| Surname | StemUp Model Solution | Centre Number | Candidate Number |
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| First name(s) | | | 2 |

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# GCE AS

B410U10-1

S24-B410U10-1

eduqas Part of WJEC

**TUESDAY, 14 MAY 2024 – MORNING**

## CHEMISTRY – AS component 1

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

1 hour 30 minutes

| | For Examiner's use only | | |
|---|---|---|---|
| | **Question** | **Maximum Mark** | **Mark Awarded** |
| **Section A** | **1. to 5.** | **10** | |
| **Section B** | **6.** | **9** | |
| | **7.** | **14** | |
| | **8.** | **6** | |
| | **9.** | **10** | |
| | **10.** | **21** | |
| | **11.** | **10** | |
| | **Total** | **80** | |

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**ADDITIONAL MATERIALS**

- A calculator, pencil and ruler
- **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.

**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 **Q7**(a)(iv).



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## SECTION A

Answer **all** questions.

**1.** Silver chloride can be precipitated by the following reaction.

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$

$M_r$ 170 $M_r$ 58.5 $M_r$ 143.5 $M_r$ 85

Calculate the atom economy for the production of silver chloride. [1]

*atom economy = $M_r$ of AgCl ÷ total $M_r$ of reactants × 100*

*= 143.5 ÷ (170 + 58.5) × 100 = 143.5 ÷ 228.5 × 100*

Atom economy = ..*62.8*.. %

**2.** When phosphoric(V) acid, $H_3PO_4$, is neutralised with sodium hydroxide, sodium phosphate is produced.

Complete and balance the equation for the reaction. [2]

..*3*.. NaOH + $H_3PO_4$ ⟶ ..*$Na_3PO_4$*.. + ..*3*.. $H_2O$



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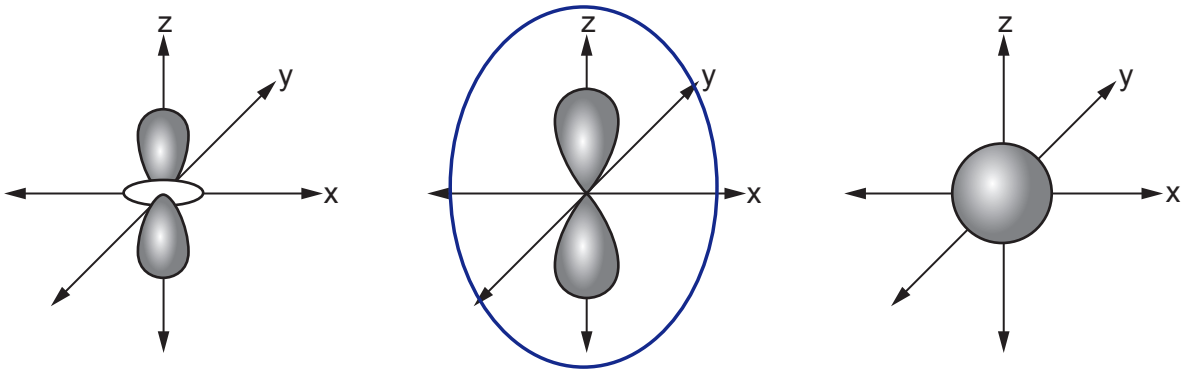
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**3.** There are four types of orbitals found in an atom – *s*, *p*, *d* and *f*.

(a) Give the meaning of the term orbital. [1]

A region (in an atom) where there is a high probability of finding an electron of a given energy; it holds up to two electrons.

(b) Identify the shape of a *p*-orbital by circling the correct diagram. [1]




**4.** Calcium hydroxide decomposes on heating as shown below.

$$Ca(OH)_2(s) \longrightarrow CaO(s) + H_2O(g)$$

Calculate the maximum mass of calcium oxide that can be produced when 75.0 g of calcium hydroxide is heated. [2]

$M_r\ Ca(OH)_2 = 40.1 + 2(16.0 + 1.01) = 74.12$; $M_r\ CaO = 56.1$

moles $Ca(OH)_2 = 75.0 \div 74.12 = 1.012$ mol

1 : 1 ratio, so moles $CaO = 1.012$ mol

mass of $CaO = 1.012 \times 56.1 = 56.8$ g

Mass of calcium oxide = 56.8 g

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**5.** Esters are made by the reaction of carboxylic acids with alcohols. Once the reagents are mixed the reaction is left to reach dynamic equilibrium.

