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|--------------------------------------|---------------|------------------|
| Surname <i>StemUp Model Solution</i> | Centre Number | Candidate Number |
| First name(s)                        |               | 2                |



**GCE AS/A LEVEL**

2410U10-1



**TUESDAY, 17 MAY 2022 – MORNING**

**CHEMISTRY – AS unit 1**

**The Language of Chemistry, Structure of Matter and Simple Reactions**

1 hour 30 minutes

**Section A**

**Section B**

**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. You may use a pencil for graphs and diagrams only.

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

**Section A** Answer **all** questions.

**Section B** Answer **all** questions.

Write your answers in the spaces provided in this booklet. 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.

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.10(a)**.

| For Examiner's use only |              |              |
|-------------------------|--------------|--------------|
| Question                | Maximum Mark | Mark Awarded |
| 1. to 7.                | 10           |              |
| 8.                      | 14           |              |
| 9.                      | 12           |              |
| 10.                     | 13           |              |
| 11.                     | 17           |              |
| 12.                     | 14           |              |
| <b>Total</b>            | <b>80</b>    |              |

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01

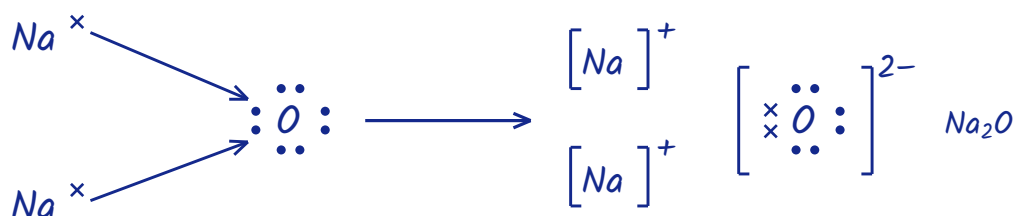


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## SECTION A

Answer **all** questions.

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



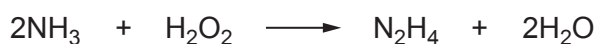
2. Complete the following sentence: [1]

Hydrogen bonding is an intermolecular force that occurs between molecules containing hydrogen atoms bonded to small, electronegative atoms which have lone pairs of electrons for example oxygen.

3. By inserting arrows to represent electrons, show the electronic configuration of a calcium atom. [1]



4. Hydrazine can be manufactured from ammonia. [1]



Calculate the atom economy of this reaction.

$$M_r(\text{N}_2\text{H}_4) = 2(14.0) + 4(1.01) = 32.04$$

$$\text{total } M_r \text{ of reactants} = 2(17.03) + 34.02 = 68.08$$

$$\text{atom economy} = 32.04 / 68.08 \times 100 = 47.1\%$$

atom economy = 47.1 %



5. The ammonium ion contains a 'coordinate bond'. Explain what is meant by this term. [1]

*A covalent bond in which both electrons of the shared pair come from the same atom (the N lone pair is donated to  $H^+$ ).*

6. Uranium is used in nuclear fuel reactors. One of its isotopes, uranium-235, has a half-life of  $7.03 \times 10^8$  years and decays by  $\alpha$ -emission.

- (a) Give the mass number and symbol of the element formed as a product of the radioactive decay of uranium-235. [1]

*Mass number 231, symbol Th (thorium-231,  $^{231}\text{Th}$ )*

- (b) If a quantity of uranium-235 decays, state what fraction is left after  $2.812 \times 10^9$  years. [1]

*$2.812 \times 10^9 / 7.03 \times 10^8 = 4$  half-lives, so  $(\frac{1}{2})^4 = 1/16$*

fraction left = *1/16*

7. Calculate the mass of calcium that contains the same number of atoms as there are molecules in 9.1 g of sulfur dioxide,  $\text{SO}_2$ . [2]

*$n(\text{SO}_2) = 9.1 / 64.1 = 0.142 \text{ mol}$*

*same number of Ca atoms, so  $n(\text{Ca}) = 0.142 \text{ mol}$*

*mass of Ca =  $0.142 \times 40.1 = 5.69 \text{ g}$*

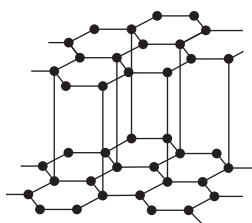
calcium mass = *5.69* g



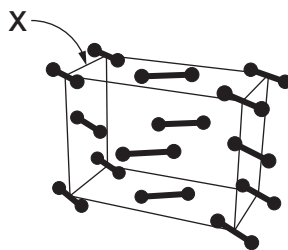
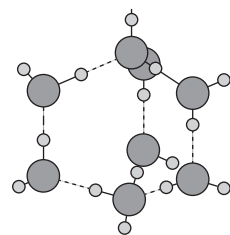
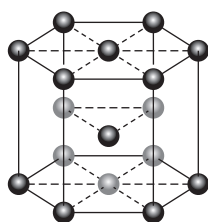
## SECTION B

Answer **all** questions.

