

Surname <i>StemUp Model Solution</i>	Centre Number	Candidate Number
Other Names		2



GCE AS/A LEVEL

2410U10-1



CHEMISTRY – AS unit 1

The Language of Chemistry, Structure of Matter and Simple Reactions

MONDAY, 20 MAY 2019 – MORNING

1 hour 30 minutes

Section A

Section B

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1. to 8.	10	
9.	16	
10.	14	
11.	12	
12.	14	
13.	14	
Total	80	

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01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:

- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.

Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.12(c)**.

If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

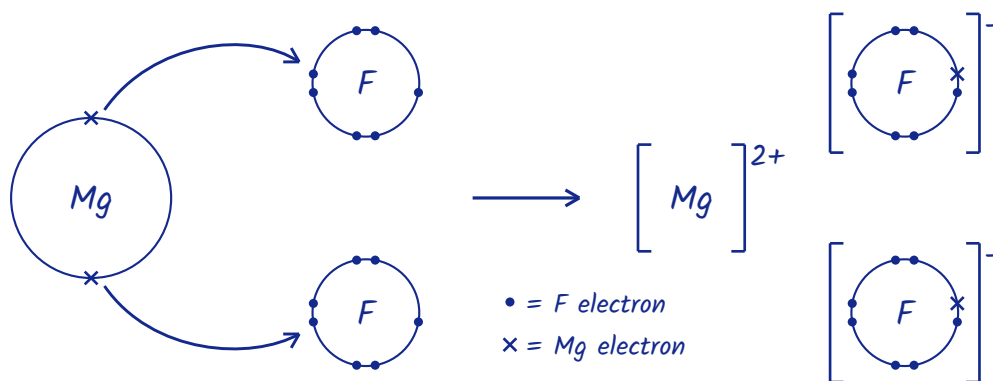


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SECTION A

Answer **all** questions in the spaces provided.

1. Using **outer** electrons only, draw a dot and cross diagram to show the formation of the bonding in magnesium fluoride. [2]



2. In some areas, fluoride ions are added to drinking water.

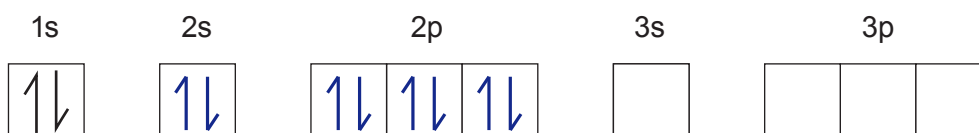
State **one** benefit of adding fluoride ions to water. [1]

It reduces tooth decay by strengthening tooth enamel.

3. Complete the following definition of relative atomic mass. [1]

The relative atomic mass of an element is the average mass of one atom of the element relative to *1/12th of the mass of one atom of carbon-12*.

4. Sodium forms only one stable ion. By inserting arrows to represent electrons, complete the electronic structure of this ion. [1]



5. Give the oxidation number of vanadium in VOCl_3 . [1]

+5

6. Phosphoric acid has the formula H_3PO_4 . Write the formula of magnesium phosphate. [1]

$\text{Mg}_3(\text{PO}_4)_2$

7. Cooking fuel for outdoor camping contains butane, which reacts with oxygen according to the following equation.



If 1.00 mol of butane reacts in this way, calculate the number of **molecules** of carbon dioxide that will be formed. [1]

1 mol C_4H_{10} gives 4 mol CO_2

molecules = $4.00 \times 6.02 \times 10^{23}$

Molecules of CO_2 = 2.41×10^{24}

8. 9.60 g of titanium reacts completely with 3.68 dm^3 of oxygen gas at 298 K and 1 atm to form an oxide.