(a) Give the meaning of the term dynamic equilibrium. [1]

*The forward and backward (reverse) reactions occur at the same rate, so the concentrations of reactants and products stay constant (in a closed system).*

(b) An example of an esterification reaction is given below.

$$CH_3OH + HCOOH \rightleftharpoons HCOOCH_3 + H_2O$$

Write an expression for $K_c$, the equilibrium constant, for this reaction.

Give the unit, if any, for $K_c$. [2]

$$K_c = \frac{[HCOOCH_3]\,[H_2O]}{[CH_3OH]\,[HCOOH]}$$

*no unit (the concentration units cancel)*

Unit *none, no unit*

10



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## SECTION B

Answer **all** questions.

**6.** This question is about some aspects of the chemistry of the noble gases.

(a) Explain why the noble gases exist as monatomic particles. [2]

They have a full (stable) outer shell of electrons, so they have no (or very little) tendency to form bonds with other atoms.

(b) Explain why argon has a very low boiling temperature. [1]

There are only very weak van der Waals forces between the Ar atoms, needing very little energy to overcome.

(c) The first ionisation energy of argon is 1521 kJ mol$^{-1}$.

Calculate the frequency of the high energy photon needed to ionise an Ar atom to form an $Ar^+$ ion. Give your answer in **MHz**. [3]

energy per atom = $1521 \times 1000 \div 6.02 \times 10^{23} = 2.53 \times 10^{-18}$ J

$E = hf$, so $f = E \div h = 2.53 \times 10^{-18} \div 6.63 \times 10^{-34}$

$f = 3.82 \times 10^{15}$ Hz

$3.82 \times 10^{15} \div 10^{6} = 3.82 \times 10^{9}$ MHz

Frequency = 3.82 x $10^9$ MHz



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(d) There are many radioactive isotopes of radon. The most stable has a relative isotopic mass of 222.

(i) Give the meaning of the term relative isotopic mass. [1]

The mass of an atom of an isotope relative to one-twelfth of the mass of an atom of carbon-12.

(ii) Write an equation for the formation of $^{218}Po$ by the radioactive decay of $^{222}Rn$. [2]

$^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}\alpha$ (alpha particle, $He^{2+}$)

9





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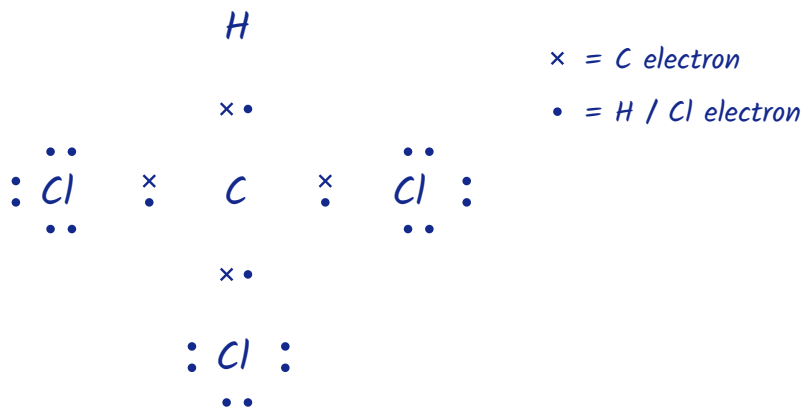
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**7.** (a) Carbon forms covalent bonds in trichloromethane and diamond.

(i) Give the meaning of the term covalent bond. [1]

A shared pair of electrons between two atoms, with each atom providing one electron.

(ii) Draw a dot and cross diagram to show the bonding in trichloromethane, $CHCl_3$. Show outer electrons only. [2]




(iii) A student proposed that the $Cl — \hat{C} — Cl$ bond angle in trichloromethane must be slightly larger than the $H — \hat{C} — Cl$ bond angle.

Suggest a reason why this might be true. [1]

There is greater electron density around the (larger, more electronegative) chlorine atoms, so there is greater repulsion between the C–Cl bonding pairs, pushing them closer to the H atom.



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(iv) The melting temperature of diamond is over 4000 °C whereas the melting temperature of trichloromethane is only –63.5 °C.