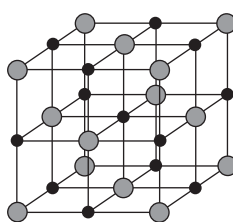
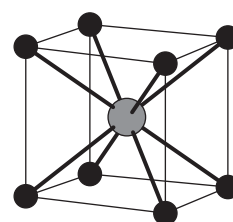
8. (a) The diagrams below represent the structures of cadmium metal, caesium chloride, graphite, ice, iodine and sodium chloride.



A graphite

B *iodine*C *ice*

D cadmium

E *sodium chloride*F *caesium chloride*

- (i) Label the remaining structures in the spaces provided.

[2]

- (ii) Complete the table showing the trend in melting temperatures of the six substances.

[2]

| Substance        | Melting temperature                                                                            |
|------------------|------------------------------------------------------------------------------------------------|
| <i>ice</i>       | <div style="text-align: center;">           Lowest<br/> <br/>           Highest         </div> |
| <i>iodine</i>    |                                                                                                |
| <i>cadmium</i>   |                                                                                                |
| caesium chloride |                                                                                                |
| sodium chloride  |                                                                                                |
| <i>graphite</i>  |                                                                                                |



- (iii) For structure **B**, name the type of bond or force represented by the letter **X**. [1]

*Van der Waals forces (induced dipole-induced dipole / London forces)*

- (iv) Name the **two** substances which are good electrical conductors in the solid state. [1]

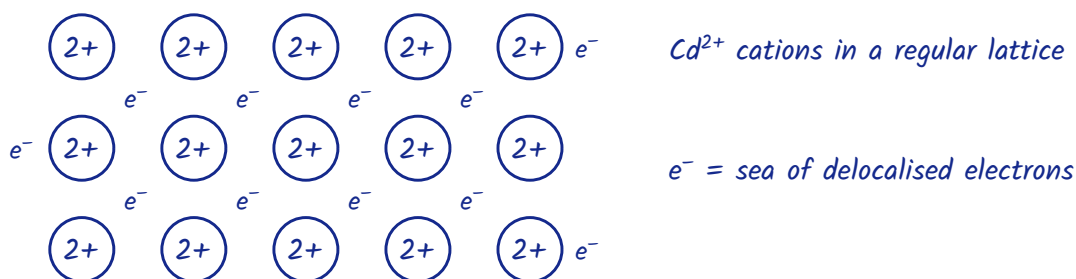
*graphite*

*cadmium*

- (v) Explain why graphite is suitable for use in pencils. [2]

*There are only weak forces between the layers of carbon atoms, which are easily broken, so the layers can slide over each other and rub off onto the paper, leaving a mark.*

- (vi) Cadmium is a typical metal.  
Give a brief description of metallic bonding.  
You may include a diagram to support your answer. [3]



*Metals consist of a regular arrangement (lattice) of positive metal ions, cations ( $\text{Cd}^{2+}$ ), surrounded by a 'sea' of delocalised electrons.*

*Metallic bonding is the strong electrostatic attraction between the cations and the delocalised electrons.*



- (b) Many houses have been built on disused industrial sites. A housing developer wants to test whether the soil on a particular site is contaminated with cadmium ions ( $\text{Cd}^{2+}$ ).

They extract a sample and prepare a solution. Cadmium ions behave in the same way as magnesium ions when treated with sodium hydroxide solution and sodium sulfate solution.

- (i) State what the developer would see if cadmium ions were present when they added:

I. sodium hydroxide solution. [1]

*white precipitate*

II. sodium sulfate solution. [1]

*no observable change (stays a colourless solution)*

- (ii) Write an ionic equation, including state symbols, for **one** of the above observations. [1]



9. (a) (i) Explain the origins of emission spectra. [2]

*Electrons in an atom absorb energy (e.g. from heat or electricity), become excited and are promoted to higher energy levels.*

*When the energy source is removed the electrons fall back down to lower energy levels, emitting the energy difference as light (a photon) of a specific frequency,  $\Delta E = hf$ , so lines are seen.*

- (ii) Give **one** difference in the appearance of absorption and emission spectra. [1]

*An absorption spectrum has dark (black) lines on a coloured background, whereas an emission spectrum has coloured lines on a dark background.*