Calculate the empirical formula of this oxide. [2]

$n(\text{Ti}) = 9.60 / 47.9 = 0.200 \text{ mol}$

$n(\text{O}_2) = 3.68 / 24.5 = 0.150 \text{ mol}$, so $n(\text{O atoms}) = 0.300 \text{ mol}$

$\text{Ti} : \text{O} = 0.200 : 0.300 = 2 : 3$

Empirical formula Ti_2O_3



SECTION B

Answer **all** questions in the spaces provided.

9. (a) Consider the elements labelled **A-G**. These are not chemical symbols.

A	$1s^2 2s^2 2p^1$
B	$1s^2 2s^2 2p^3$
C	$1s^2 2s^2 2p^6$
D	$1s^2 2s^2 2p^6 3s^2$
E	$1s^2 2s^2 2p^6 3s^2 3p^1$
F	$1s^2 2s^2 2p^6 3s^2 3p^6$
G	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

- (i) Give the letter (**A-G**) of the element with the largest **first** ionisation energy.

Give **two** reasons for your answer.

[3]

C

It has only two shells (not three or four), so its outer electron is closer to the nucleus and there is less shielding of the outer electron.

Of the elements with two shells (A, B and C) it has the greatest nuclear charge (most protons).

- (ii) Give the letter (**A-G**) of the element with the largest **last** ionisation energy.

Give a reason for your answer.

[2]

G

Its nucleus is the most positively charged (19 protons), so there is the greatest attraction for the last (1s) electron removed.

- (iii) Give the letters (**A-G**) of **all** the elements above that are metals.

[2]

D, E and G

- (iv) Give the letters (**A-G**) of **all** the elements above that form basic oxides.

[1]

D and G



- (b) Magnesium exists as three naturally-occurring stable isotopes. They can be identified using a mass spectrometer.

- (i) State how magnesium ions are formed in a mass spectrometer. [1]

*Gaseous magnesium atoms are bombarded with high-energy electrons,
which knock out an electron to form Mg^+ ions.*

- (ii) State how magnesium ions are separated in a mass spectrometer. [1]

*The ions are deflected through a magnetic field according to their mass
to charge ratio.*

- (c) Magnesium-28 is an unstable radioactive isotope that decays by β -emission.

- (i) Give the mass number and symbol of the element formed as a product of the radioactive decay of magnesium-28. [1]

Mass number 28, aluminium: ^{28}Al

- (ii) If it takes 84 hours for the activity of the isotope to decay to $\frac{1}{16}$ th of its original activity, calculate its half-life. [1]

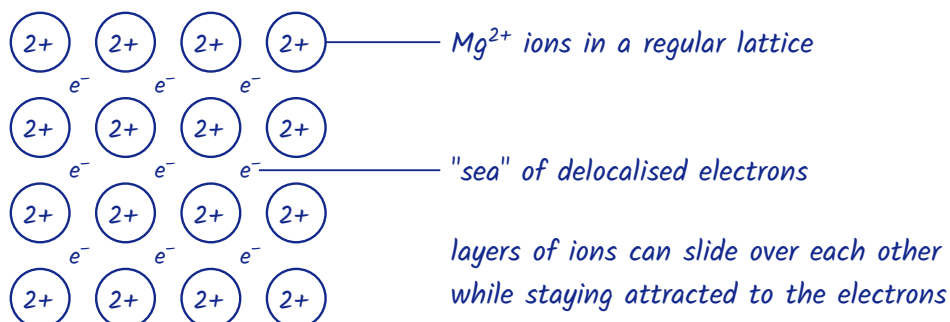
$1 \rightarrow 1/2 \rightarrow 1/4 \rightarrow 1/8 \rightarrow 1/16$ is 4 half-lives

half-life = $84 / 4$

Half-life = ...21..... hours



- (d) Magnesium is a typical metal. Describe the bonding in magnesium and explain why it is ductile. You may include a diagram as part of your answer. [3]



A regular lattice of Mg²⁺ ions surrounded by a sea of delocalised electrons, held by electrostatic attraction between the ions and the electrons.