Compare and contrast the structures of trichloromethane and diamond. Explain why the melting temperature of diamond is so high compared to that of trichloromethane. [6 QER]

Trichloromethane has a simple molecular structure. Within each molecule there are strong covalent bonds between the atoms, arranged tetrahedrally around the carbon. Between the molecules there are only weak van der Waals forces.

Diamond has a giant covalent structure. Each carbon atom forms strong covalent bonds to four other carbon atoms in a tetrahedral arrangement, extending throughout the whole lattice.

Similarity: both contain strong covalent bonds with a tetrahedral arrangement around C. Difference: diamond has no separate molecules.

Covalent bonds are much stronger than intermolecular forces, so much more energy is needed to break them. To melt diamond, millions of strong covalent bonds must be broken, so its melting temperature is very high. To melt trichloromethane only the weak van der Waals forces between molecules must be overcome; no covalent bonds break, so little energy is needed.





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(b) Boron is in Group 3 of the Periodic Table.

(i) Explain why the bond angles in boron trifluoride, $BF_3$, are exactly 120°. [2]

B has three bond pairs and no lone pairs (three identical B–F bond pairs). The bond pairs repel equally, so minimum repulsion is when they are as far apart as possible, at exactly 120° (trigonal planar).

(ii) Boron trifluoride forms a compound with ammonia, $NH_3$.

Suggest how a bond forms between the nitrogen atom and the boron atom. [2]

The lone pair on the nitrogen atom is donated into the empty valence orbital of the boron atom, forming a coordinate (dative) bond: $H_3N \rightarrow BF_3$.

14



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**8.** Gold leaf is gold that has been hammered into very thin sheets and it is usually 0.1 $\mu$m thick.

(a) Explain why gold is malleable. [1]

When a force is applied the layers of cations (atoms) can slide over each other, while the delocalised electrons keep the metallic bonding.

(b) The density of pure gold is 19.32 g cm$^{-3}$.

(i) Calculate the number of gold atoms present in a square of pure gold leaf that is 3.0 cm × 3.0 cm and 0.1 $\mu$m thick. [3]

0.1 μm = 0.1 × $10^{-4}$ cm = 1 × $10^{-5}$ cm

volume = 3.0 × 3.0 × 1 × $10^{-5}$ = 9.0 × $10^{-5}$ $cm^3$

mass = 19.32 × 9.0 × $10^{-5}$ = 1.74 × $10^{-3}$ g

moles = 1.74 × $10^{-3}$ ÷ 197 = 8.83 × $10^{-6}$ mol

atoms = 8.83 × $10^{-6}$ × 6.02 × $10^{23}$ = 5.32 × $10^{18}$

Number of atoms = 5.32 × $10^{18}$

(ii) Pure gold is 24-karat but the most commonly used gold is 22-karat yellow gold.

Calculate the number of moles of gold in a 1.0 cm **cube** of 22-karat yellow gold. [2]

moles Au in 1 $cm^3$ of 24-karat gold = 19.32 ÷ 197 = 0.0981 mol

22-karat is 22/24 gold, so 22/24 × 0.0981 = 0.0899 mol

Number of moles = 0.0899 mol

6

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11



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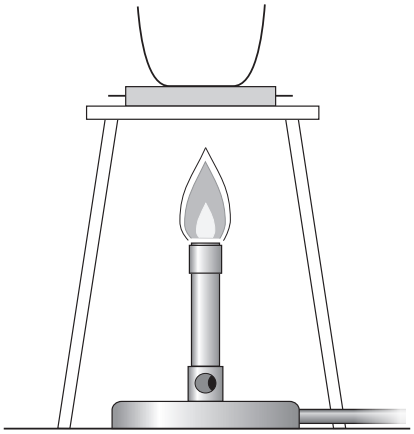
**9.** When calcium carbonate is heated the following reaction occurs.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

(a) Name this type of reaction. [1]

*thermal decomposition*

(b) This reaction was carried out in a laboratory using the apparatus shown.



The following results were obtained.

| | |
|---|---|
| Mass of empty crucible / g | 9.732 |
| Mass of crucible and $CaCO_3$ / g | 9.908 |
| Mass of crucible and CaO / g | 9.842 |

(i) The reaction did not go to completion.