- (b) A line in the emission spectrum of an element has a wavelength of 95.0 nm. Calculate the frequency of this line in megahertz, MHz. [2]

$$f = c / \lambda = 3.00 \times 10^8 / 95.0 \times 10^{-9}$$

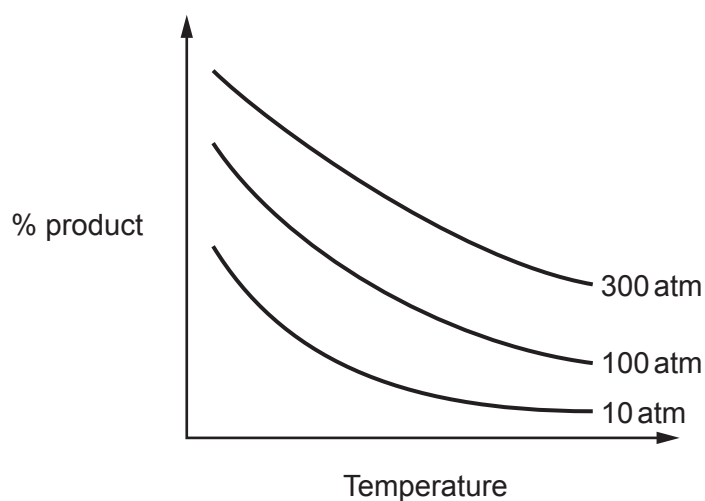
$$f = 3.16 \times 10^{15} \text{ Hz}$$

$$1 \text{ MHz} = 10^6 \text{ Hz, so } f = 3.16 \times 10^{15} / 10^6 = 3.16 \times 10^9 \text{ MHz}$$

frequency =  $3.16 \times 10^9$  MHz



- (c) The diagram below shows how the percentage product varies with temperature and pressure for an equilibrium process.



Use the diagram and Le Chatelier's principle to explain whether:

- (i) the forward reaction is endothermic or exothermic. [2]

*Exothermic, since the % product decreases as the temperature increases.*

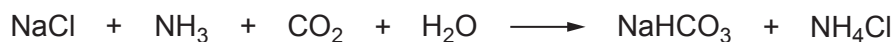
*The system opposes the increase in temperature by taking in heat, shifting the equilibrium to the left (endothermic direction).*

- (ii) the forward reaction involves an increase or decrease in the number of moles of gas. [2]

*A decrease in moles of gas, since the % product increases as the pressure increases. The system opposes an increase in pressure by shifting the equilibrium to the right, the side with fewer moles of gas.*



- (d) The Solvay process is the major industrial process for the manufacture of sodium carbonate. Two of the stages in the process are shown below:



Calculate the maximum mass of sodium carbonate, in kg, which could be obtained from 15.0 tonnes of sodium chloride. Give your answer to an appropriate number of significant figures.

[3]

$$\text{moles NaCl} = 15.0 \times 10^6 \text{ g} / 58.5 = 2.56 \times 10^5 \text{ mol}$$

$2\text{NaCl}$  gives  $2\text{NaHCO}_3$ , which gives  $1\text{Na}_2\text{CO}_3$

$$\text{moles Na}_2\text{CO}_3 = 2.56 \times 10^5 / 2 = 1.28 \times 10^5 \text{ mol}$$

$$M_r(\text{Na}_2\text{CO}_3) = 2(23.0) + 12.0 + 3(16.0) = 106.0$$

$$\text{mass} = 1.28 \times 10^5 \times 106 = 1.36 \times 10^7 \text{ g}$$

$$= 1.36 \times 10^4 \text{ kg (3 sig figs)}$$

maximum mass =  $1.36 \times 10^4$  kg

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09

12



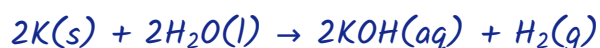
10. (a) Group 1 and Group 2 metals are in the s-block of the Periodic Table. Using potassium and calcium as examples, discuss the similarities and differences between Group 1 and Group 2 with respect to:

- the reaction of the metals with cold water.
- the solubility of the carbonates.

[6 QER]

You should include appropriate chemical equations in your answer.

*Similarities: both potassium and calcium react with cold water to form the metal hydroxide (an alkaline solution) and hydrogen gas, and reactivity increases down both groups.*



*Differences: Group 1 metals react more vigorously. Potassium floats, melts into a ball, fizzes rapidly and the hydrogen catches fire with a lilac flame. Calcium sinks and gives a steady stream of bubbles and a cloudy white solution, as  $\text{Ca(OH)}_2$  is only slightly soluble.*

*This is because a Group 1 metal loses only one electron to form a 1+ ion, whereas a Group 2 metal must lose two electrons, which needs more energy, so Group 1 metals form cations more easily.*

*Carbonates: Group 1 and Group 2 carbonates show different properties. Group 1 carbonates such as  $\text{K}_2\text{CO}_3$  are soluble in water, whereas Group 2 carbonates such as  $\text{CaCO}_3$  are insoluble.*



- (b) The equation for the reaction between potassium carbonate and hydrochloric acid is given below.