When a force is applied, the layers of metal ions slide over each other into a new shape without the bonding breaking, so it can be drawn into wires.

- (e) According to the label on the bottle, the concentration of magnesium ions in a sample of Welsh mineral water is 15 mg/litre.

Calculate the concentration of magnesium ions in mol dm⁻³.

[1]

$$15 \text{ mg} = 0.015 \text{ g in } 1 \text{ dm}^3$$

$$\text{concentration} = 0.015 / 24.3 = 6.17 \times 10^{-4}$$

Concentration = 6.17×10^{-4} mol dm⁻³



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10. When an electrical discharge passes through gaseous hydrogen at low pressure, electromagnetic radiation is emitted.

- (a) Describe the processes within a hydrogen atom that cause electromagnetic radiation to be emitted. [2]

The electrical energy excites the electron, so it is promoted to a higher energy level.

The electron then falls back down to a lower energy level, emitting the energy difference as a photon of electromagnetic radiation ($\Delta E = hf$).

- (b) If the electromagnetic radiation in part (a) is passed through a spectrometer, several series of converging lines are observed.

- (i) Explain why there are several series of lines. [1]

Each series corresponds to electrons falling to a different lower energy level (e.g. $n = 1$ Lyman, $n = 2$ Balmer).

- (ii) Explain why the lines within each series converge. [1]

The energy levels get closer together at higher energy, so the energy difference between the shells decreases.

- (c) The convergence limit of the Lyman series of lines occurs at a wavelength of 91.2 nm.

- (i) State what the limit represents. [1]

Ionisation of the atom: the point at which the electron leaves the atom (falls from $n = \infty$ to $n = 1$).

- (ii) Calculate the energy, in kJ mol^{-1} , of the convergence limit. [4]

$$\Delta E = hf \text{ and } f = c/\lambda, \text{ so } \Delta E = hc/\lambda$$

$$\Delta E = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (91.2 \times 10^{-9})$$

$$\Delta E = 2.18 \times 10^{-18} \text{ J (for one atom)}$$

$$\text{per mole} = 2.18 \times 10^{-18} \times 6.02 \times 10^{23} = 1.312 \times 10^6 \text{ J mol}^{-1}$$

Energy = ...1312..... kJ mol^{-1}



- (d) Hydrogen forms when aluminium reacts with sulfuric acid.



- (i) Calculate the volume of hydrogen, in cm^3 , that would be produced if 0.131 g of aluminium were added to an excess of sulfuric acid at a temperature of 25°C and a pressure of 1 atm. [3]

$$n(\text{Al}) = 0.131 / 27.0 = 4.85 \times 10^{-3} \text{ mol}$$

$$n(\text{H}_2) = 4.85 \times 10^{-3} \times 3/2 = 7.28 \times 10^{-3} \text{ mol}$$

$$\text{volume} = 7.28 \times 10^{-3} \times 24.5 = 0.178 \text{ dm}^3$$

$$= 178 \text{ cm}^3$$

$$\text{Volume} = \dots\dots\dots 178 \dots\dots\dots \text{cm}^3$$

- (ii) Calculate the volume of hydrogen that would be produced if the same experiment were carried out at 50°C and 1.6 atm. [2]

(If you do not have an answer in part (i), assume that the volume is 200 cm^3 . This is **not** the correct answer.)

$$p_1V_1/T_1 = p_2V_2/T_2$$

$$V_2 = (1 \times 178 \times 323) / (298 \times 1.6)$$

$$V_2 = 121 \text{ cm}^3$$

$$\text{Volume} = \dots\dots\dots 121 \dots\dots\dots \text{cm}^3$$



11. A student was asked to find the percentage of calcium carbonate in a sample of chalk. He used the following chemicals.

