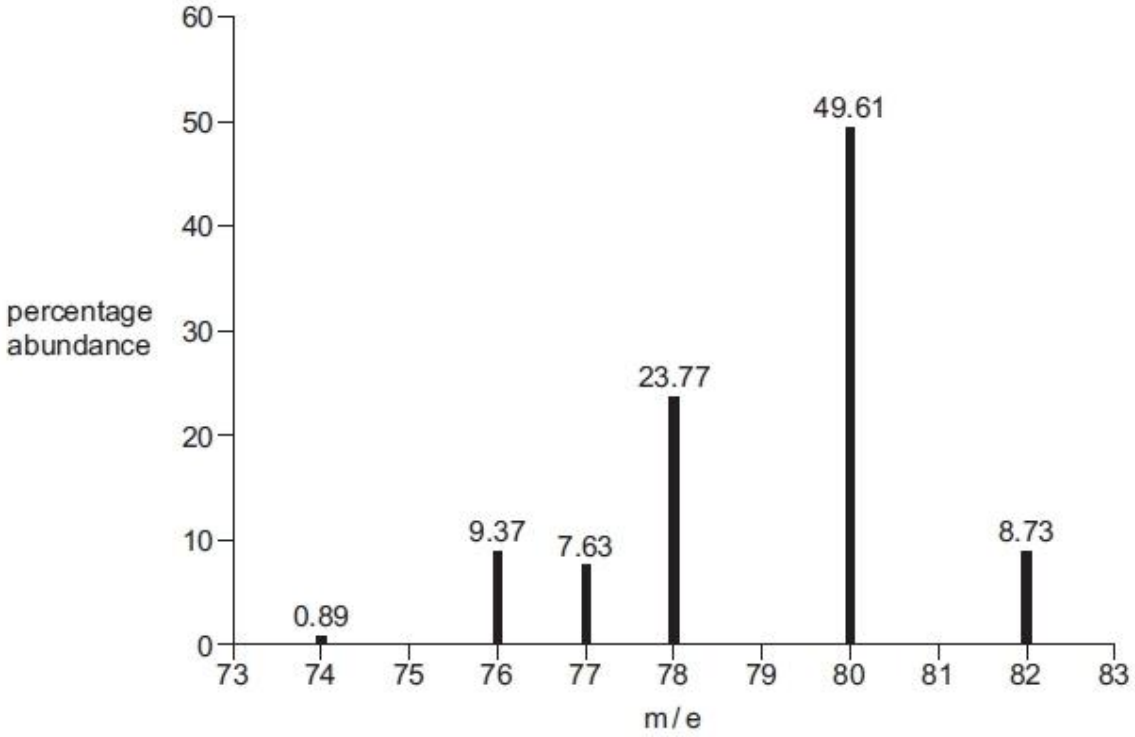
(iv) Deduce the molecular formula of this chloride at 200 °C.

..... [1]

[Total: 13]

(b) The relative atomic mass of an element can be determined using data from its mass spectrum.

The mass spectrum of element **X** is shown, with the percentage abundance of each isotope labelled.



(i) Define the terms *relative atomic mass* and *isotope*.

relative atomic mass .....

.....

.....

isotope .....

.....

[3]

(ii) Use the data in the mass spectrum to calculate the relative atomic mass, A_r, of **X**. Give your answer to **two** decimal places and suggest the identity of **X**.

A_r of **X** .....

identity of **X** .....

[2]