I. Calculate the maximum possible number of moles of carbon dioxide that could be produced. [1]

*mass $CaCO_3$ = 9.908 − 9.732 = 0.176 g*

*moles $CO_2$ = moles $CaCO_3$ = 0.176 ÷ 100.1 = $1.76 \times 10^{-3}$ mol*

Moles of carbon dioxide = *$1.76 \times 10^{-3}$* mol



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II. Calculate the percentage yield of carbon dioxide in this reaction. [2]

mass $CO_2$ lost = 9.908 − 9.842 = 0.066 g

moles $CO_2$ = 0.066 ÷ 44.0 = $1.50 \times 10^{-3}$ mol

yield = $1.50 \times 10^{-3} \div 1.76 \times 10^{-3} \times 100$

Yield = 85.2 %

(ii) Describe and explain how the yield of calcium oxide can be maximised. [2]

Heat, cool and reweigh repeatedly until the mass is constant (heat to constant mass), to ensure that the reaction has finished and all the $CaCO_3$ has decomposed.

(c) Calculate the volume occupied by $3.75 \times 10^{-3}$ mol of carbon dioxide at a temperature of 800 °C and 2 atm pressure. Give your answer in **cm$^3$**. [4]

$pV = nRT$, so $V = nRT \div p$

$T = 800 + 273 = 1073$ K; $p = 2 \times 1.01 \times 10^5 = 2.02 \times 10^5$ Pa

$V = 3.75 \times 10^{-3} \times 8.31 \times 1073 \div 2.02 \times 10^5$

$V = 1.66 \times 10^{-4}$ m$^3$

$1.66 \times 10^{-4} \times 10^6 = 166$ cm$^3$

Volume = 166 cm$^3$

10



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**10.** (a) A student wanted to make a solution of magnesium sulfate.

Give a description, including quantities, of how she could make 250 $cm^3$ of an aqueous solution of 1.00 mol $dm^{-3}$ magnesium sulfate ($M_r$ 120.4). [4]

moles = 1.00 × 250 ÷ 1000 = 0.250 mol

mass $MgSO_4$ = 0.250 × 120.4 = 30.1 g

Weigh out 30.1 g of magnesium sulfate accurately (weighing by difference).

Dissolve the solid in a small amount of deionised water in a beaker.

Transfer the solution quantitatively to a 250 $cm^3$ volumetric flask, rinsing the beaker and adding the washings.

Make up to the 250 $cm^3$ mark with deionised water and invert to mix.

(b) The solution she obtained was slightly cloudy. Analysis showed that the original solid was contaminated with magnesium hydroxide.

(i) Give a reason why the solution appeared cloudy. [1]

Magnesium hydroxide is insoluble in water.

(ii) She decided to assess the level of impurity by carrying out a back titration.

She added 0.50 g of the impure magnesium sulfate to 100 $cm^3$ of 0.40 mol $dm^{-3}$ hydrochloric acid. She then titrated 25.0 $cm^3$ samples of her solution against 1.00 mol $dm^{-3}$ aqueous sodium hydroxide.

Her results are given in the table.

| Titration number | 1 | 2 | 3 |
|---|---|---|---|
| Final burette reading / $cm^3$ | 9.20 | 18.30 | 27.50 |
| Initial burette reading / $cm^3$ | 0.00 | 9.20 | 18.30 |
| Titre / $cm^3$ | 9.20 | 9.10 | 9.20 |



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I. Complete the table and use the data to calculate a mean titre. [1]

mean = (9.20 + 9.10 + 9.20) ÷ 3

Mean titre = 9.17 $cm^3$

II. Calculate the number of moles of hydrochloric acid that reacted with the impure magnesium sulfate sample. [3]

original moles HCl = 0.40 × 100 ÷ 1000 = 0.040 mol

moles NaOH in titre = 1.00 × 9.17 ÷ 1000 = $9.17 \times 10^{-3}$ mol

unreacted HCl in 100 $cm^3$ = 4 × 9.17 × $10^{-3}$ = 0.03668 mol

HCl reacted = 0.040 − 0.03668

Moles of HCl = $3.32 \times 10^{-3}$ mol

III. Hydrochloric acid reacts with magnesium hydroxide as shown.

$$2HCl + Mg(OH)_2 \longrightarrow MgCl_2 + 2H_2O$$

Calculate the percentage purity by mass of the impure magnesium sulfate. [3]

moles $Mg(OH)_2$ = $3.32 \times 10^{-3} \div 2 = 1.66 \times 10^{-3}$ mol

mass $Mg(OH)_2$ = $1.66 \times 10^{-3} \times 58.32 = 0.0968$ g

% purity = (0.50 − 0.0968) ÷ 0.50 × 100

Purity = 80.6 %



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IV. Calculate the percentage error in the titre value of titration number 1. [1]

% error = 2 × 0.05 ÷ 9.20 × 100

Percentage error = 1.09 %

V. The student realised that this percentage error was significant and decided to repeat the experiment using hydrochloric acid of concentration 1.00 mol $dm^{-3}$ instead of the original 0.40 mol $dm^{-3}$.