A 1.40 g sample of impure potassium carbonate was added to excess dilute hydrochloric acid. The impurity is unreactive and only the potassium carbonate reacts with the acid.

The volume of carbon dioxide released was 186 cm<sup>3</sup> when measured at 298 K and  $1.01 \times 10^5$  Pa.

Calculate the mass of the impurity.

[3]

$$n(\text{CO}_2) = 186 / 24\,500 = 7.59 \times 10^{-3} \text{ mol}$$

$$n(\text{K}_2\text{CO}_3) = n(\text{CO}_2) = 7.59 \times 10^{-3} \text{ mol (1:1 ratio)}$$

$$M_r(\text{K}_2\text{CO}_3) = 2(39.1) + 12.0 + 3(16.0) = 138.2$$

$$\text{mass K}_2\text{CO}_3 = 7.59 \times 10^{-3} \times 138.2 = 1.05 \text{ g}$$

$$\text{mass of impurity} = 1.40 - 1.05 = 0.35 \text{ g}$$

mass of impurity = ..... 0.35 ..... g

- (c) A solution is thought to contain potassium chloride. Describe suitable tests that a student could do to confirm this. Include the expected observations.

[2]

*Flame test: dip a nichrome wire in the solution and hold it in a hot Bunsen flame; a lilac flame shows K<sup>+</sup>.*

*Add dilute nitric acid then silver nitrate solution; a white precipitate (AgCl) shows Cl<sup>-</sup>.*

- (d) By referring to ionisation energies, explain why stable compounds containing K<sup>2+</sup> ions are unlikely to form.

[2]

*The 2nd ionisation energy of potassium is very high (a large increase from the 1st to the 2nd), so too much energy is needed to remove a 2nd electron. It is removed from a shell nearer the nucleus, with less shielding and greater effective nuclear attraction.*



11. (a) Arsenic oxide,  $\text{As}_2\text{O}_3$ , is prepared on an industrial scale by roasting arsenic-containing ores such as arsenopyrite,  $\text{FeAsS}$ , in air. The other products formed are iron(III) oxide and sulfur dioxide.

- (i) State the oxidation state of arsenic in  $\text{As}_2\text{O}_3$ . [1]

+3

- (ii) Give a balanced chemical equation for the industrial production of  $\text{As}_2\text{O}_3$  from  $\text{FeAsS}$ . [2]



- (b)  $\text{As}_2\text{O}_3$  is moderately soluble in water.  $100\text{ cm}^3$  of a saturated solution at  $25^\circ\text{C}$  contains 2.06 g.

When dissolved in water, the oxide reacts to form arsenous acid.



- (i) Calculate the concentration of the arsenous acid, in  $\text{mol dm}^{-3}$ , in the saturated solution. [3]

$$M_r(\text{As}_2\text{O}_3) = 2(74.9) + 3(16.0) = 197.8$$

$$\text{moles As}_2\text{O}_3 \text{ in } 100\text{ cm}^3 = 2.06 / 197.8 = 0.0104\text{ mol}$$

$$\text{moles As}_2\text{O}_3 \text{ in } 1\text{ dm}^3 = 0.0104 \times 10 = 0.104\text{ mol}$$

$$[\text{H}_3\text{AsO}_3] = 0.104 \times 2 = 0.208\text{ mol dm}^{-3}$$

$$\text{concentration of H}_3\text{AsO}_3 = 0.208\text{ mol dm}^{-3}$$

- (ii) A solution of arsenous acid has a pH of 5.11.

Calculate the hydrogen ion concentration of this solution. [1]

$$[\text{H}^+] = 10^{-5.11}$$

$$[\text{H}^+] = 7.76 \times 10^{-6}\text{ mol dm}^{-3}$$



- (c) The formula for arsenous acid can be written as  $\text{As}(\text{OH})_3$  since it contains three hydroxyl (OH) groups bonded to arsenic.

Suggest the shape around the arsenic atom in  $\text{As}(\text{OH})_3$ . Justify your answer by using VSEPR theory. [3]



*Pyramidal (trigonal pyramidal) shape around the arsenic atom.*

*As has 5 outer electrons; there are three bonding pairs (As–O bonds) and one lone pair of electrons.*

*Electron pairs arrange themselves as far apart as possible so that repulsion is at a minimum; lone pair–bond pair repulsion > bond pair–bond pair repulsion.*

- (d) Phosphorus can form two chlorides,  $\text{PCl}_3$  and  $\text{PCl}_5$ .

0.181 g of a chloride of phosphorus gave  $39 \text{ cm}^3$  of vapour at 1 atm pressure when heated to  $87^\circ\text{C}$ . The sample was completely vapourised.