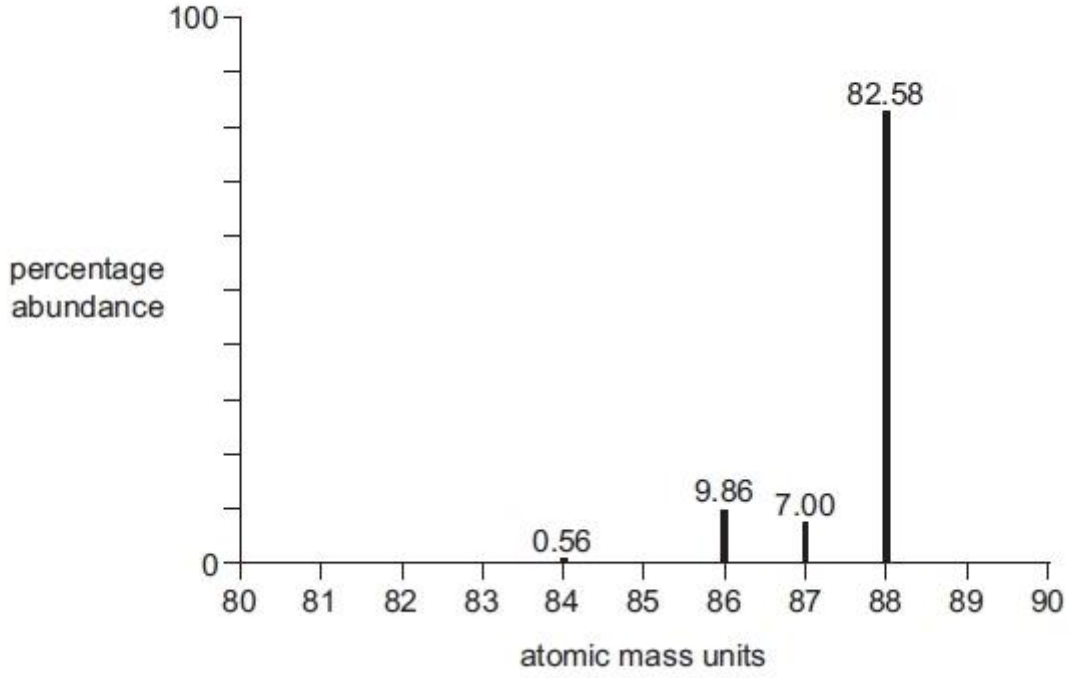
(c) The element tellurium, Te, reacts with chlorine to form a single solid product, with a relative formula mass of 270. The product contains 52.6% chlorine by mass.

(i) Calculate the molecular formula of this chloride.

molecular formula ..... [3]

Q# 45/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) A sample of strontium, atomic number 38, gave the mass spectrum shown. The percentage abundances are given above each peak.



(ii) Explain why there are four different peaks in the mass spectrum of strontium.

.....

..... [1]

(iii) Calculate the atomic mass, A_r, of this sample of strontium.
Give your answer to **three** significant figures.

A_r = ... [2]

(c) A compound of barium, **A**, is used in fireworks as an oxidising agent and to produce a green colour.

(ii) **A** has the following percentage composition by mass: Ba, 45.1; C*l*, 23.4; O, 31.5.

Calculate the empirical formula of **A**.

empirical formula of **A** ..... [3]

Q# 46/ ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) The first seven ionisation energies of an element, **A**, in kJ mol^{-1}, are

1012 1903 2912 4957 6274 21269 25398.

(c) Another element, **Z**, in the same period of the Periodic Table as **A**, reacts with chlorine to form a compound with empirical formula **Z**C*l*$_2$. The percentage composition by mass of **Z**C*l*$_2$ is **Z**, 31.13; C*l*, 68.87.

(i) Define the term *relative atomic mass*.

.....

.....

..... [2]

(ii) Calculate the relative atomic mass, A_r, of **Z**.
Give your answer to **three** significant figures.

A_r of **Z** = ... [2]

Q# 47/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate, $ZnSO_4.xH_2O$, which is a colourless crystalline solid.

(b) A simple experiment to determine the value of x in the formula $ZnSO_4.xH_2O$ is to heat it carefully to drive off the water.

$$ZnSO_4.xH_2O(s) \rightarrow ZnSO_4(s) + xH_2O(g)$$

A student placed a sample of the hydrated zinc sulfate in a weighed boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

mass of empty tube / g	mass of tube + hydrated salt / g	mass of tube + salt after fourth heating / g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

.....

.....

(ii) Calculate the amount, **in moles**, of the anhydrous salt produced.

(iii) Calculate the amount, **in moles**, of water driven off by heating.

(iv) Use your results to **(ii)** and **(iii)** to calculate the value of x in $ZnSO_4.xH_2O$.

[7]

(c) For many people, an intake of approximately 15 mg per day of zinc will be sufficient to prevent deficiencies.

Zinc ethanoate crystals, $(CH_3CO_2)_2Zn.2H_2O$, may be used in this way.

(i) What mass of pure crystalline zinc ethanoate (M_r = 219.4) will need to be taken to obtain a dose of 15 mg of zinc?

(ii) If this dose is taken in solution as 5 cm^3 of aqueous zinc ethanoate, what would be the concentration of the solution used?
Give your answer in mol dm^{-3}.