- Three chalk pieces of identical composition and mass 2.54 g
- Hydrochloric acid solution of concentration 1.00 mol dm^{-3}
- Sodium hydroxide solution of concentration $0.100 \text{ mol dm}^{-3}$

Method

- Use a burette to measure 50.00 cm^3 of hydrochloric acid (an excess) into a 100 cm^3 beaker.
- Put a piece of chalk into the beaker and leave until the reaction finishes.
- Filter the solution into a conical flask to remove any solid impurities.
- Add a few drops of indicator to the solution in the conical flask and titrate against the sodium hydroxide solution.
- Repeat the procedure using the other chalk pieces and calculate a mean titre.
- Use the mean titre to calculate the percentage of calcium carbonate in the chalk sample.

Results

Mass of each chalk piece = 2.54 g

Titration	1	2	3
Final reading / cm^3	16.80	33.05	16.70
Initial reading / cm^3	0.20	16.80	0.35
Titre / cm^3	16.60	16.25	16.35

$$\text{Mean titre} = \frac{16.60 + 16.25 + 16.35}{3} = 16.40 \text{ cm}^3$$

- (a) State how the student would know that the reaction between the chalk and acid had finished. [1]

There is no more effervescence (no more bubbles of CO_2 given off).



- (b) Suggest and explain **two** improvements to the student's method. [4]

Rinse the beaker (and filter paper) with distilled water and add the washings to the conical flask; this ensures no acid is left behind in the beaker.

Carry out the reaction in a conical flask (or larger beaker) rather than a 100 cm³ beaker; this prevents acid spray from escaping during the effervescence.

- (c) The equation for the reaction between calcium carbonate and hydrochloric acid is as follows.



Use this and the student's results, including the mean titre of 16.40 cm³, to calculate the percentage of calcium carbonate in the chalk sample. [4]

$$n(\text{NaOH}) = 16.40/1000 \times 0.100 = 1.64 \times 10^{-3} \text{ mol}$$

$$\text{excess } n(\text{HCl}) = 1.64 \times 10^{-3} \text{ mol (1:1)}$$

$$\text{initial } n(\text{HCl}) = 50.00/1000 \times 1.00 = 0.0500 \text{ mol}$$

$$n(\text{HCl}) \text{ reacted} = 0.0500 - 1.64 \times 10^{-3} = 0.0484 \text{ mol}$$

$$n(\text{CaCO}_3) = 0.0484 / 2 = 0.0242 \text{ mol}$$

$$\text{mass CaCO}_3 = 0.0242 \times 100.1 = 2.42 \text{ g}$$

$$\text{percentage} = 2.42 / 2.54 \times 100$$

Percentage = 95.3 %



- (d) Comment on the validity of the mean titre calculated.

[1]

Not valid: the first titre (16.60 cm^3) is a rough value that is not concordant, so it should be disregarded (mean of 16.25 and $16.35 = 16.30\text{ cm}^3$).

- (e) Another student follows the same procedure but filters the solution before the reaction is complete. State what effect, if any, this would have on the value of the titre. Justify your answer.

[2]

The titre would increase.

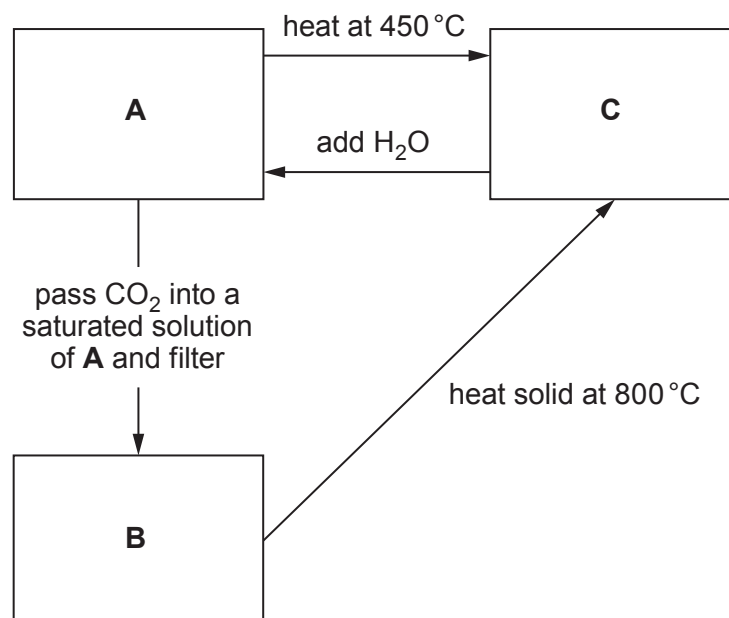
Fewer moles of HCl react with the chalk, so more HCl is left in excess and more moles of NaOH are needed to react with it.