Show that the chloride of phosphorus was  $\text{PCl}_3$ . [4]

$$n = pV / RT$$

$$p = 1.01 \times 10^5 \text{ Pa}, V = 39 \times 10^{-6} \text{ m}^3, T = 87 + 273 = 360 \text{ K}$$

$$n = (1.01 \times 10^5 \times 39 \times 10^{-6}) / (8.31 \times 360)$$

$$n = 1.317 \times 10^{-3} \text{ mol}$$

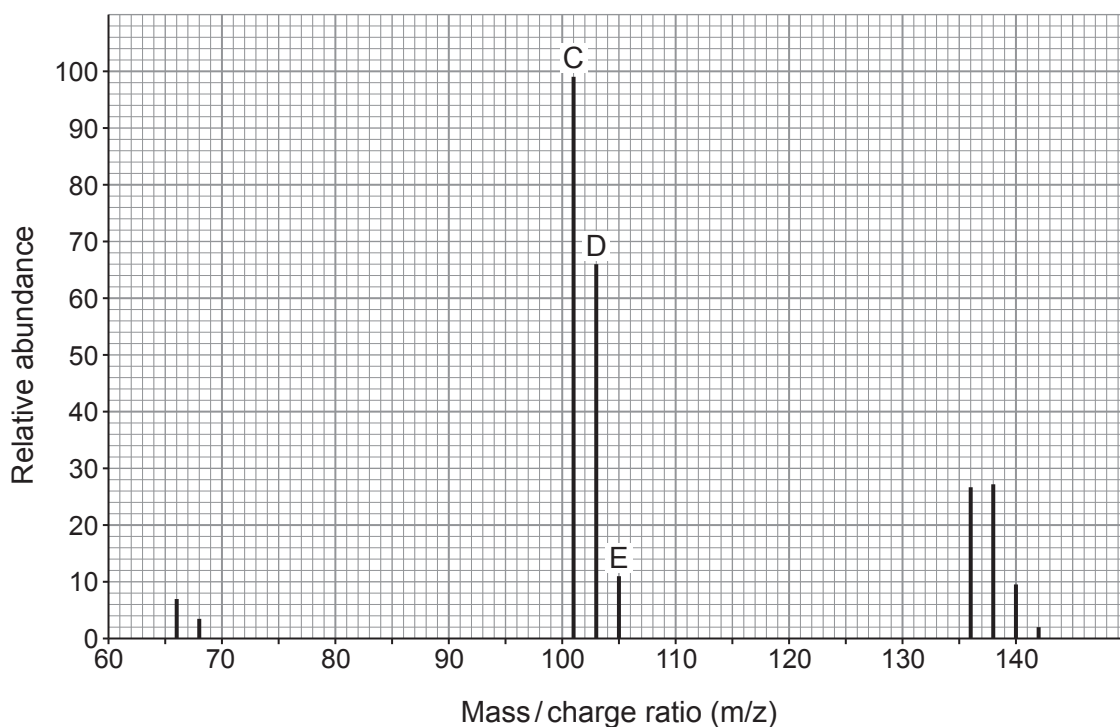
$$M_r = m / n = 0.181 / 1.317 \times 10^{-3} = 137.4$$

$$M_r(\text{PCl}_3) = 31.0 + 3(35.5) = 137.5 \quad (\text{PCl}_5 = 208.5)$$

137.4 matches 137.5, therefore the chloride is  $\text{PCl}_3$



- (e) The molecular ion region of the mass spectrum of  $\text{PCl}_3$ , is shown below.



- (i) Identify the species responsible for peak C at  $m/z$  101. [1]



- (ii) Explain why the height ratio of peaks C:E is 9:1. [2]

Chlorine has two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ , in the ratio 3:1 (75% to 25%).

Peak C is due to  $(\text{P}^{35}\text{Cl}_2)^+$  and peak E is due to  $(\text{P}^{37}\text{Cl}_2)^+$ , so the height ratio C:E =  $(3:1) \times (3:1) = (\frac{3}{4} \times \frac{3}{4}) : (\frac{1}{4} \times \frac{1}{4}) = 9:1$ .



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12. A student was asked to find the identity of a Group 1 metal carbonate by titration.

He was told to use the following method.

- Weigh a sample of the carbonate in a weighing bottle.
- Transfer the carbonate into a beaker and weigh the bottle afterwards.
- Add water to the beaker to dissolve the carbonate.
- Transfer the solution to a volumetric flask.
- Add more water to make the final volume  $250.0\text{ cm}^3$  of solution.
- Accurately transfer  $25.0\text{ cm}^3$  of this solution into a conical flask.
- Add 2–3 drops of a suitable indicator to this solution.
- Fill a burette with  $0.100\text{ mol dm}^{-3}$  hydrochloric acid solution.
- Carry out a rough titration of the carbonate solution with the hydrochloric acid.
- Accurately repeat the titration until you get concordant titres and calculate a mean titre.