[4]

[Total: 13]

Q# 48/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 The gas ethyne, C_2H_2, more commonly known as acetylene, is manufactured for use in the synthesis of organic compounds. It is also used, in combination with oxygen, in 'oxy-acetylene' torches for the cutting and welding of metals.

Industrially, ethyne is made from calcium carbide, CaC_2, or by cracking liquid hydrocarbons.

(a) When calcium carbide is reacted with water, ethyne and calcium hydroxide are formed.

Construct a balanced equation for this reaction.

.....[1]

Q# 49/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, **A**, from the ground near Florence in Italy.
They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

(a) What is meant by the term *molecular formula*?

.....

.....

.....[2]

Q# 50/ ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Magnesium, Mg, and radium, Ra, are elements in Group II of the Periodic Table.

Magnesium has three isotopes.
A sample of magnesium has the following isotopic composition by mass.

isotope mass	24	25	26
% by mass	78.60	10.11	11.29

(b) Calculate the relative atomic mass, A_r, of magnesium to **four** significant figures.

A_r = ...
[2]

Q# 51/ ALvl Chemistry/2009/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, Al, is in the third period of the Periodic Table; copper and titanium are both transition elements.

Aluminium reacts with chlorine.

Copper forms two chlorides, CuCl and $CuCl_2$.

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

.....

[4]

Mark Scheme ALvl Chem 2 EQ P2 22w to 09s Paper 2 Atoms, molecules and stoichiometry 96marks

Q# 26/ ALvl Chemistry/2022/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)(i)	columns 1 & 3 identical *isotope* / *No of p's* / *No of n's* / *No of e's* ^{69}Ga / 31 / 38 / 31 ^{71}Ga / 31 / 40 / 31	1
	• √ √	1
1(a)(ii)	**M1** (weighted) average / mean mass of the isotopes / average mass of the atom(s) (of an element)	1
	M2 compared to (the mass of) the unified atomic mass unit	1
1(a)(iii)	$69.723 = 68.926x + 70.925(1-x) \therefore x = 0.6013$ $/ 69.723 = \frac{68.926x + 70.925(100-x)}{100}$	1
	60.13%	1

Q# 27/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4(a)	**M1** % / A_r for C H O **M2** each % / A_r for C H O divided by the smallest value for % / Ar to give simplest whole number ratio / empirical formula **M3** compare M_r from **M2** ratio with 280 to deduce the actual molecular formula C H O 77.2 / 12 = 6.433 11.4 / 1 = 11.4 11.4 / 16 = 0.7125 9(.03) 16 1 $M_r(C_9H_{16}O)$ = 140 so molecular formula of V = $C_{18}H_{32}O_2$	3
4(b)(i)	**M1** (add) group 1 carbonate / group 1 bicarbonate / Na_2CO_3 / $NaHCO_3$ etc. **M2** effervescence / fizzing / bubbling	2

Q# 28/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(e)(i)	1 / 12 (one twelfth) the mass of a carbon-12 / ^{12}C atom	1
1(e)(ii)	**M1** correct expression relating A_r to the mass / % abundance of the three isotopes $24.31 = x \times 0.7899 + 24.99 \times 0.1000 + 25.98 \times 0.1101$ **M2** correct answer to 4 sig figs atomic mass of **X** = 23.99	2

Q# 29/ ALvl Chemistry/2022/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(a)(i)	species that donates electrons	1
2(c)(ii)	(+)3 / III	1

Q# 30/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(d)(i)	**M1** moles of $NH_3 = 1.50 \times 10^6 \times 10^6 \div 17 = 8.82 \times 10^{10}$ **M2** mass of $CaCN_2 = \frac{½ \times M1 \times 80.1}{10^6} = 3.53 \times 10^6$	2