12



12. (a) A series of experiments is performed on three white solids, **A**, **B** and **C**. All contain the same Group 2 metal ion. Compound **A** is the metal hydroxide.

The experiment is summarised below.



- The compounds give a definite colour in a flame test
- Compound **A** is only slightly soluble in water
- Compound **B** is insoluble in water

- (i) A student correctly identified the metal ion as calcium. Give **two** reasons why she came to that conclusion. [2]

It cannot be magnesium, since magnesium compounds give no colour in a flame test.

It cannot be strontium or barium, since their hydroxides are too soluble; compound A (the hydroxide) is only slightly soluble.

- (ii) Name compound **B**. [1]

calcium carbonate



- (iii) 0.110 g of compound **C** was completely neutralised by 26.10 cm³ of 0.150 mol dm⁻³ hydrochloric acid.

Given that 1 mol of compound **C** reacts with 2 mol of acid, calculate the relative formula mass of compound **C** and hence confirm that the metal ion is calcium.

You **must** show your working.

[2]

$$n(\text{HCl}) = 26.10/1000 \times 0.150 = 3.92 \times 10^{-3} \text{ mol}$$

$$n(\text{C}) = 3.92 \times 10^{-3} / 2 = 1.96 \times 10^{-3} \text{ mol}$$

$$M_r(\text{C}) = 0.110 / 1.96 \times 10^{-3} = 56.1$$

$$\text{C is the oxide MO; } A_r(\text{O}) = 16.0$$

$$\text{so } A_r(\text{metal}) = 56.1 - 16.0 = 40.1, \text{ which is calcium (CaO)}$$

- (b) Group 2 metals are not the only elements that form 2+ ions.

A sample of an element has two isotopes, one with 70 neutrons and the other 72 neutrons. This element forms a 2+ ion containing 48 electrons. The relative abundances of the isotopes are 57.9% and 42.1% respectively.

Calculate the relative atomic mass of the element. Give your answer to **four** significant figures. [3]

2+ ion has 48 electrons, so 50 protons (tin)

isotope masses: 50 + 70 = 120 and 50 + 72 = 122

$$A_r = (120 \times 57.9 + 122 \times 42.1) / 100$$

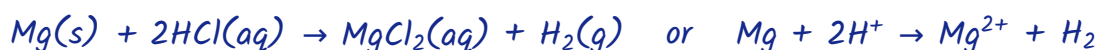
$$A_r = (6948 + 5136.2) / 100 = 120.842$$

$$A_r = \dots\dots\dots 120.8 \dots\dots\dots$$

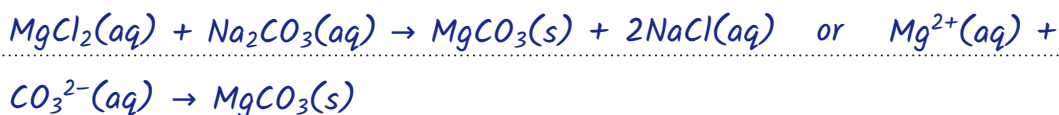


- (c) Describe, giving **brief** experimental details, how you would obtain the maximum amount of magnesium carbonate from a known mass of magnesium, in a **two-stage** process. Include appropriate chemical/ionic equations in your answer. [6 QER]

Stage 1: weigh the magnesium and add it to excess dilute hydrochloric acid in a beaker, stirring until all of the magnesium has dissolved and no more effervescence is seen. Excess acid ensures all the magnesium reacts, giving the maximum amount of soluble magnesium salt.