(a) Another student said that there were two errors in making the  $250.0\text{ cm}^3$  carbonate solution.

Error 1: A small amount of solid remained in the weighing bottle.

Error 2: A small amount of solution remained in the beaker.

Comment on the suggested errors.

If the student is correct suggest how the method could be improved.

If the student is incorrect, explain why.

[2]

Error 1 *Incorrect: the solid was weighed by difference,*

*as the bottle was reweighed after the transfer, so any solid left in the bottle was not included in the mass used.*

Error 2 *Correct: rinse the beaker with distilled water*

*and transfer all the washings into the volumetric flask before making up to  $250.0\text{ cm}^3$ .*

(b) State why he adds an indicator to this solution.

[1]

*To show the end point, i.e. when the carbonate is exactly neutralised and he should stop adding acid.*

(c) Suggest why he was told to carry out a rough titration first.

[1]

*To give a rough idea of the end point, so a certain volume of acid can be added quickly before adding it drop by drop.*



(d) State what you understand by the term 'concordant titres'.

[1]

*Titres that are very close to each other, within  $0.20 \text{ cm}^3$  of each other.*

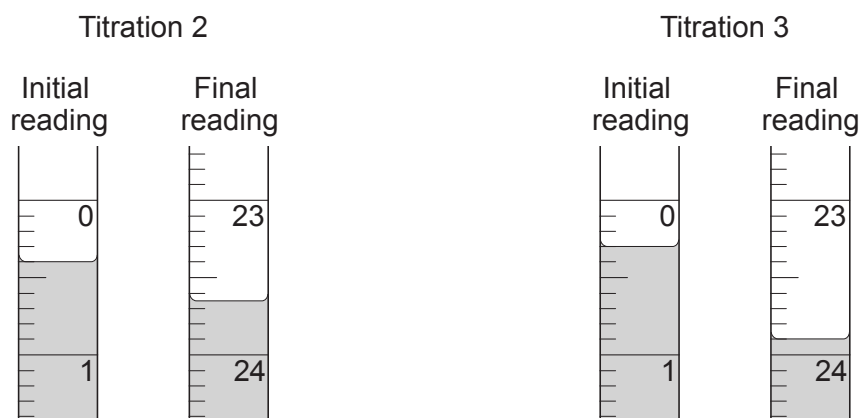
(e) Some of the student's results are shown below:

|                                         |       |
|-----------------------------------------|-------|
| Mass of weighing bottle + carbonate / g | 13.73 |
| Mass of weighing bottle / g             | 12.48 |

| Titration                       | Rough        | 1            | 2            | 3            |
|---------------------------------|--------------|--------------|--------------|--------------|
| Final reading / $\text{cm}^3$   | 24.20        | 23.70        | <i>23.65</i> | <i>23.90</i> |
| Initial reading / $\text{cm}^3$ | 0.00         | 0.10         | <i>0.40</i>  | <i>0.30</i>  |
| Titre / $\text{cm}^3$           | <i>24.20</i> | <i>23.60</i> | <i>23.25</i> | <i>23.60</i> |

concentration of hydrochloric acid =  $0.100 \text{ mol dm}^{-3}$

The diagrams below show the initial burette reading and the final burette reading for the second and third titrations.



Complete the student's table and calculate the mean titre.

[3]

*titrations 1 and 3 are concordant:  $(23.60 + 23.60) / 2$*

mean titre = ..... *23.60* .....  $\text{cm}^3$



- (f) The equation for the reaction between the metal carbonate and hydrochloric acid is given below. **M** represents the symbol of the Group 1 metal.



- (i) Calculate the number of moles of  $\text{M}_2\text{CO}_3$  in  $25.0\text{ cm}^3$  of the solution. [2]

$$n(\text{HCl}) = 0.100 \times 23.60 / 1000 = 2.36 \times 10^{-3} \text{ mol}$$

$$n(\text{M}_2\text{CO}_3) = 2.36 \times 10^{-3} / 2 = 1.18 \times 10^{-3} \text{ mol}$$

$$\text{number of moles} = 1.18 \times 10^{-3} \text{ mol}$$

- (ii) Calculate the relative formula mass of the carbonate and hence deduce the Group 1 metal in the carbonate. [4]

You **must** show your working.

$$\text{mass of carbonate} = 13.73 - 12.48 = 1.25 \text{ g}$$

$$n(\text{M}_2\text{CO}_3) \text{ in } 250.0 \text{ cm}^3 = 1.18 \times 10^{-3} \times 10 = 1.18 \times 10^{-2} \text{ mol}$$

$$M_r = 1.25 / 1.18 \times 10^{-2} = 106$$

$$M_r(\text{CO}_3) = 12.0 + 3(16.0) = 60.0$$

$$A_r(\text{M}) = (106 - 60) / 2 = 23$$

$$A_r = 23 \text{ is sodium, so the carbonate is } \text{Na}_2\text{CO}_3$$

$$\text{group 1 metal} = \text{sodium (Na)}$$

END OF PAPER



[illegible]