Q# 31/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(d)(i)	**M1** moles of $As_2S_3 = 0.198 / 246.1 / 8.05 \times 10^{-4}$ **M2** moles SO_2 (using moles of As_2S_3 as limiting factor) = $2.41(36) \times 10^{-3}$ moles ($6 / 2 \times 8.05 \times 10^{-4}$) Volume $SO_2 = 2.41(36) \times 10^{-3} \times 24 = 0.0579\ dm^3$ **M3** Moles O_2 used in reaction = $8.05 \times 10^{-4} \times 9 / 2 = 3.62 \times 10^{-3}$ Volume O_2 used in reaction = $3.62 \times 10^{-3} \times 24 = 0.0869\ dm^3$ **M4** Final total volume gas = (0.1 – 0.0869) + 0.0579 = [0.0131 + 0.0579] = <u>0.071</u>(0) dm^3 **M4 ONLY award 4th mark if the final answer rounds to <u>0.071</u>** Answer to minimum of 2 sig figs **MAX 3 for using ecf** from M1 to M2 to M3 and M4 **Award all 4 marks if final answer rounds to 0.071**	4

Q# 32/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)(i)	**option 1** **M1** the mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecule(s)	1
	option 1 and **M2** relative / compared to 1 / 12 (the mass) of **an atom** of carbon–12	1
	OR on a scale in which a carbon–12 atom / isotope has a mass of (exactly) 12 (units) **option 2** **M1** mass of one mol of molecules	

	option 2 **M2** relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	
1(a)(ii)	CO_2H	1
1(a)(iii)	$0.18/90 \times 2 \times 6.02 \times 10^{23} = 2.408 \times 10^{21}$ (atoms) OR **$2.4(1) \times 10^{21}$** (atoms) **M1** no mole ethanedioic acid $0.18 / 90 = 0.0020$	1
	M2 no mole ethanedioic acid $\times 2$ $0.0020 \times 2 = 0.0040$	1
	M3 no mole ethanedioic acid $\times 6.02 \times 10^{23}$ 2.4×10^{21}	1

Q# 33/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)	Mass of 0.0982mol $CuSO_4$ in 17.43g $CuSO_4.yH_2O$	**M1** *calculate M_r $CuSO_4$ using Ar from data booklet* 63.5 + 32.1 + 64.0 = 159.6 **M2** *use Mr to calculate mass of $CuSO_4$* (0.0982 × M1) =15.67272g	4
	number of water in 17.43g of $CuSO_4$ yH_2O	**M3** *calculate the mass amount of water in sample AND use this value to calculate the amount of water present* (17.43-15.67)/18 = 0.097778 mol	
	value of y	**M4** *use the ratio of M2: 0.0982 to find y* (mol H_2O ÷ mol $CuSO_4$) = 1	

Q# 34/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)(ii)	the relative abundance / % abundance of (each) the isotopes.	1

Q# 35/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3(d)(i)	**M1** *correct conversions of data to SI/consistent units* p = 404 000; $V = 20 \times 10^{-6}$; T = 298	1
	M2 *calculation of n (= pV/RT) from M1 values* $n = \frac{404000 \times 20 \times 10^{-6}}{8.31 \times 298} = 3.263 \times 10^{-3}$ mol of Cl_2	1
	M3 *finding the mass of Cl_2* $= 3.263 \times 10^{-3} \times 71.0 = 0.23$ (g)	1

3(d)(ii)	**Method 1** **M1** = $3.263 \times 10^{-3} \times 2$	**Method 2** **M1** = $\frac{0.23}{71.0} \times 2$ OR 6.53×10^{-3}	1
	M2 = $6.02 \times 10^{23} \times$ **M1** = 3.93×10^{21} atoms of Cl	**M2** = $6.02 \times 10^{23} \times$ **M1** = 3.90×10^{21} atoms of Cl	1
3(d)(iii)	**M1** size / volume of **molecule** / **particle** becomes significant / non-negligible OR IMFs become significant / non-negligible		1
	M2 IMFs becomes significant / non-negligible / collisions are not elastic		1

Q# 36/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)	$Mg_2Si(s) + 4H_2O(l) \rightarrow 2Mg(OH)_2(aq) + SiH_4(g)$ **M1** correct balancing and formulae	1
	M2 state symbols	1

Q# 37/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(b)(i)	$3Mg + N_2 \rightarrow Mg_3N_2$	1
1(b)(ii)	solid disappears	1

Q# 38/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(a)(i)	$Ca + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2$	1

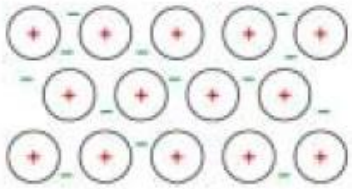
Q# 39/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(d)(iii)	$Mg_2Si(s) + 4HCl(aq) \rightarrow SiH_4(g) + 2MgCl_2(aq)$ species **AND** balancing state symbols	2
2(d)(v)	$SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O$	1