State whether or not this change would reduce the percentage error.

Justify your answer by calculating and commenting upon the new titre value. [4]

original HCl = 1.00 × 100 ÷ 1000 = 0.100 mol

unreacted HCl = 0.100 − 3.32 × $10^{-3}$ = 0.09668 mol

in 25.0 $cm^3$: 0.09668 ÷ 4 = 0.02417 mol NaOH needed

titre = 0.02417 ÷ 1.00 × 1000

New titre value = 24.17 $cm^3$

Yes, it would reduce the % error: the larger titre (24.17 $cm^3$)

gives an error of only 2 × 0.05 ÷ 24.17 × 100 = 0.41%.

(iii) State how a flame test could be used to prove that the impurity was **not** calcium hydroxide. [1]

No brick-red flame colour would be seen (calcium ions give brick red).



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(iv) I. Calculate the pH of 0.40 mol $dm^{-3}$ hydrochloric acid. [1]

$pH = -\log[H^+] = -\log 0.40$

pH = 0.398

II. Suggest how the pH of 0.40 mol $dm^{-3}$ sulfuric acid would differ, if at all, from the pH of 0.40 mol $dm^{-3}$ hydrochloric acid.

Justify your answer. [2]

The pH of the sulfuric acid would be lower. $H_2SO_4$ releases two $H^+$ ions per molecule, so $[H^+] = 0.80$ mol $dm^{-3}$ (twice as many $H^+$), $pH = -\log 0.80 = 0.097$.

21



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**11.** Bromine can be extracted from seawater and other water sources by the oxidation of bromide ions.

(a) Write a half-equation for the oxidation of bromide ions. [1]

$2Br^- \rightarrow Br_2 + 2e^-$

(b) State why this reaction is described as an oxidation reaction. [1]

The bromide ions lose electrons (the oxidation state of bromine increases from −1 to 0).

(c) Chlorine can be used as an oxidising agent.

Explain why chlorine can oxidise bromide ions. [1]

Chlorine atoms are smaller, so chlorine has a greater ability to attract electrons than bromine.

(d) The concentration of bromide ions in seawater from the Dead Sea can be as high as $12\,g\,dm^{-3}$.

Calculate the maximum number of moles of bromine that can be extracted from $4500\,m^3$ of this seawater. [2]

moles $Br^-$ per $dm^3$ = 12 ÷ 79.9 = 0.150 mol

moles $Br_2$ per $dm^3$ = 0.150 ÷ 2 = 0.0751 mol

4500 $m^3$ = 4500 × 1000 = 4.5 × $10^6$ $dm^3$

moles $Br_2$ = 0.0751 × 4.5 × $10^6$

Number of moles = 3.38 × $10^5$ mol



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(e) A student decided to investigate other halogen-halide reactions under standard laboratory conditions.

(i) He added an aqueous solution of iodine to an aqueous solution of potassium bromide. He observed a brown colour in the test tube.

He decided that the brown colour was due to the formation of bromine.

Explain why the student is incorrect. [2]

Iodine is less reactive than bromine, so iodine cannot oxidise (displace) bromide ions and no bromine forms. The brown colour is just the colour of the iodine solution added.

(ii) The halogen can be identified by shaking the reaction mixture with cyclohexane. Two layers form and the purple colour of the cyclohexane layer shows that iodine is present.

Explain why iodine is more soluble in cyclohexane than in water. [3]

Halogens such as $I_2$ are non-polar molecules, and cyclohexane is also non-polar, whereas water is a polar molecule (with hydrogen bonding). Iodine forms more van der Waals attractions with a non-polar solvent like cyclohexane than it does with water, so it is more soluble in cyclohexane.

10

**END OF PAPER**



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