[illegible]



**GCE AS/A LEVEL**

2410U10-1A



Z22-2410U10-1A

**TUESDAY, 17 MAY 2022 – MORNING**

**CHEMISTRY – AS unit 1**

**Data Booklet**

Avogadro constant  
molar gas constant  
molar gas volume at 273 K and 1 atm  
molar gas volume at 298 K and 1 atm  
Planck constant  
speed of light  
density of water  
specific heat capacity of water  
ionic product of water at 298 K  
fundamental electronic charge

$$\begin{aligned}N_A &= 6.02 \times 10^{23} \text{ mol}^{-1} \\R &= 8.31 \text{ J mol}^{-1} \text{ K}^{-1} \\V_m &= 22.4 \text{ dm}^3 \text{ mol}^{-1} \\V_m &= 24.5 \text{ dm}^3 \text{ mol}^{-1} \\h &= 6.63 \times 10^{-34} \text{ Js} \\c &= 3.00 \times 10^8 \text{ ms}^{-1} \\d &= 1.00 \text{ g cm}^{-3} \\c &= 4.18 \text{ J g}^{-1} \text{ K}^{-1} \\K_w &= 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \\e &= 1.60 \times 10^{-19} \text{ C}\end{aligned}$$

temperature (K) = temperature (°C) + 273

$1 \text{ dm}^3 = 1000 \text{ cm}^3$   
 $1 \text{ m}^3 = 1000 \text{ dm}^3$   
1 tonne = 1000 kg  
 $1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$

| Multiple  | Prefix | Symbol |
|-----------|--------|--------|
| $10^{-9}$ | nano   | n      |
| $10^{-6}$ | micro  | $\mu$  |
| $10^{-3}$ | milli  | m      |

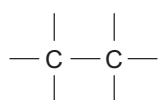
| Multiple | Prefix | Symbol |
|----------|--------|--------|
| $10^3$   | kilo   | k      |
| $10^6$   | mega   | M      |
| $10^9$   | giga   | G      |

## Infrared absorption values

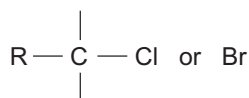
| Bond                     | Wavenumber / $\text{cm}^{-1}$ |
|--------------------------|-------------------------------|
| C — Br                   | 500 to 600                    |
| C — Cl                   | 650 to 800                    |
| C — O                    | 1000 to 1300                  |
| C = C                    | 1620 to 1670                  |
| C = O                    | 1650 to 1750                  |
| C $\equiv$ N             | 2100 to 2250                  |
| C — H                    | 2800 to 3100                  |
| O — H (carboxylic acid)  | 2500 to 3200 (very broad)     |
| O — H (alcohol / phenol) | 3200 to 3550 (broad)          |
| N — H                    | 3300 to 3500                  |

<sup>13</sup>C NMR chemical shifts relative to TMS = 0

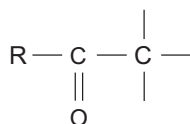
| Type of carbon | Chemical shift, $\delta$ (ppm) |
|----------------|--------------------------------|
|----------------|--------------------------------|