Q# 40/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)	The mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecules	1
	Relative / compared to $\frac{1}{12}$ (the mass) of an atom of carbon–12 OR on a scale in which a carbon–12 atom / isotope has a mass of (exactly) 12 (units)	1

Q# 41/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(a)(i)	max O.N. | +1 | (+)2 | (+)3 | (+)5 | (+)6 | +7	1
1(a)(ii)	(from Na to Cl) nuclear charge increases	1
	electrons are in the same shell / have same shielding	1
	greater / stronger attraction (of electrons to nucleus)	1
1(a)(iii)	Mg^{2+} **AND** S^{2-}	1
	ion of Mg / Mg^{2+} has one fewer shell (than ion of S / S^{2-})	1
1(b)(i)	$P_4 + 5O_2 \rightarrow P_4O_{10}$ / $2P_2O_5$	1
1(b)(ii)	any 2 from: • yellow / green colour (of chlorine gas) disappears • white flame • white solid • solid melts	2
1(b)(iii)	phosphoric(V) acid	1
1(c)(i)	 diagram showing regular arrangement of (positive) ions surrounded by / sea of (delocalised) electrons	2 1 1
1(c)(ii)	any 2 from: • high melting / boiling / sublimation point • electrical / thermal insulator • hard / rigid • retains strength at high temperature / pressure	2

1(c)(iii)	**M1** % abundance of fourth isotope = 100 – (0.185 + 0.251 + 88.450) = 11.114	**1**
	M2 $\frac{(0.185\times135.907)+(0.251\times137.906)+(88.450\times139.905)+(11.114\times\text{RIM})}{100}$ = 140.116 ∴ (140.116 × 100) – 12434.35 = 1577.246 = 11.114 × RIM	**1**
	M3 RIM = $\frac{1577.246}{11.114}$ = 141.915	**1**

Q# 42/ ALvl Chemistry/2016/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) (i)	0.56(%)	[1]	[1]
(ii)	$\frac{(A\times0.56)+(86\times9.86)+(87\times7.00)+(88\times82.58)}{100}=87.71$ $A = 84$	[1] [1]	[2]
			[16]

Q# 43/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(ii)	Al Cl $\frac{20.3}{27}$ $\frac{79.7}{35.5}$ $\frac{0.752}{0.752}$ $\frac{2.25}{0.752}$ 1 3 $AlCl_3$	[1] [1]	[2]
(iii)	$pV=\frac{m}{M_r}RT$ $M_r=\frac{mRT}{pV}$ $=\frac{1.36\times8.31\times473}{100\times10^3\times200\times10^{-6}}$ = 267 **OR** $pV=nRT$ $n=\frac{pV}{RT}$ $=\frac{100\times10^3\times200\times10^{-6}}{8.31\times473}$ $=5.09\times10^{-3}$ $M_r=\frac{1.36}{5.09\times10^{-3}}=267$	[1] [1] [1] [1]	[2]
(iv)	Al_2Cl_6	[1]	[1]
			[13]

Q# 44/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i)	RAM = mean / average mass of the isotopes / an atom(s) relative to 1/12 the mass of an atom of ^{12}C / on a scale where an atom of ^{12}C is (exactly) 12 (units) isotope = atoms with the same number of protons / atomic number / proton number with different mass numbers / numbers of neutrons / nucleon number	[1] [1] [1]	[3]
(ii)	$\frac{(0.89\times74)+(9.37\times76)+(7.63\times77)+(23.77\times78)+(49.61\times80)+(8.73\times82)}{100}$ = 79.04 (2 d.p.) **AND** Se	[1] [1]	[2]
(c) (i)	**Te** **Cl** $\frac{47.4}{128}$ $\frac{52.6}{35.5}$ $\frac{0.370}{0.370}$ $\frac{1.48}{0.370}$ 1 4 so EF = $TeCl_4$ Empirical Formula Mass = 270 so MF = $TeCl_4$	[1] [1] [1]	[3]

Q# 45/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(ii)	four isotopes owtte	1	[1]
(iii)	$\frac{(84\times0.56)+(86\times9.86)+(87\times7)+(88\times82.58)}{100}$ = 87.7 (must be 3 sig figs)	1 1	[2]