Stage 2: add an excess of a soluble carbonate, e.g. sodium carbonate solution, to the magnesium chloride solution. Excess carbonate neutralises any leftover acid and ensures all the Mg^{2+} ions are precipitated as magnesium carbonate.



Filter off the white precipitate, wash it with distilled water to remove soluble NaCl, then dry it in a low-temperature oven or desiccator.



- When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.



- [1]

[2]

The equilibrium shifts to the right to oppose this change, so the concentration of Cl_2 decreases and the concentration of HClO increases, so the green colour fades.



(b) Chlorine can react directly with metals to form chlorides.

- (i) I. Calcium chloride can exist as an anhydrous salt or as a hydrated salt, $\text{CaCl}_2 \cdot x\text{H}_2\text{O}$.

In an experiment to determine the extent of hydration a sample of hydrated calcium chloride, $\text{CaCl}_2 \cdot x\text{H}_2\text{O}$, with a mass of 3.29 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.67 g.

Calculate the value of x in the formula $\text{CaCl}_2 \cdot x\text{H}_2\text{O}$.

You **must** show your working.

[3]

$$\text{mass of water} = 3.29 - 1.67 = 1.62 \text{ g}$$

$$n(\text{CaCl}_2) = 1.67 / 111.1 = 0.0150 \text{ mol}$$

$$n(\text{H}_2\text{O}) = 1.62 / 18.02 = 0.0899 \text{ mol}$$

$$x = 0.0899 / 0.0150 = 5.99, \text{ so } x = 6$$

$$x = \dots\dots\dots 6 \dots\dots\dots$$

- II. Suggest how a student doing this experiment would ensure that all the water had been removed. [1]

Heat to constant mass: reheat and reweigh until two consecutive masses are the same.

- (ii) The melting temperature of sodium chloride is 1074 K but sodium iodide has a melting temperature of 934 K.

Suggest why the melting temperature of sodium iodide is lower than that of sodium chloride. [1]

The iodide ion is larger than the chloride ion, so there is less attraction to the sodium ion.



(c) Chlorine forms molecules and ions with other halogens.

- (i) While chlorine has a boiling temperature of 238 K, the boiling temperature of iodine monochloride, ICl, is 371 K.

Suggest why the boiling temperature of iodine monochloride is higher than that of chlorine. [2]

ICl is polar, so there are permanent dipole forces between ICl molecules, but Cl₂ has only temporary dipoles (van der Waals forces).

Permanent dipoles are stronger than temporary dipoles (van der Waals forces).

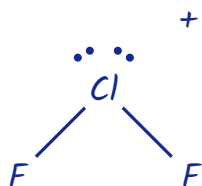
- (ii) Name the shape of the [ClF₆]⁺ ion. [1]

Octahedral

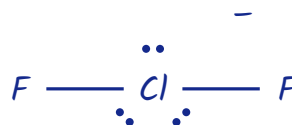
- (iii) [ClF₂]⁺ and [ClF₂]⁻ are two other ions containing a chlorine atom.

A student said that their shapes must be different.

Is he correct? Justify your answer using VSEPR theory. [3]



*[ClF₂]⁺: 2 bond pairs, 2 lone pairs
bent (V-shaped)*



*[ClF₂]⁻: 2 bond pairs, 3 lone pairs
linear*

Yes, he is correct: [ClF₂]⁺ has 2 bond pairs and 2 lone pairs, [ClF₂]⁻ has 2 bond pairs and 3 lone pairs. Pairs repel to be as far apart as possible, so different numbers of pairs give different shapes.

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