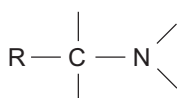
5 to 40



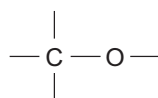
10 to 70



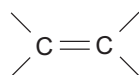
20 to 50



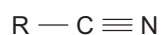
25 to 60



50 to 90



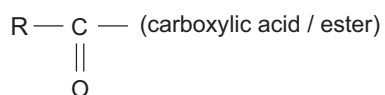
90 to 150



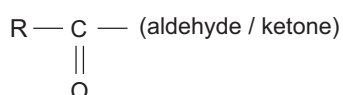
110 to 125



110 to 160



160 to 185



190 to 220

**$^1\text{H}$  NMR chemical shifts relative to TMS = 0**

| Type of proton                                                                                             | Chemical shift, $\delta$ (ppm) |
|------------------------------------------------------------------------------------------------------------|--------------------------------|
| $-\text{CH}_3$                                                                                             | 0.1 to 2.0                     |
| $\text{R}-\text{CH}_3$                                                                                     | 0.9                            |
| $\text{R}-\text{CH}_2-\text{R}$                                                                            | 1.3                            |
| $\text{CH}_3-\text{C}\equiv\text{N}$                                                                       | 2.0                            |
| $\text{CH}_3-\text{C}(=\text{O})$                                                                          | 2.0 to 2.5                     |
| $-\text{CH}_2-\text{C}(=\text{O})$                                                                         | 2.0 to 3.0                     |
|  - $\text{CH}_3$          | 2.2 to 2.3                     |
| $\text{HC}-\text{Cl}$ or $\text{HC}-\text{Br}$                                                             | 3.1 to 4.3                     |
| $\text{HC}-\text{O}$                                                                                       | 3.3 to 4.3                     |
| $\text{R}-\text{OH}$                                                                                       | 4.5 *                          |
| $-\text{C}=\text{CH}$                                                                                      | 4.5 to 6.3                     |
| $-\text{C}=\text{CH}-\text{CO}$                                                                            | 5.8 to 6.5                     |
|  - $\text{CH}=\text{C}$ | 6.5 to 7.5                     |
|  - $\text{H}$           | 6.5 to 8.0                     |
|  - $\text{OH}$          | 7.0 *                          |
| $\text{R}-\text{C}(=\text{O})\text{H}$                                                                     | 9.8 *                          |
| $\text{R}-\text{C}(=\text{O})\text{OH}$                                                                    | 11.0 *                         |

\*variable figure dependent on concentration and solvent

# THE PERIODIC TABLE

Group

1 2 3 4 5 6 7 0

Period

1 2

s block

p block

d block

f block

Key

relative atomic mass

atomic number

Ar

Symbol

Name

Z

1.01  
H  
Hydrogen  
1

6.94  
Li  
Lithium  
3

23.0  
Na  
Sodium  
11

24.3  
Mg  
Magnesium  
12

9.01  
Be  
Beryllium  
4

45.0  
Sc  
Scandium  
21

47.9  
Ti  
Titanium  
22

50.9  
V  
Vanadium  
23

52.0  
Cr  
Chromium  
24

54.9  
Mn  
Manganese  
25

55.8  
Fe  
Iron  
26

58.9  
Co  
Cobalt  
27

58.7  
Ni  
Nickel  
28

63.5  
Cu  
Copper  
29

65.4  
Zn  
Zinc  
30

69.7  
Ga  
Gallium  
31

72.6  
Ge  
Germanium  
32

74.9  
As  
Arsenic  
33

79.0  
Se  
Selenium  
34

79.9  
Br  
Bromine  
35

83.8  
Kr  
Krypton  
36

85.5  
Rb  
Rubidium  
37

87.6  
Sr  
Strontium  
38

88.9  
Y  
Yttrium  
39

91.2  
Zr  
Zirconium  
40

92.9  
Nb  
Niobium  
41

95.9  
Mo  
Molybdenum  
42

98.9  
Tc  
Technetium  
43

101  
Ru  
Ruthenium  
44

103  
Rh  
Rhodium  
45

106  
Pd  
Palladium  
46

108  
Ag  
Silver  
47

112  
Cd  
Cadmium  
48

115  
In  
Indium  
49

119  
Sn  
Tin  
50

122  
Sb  
Antimony  
51

127  
I  
Iodine  
53

131  
Xe  
Xenon  
54

133  
Cs  
Caesium  
55

137  
Ba  
Barium  
56

179  
Hf  
Hafnium  
72

181  
Ta  
Tantalum  
73

184  
W  
Tungsten  
74

186  
Re  
Rhenium  
75

190  
Os  
Osmium  
76

192  
Ir  
Iridium  
77

195  
Pt  
Platinum  
78

197  
Au  
Gold  
79

201  
Hg  
Mercury  
80

204  
Tl  
Thallium  
81

207  
Pb  
Lead  
82

209  
Bi  
Bismuth  
83

210  
Po  
Polonium  
84

210  
At  
Astatine  
85

222  
Rn  
Radon  
86

223  
Fr  
Francium  
87

226  
Ra  
Radium  
88

227  
Ac  
Actinium  
89

232  
Th  
Thorium  
90

231  
Pa  
Protactinium  
91

238  
U  
Uranium  
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237  
Np  
Neptunium  
93

242  
Pu  
Plutonium  
94

243  
Am  
Americium  
95

247  
Cm  
Curium  
96

245  
Bk  
Berkelium  
97

251  
Cf  
Californium  
98

254  
Es  
Einsteinium  
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253  
Fm  
Fermium  
100

256  
Md  
Mendelevium  
101

254  
No  
Nobelium  
102

257  
Lr  
Lawrencium  
103

140  
Ce  
Cerium  
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141  
Pr  
Praseodymium  
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144  
Nd  
Neodymium  
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147  
Pm  
Promethium  
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Sm  
Samarium  
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Europium  
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Gadolinium  
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Tb  
Terbium  
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Dysprosium  
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Ho  
Holmium  
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Erbium  
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Tm  
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Yb  
Ytterbium  
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Lutetium  
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