(ii)	Ba Cl O $\frac{45.1}{137}$ $\frac{23.4}{35.5}$ $\frac{31.5}{16}$ $\frac{0.329}{0.329}$ $\frac{0.659}{0.329}$ $\frac{1.969}{0.329}$ 1.00 2.00 5.98/6 emp form = $BaCl_2O_6$	1 1 1	[3]

Q# 46/ ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) (i)	(Weighted) mean / average mass of an atom(s) (of an element) Relative to 1/12th of (the mass of an atom of) carbon-12 **OR** relative to carbon-12 which is (exactly) 12 (units) allow as an expression	1 1	2
(ii)	**Z** Cl $\frac{31.13}{A_r}$ $\frac{68.87}{35.5}=1:2$ So $\frac{68.87/35.5}{31.13/A_r}=2$ $A_r=\frac{2\times31.13\times35.5}{68.87}=32.0923=32.1$ to 3s.f. Allow alternative correct methods	 1 1	 2

Q# 47/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i) to ensure all of the water of crystallisation had been driven off **or** to be at constant mass (1)

(ii) mass of $ZnSO_4$ = 76.34 – 74.25 = 2.09 g (1)

M_r $ZnSO_4$ = 65.4 + 32.1 + (4 × 16.0) = 161.5

allow use of Zn = 65 and/or S = 32 to give values between 161 and 161.5 (1)

$n(ZnSO_4) = \frac{2.09}{161.5} = 0.01294 = 1.29 \times 10^{-2}$

$ZnSO_4$ = 161 gives 1.30×10^{-2} (1)

(iii) mass of H_2O driven off = 77.97 – 76.34 = 1.63 g (1)

$n(H_2O) = \frac{1.63}{18} = 0.0905 = 9.1 \times 10^{-2}$ (1)

(iv) 1.29×10^{-2} mol $ZnSO_4$ are combined with 9.1×10^{-2} mol H_2O

1 mol $ZnSO_4$ is combined with $\frac{9.1 \times 10^{-2}}{1.29 \times 10^{-2}}$

= 7.054 ≡ 7 mol H_2O

answer must be expressed as a whole number
allow ecf on candidate's answers to **(b)(ii)** and **(b)(iii)** (1) [7]

(c) (i) $n(Zn) = n\ (CH_3CO_2)_2Zn.2H_2O$ (1)

$n(Zn) = \frac{0.015}{65.4} = 2.290 \times 10^{-4}$

$= 2.29 \times 10^{-4}$ (1)

mass of crystals = $2.29 \times 10^{-4} \times 219.4 = 0.0502655$ g
= 0.05 g = 50 mg (1)

(ii) concentration of $(CH_3CO_2)_2Zn.2H_2O = \frac{2.29 \times 10^{-4}}{0.005} = 0.0458$

$= 4.58 \times 10^{-2}$ mol dm^{-3} (1)

allow correct answers if Zn = 65 is used [4]

[Total: 13]

Q# 48/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 (a) $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$ (1) [1]

Q# 49/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) the actual number of atoms of each element present (1)

in one molecule of a compound (1) [2]

Q# 50/ ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) $A_r = \frac{(24 \times 78.60) + (25 \times 10.11) + (26 \times 11.29)}{100}$ (1)

$= \frac{1886.4 + 252.75 + 293.54}{100} = \frac{2432.69}{100}$

which gives A_r = 24.33 (1)
penalise (–1) for misuse of significant figures [2]

(d) (i) Ra^{2+} (1)

(ii) less than (502 + 966)
allow answers in the range 1000–1400 kJ mol^{-1} (1)

ionisation energies decrease down the Group
or must be less than IE for $Ba \rightarrow Ba^{2+}$
or size of atom increases down Group/
electrons are further away from nucleus
or there is increased shielding down Group (1)

allow ecf on answer to (i) [3]

[Total: 10]

Q# 51/ ALvl Chemistry/2009/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) (i) $n(Ti) = \frac{0.72}{47.9} = 0.015$ (1)

(ii) $n(Cl) = \frac{(2.85 - 0.72)}{35.5} = 0.06$ (1)

(iii) 0.015 : 0.06 = 1:4
empirical formula of **A** is $TiCl_4$
Allow ecf on answers to (i) and/or (ii). (1)

(iv) $Ti + 2Cl_2 \rightarrow TiCl_4$ (1)
Allow ecf on answers to (iii). [4]