

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

AS CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 16 May 2023

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do **all** rough work in this book. Cross through any work you do not want to be marked.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
TOTAL	

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice

You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.



J U N 2 3 7 4 0 4 1 0 1

Section A

Answer **all** questions in this section.

0 1

This question is about the elements in Period 3.

0 1 . 1

Give the full electron configuration of the element in Period 3 with the highest first ionisation energy.

[1 mark]



0 1 . 2

Give an equation, including state symbols, to represent the process that occurs when the second ionisation energy of sodium is measured.

[1 mark]



0 1 . 3

Table 1 shows some successive ionisation energies for an element in Period 3.

Table 1

Ionisation number	1	2	3	4	5	6	7	8
Ionisation energy / kJ mol^{-1}	1000	2260	3390	4540	6990	8490	27 100	31 700

Identify the Period 3 element.

Explain your answer.

[3 marks]

Element Sulfur (S)

Explanation There is a large jump between the 6th and 7th ionisation energies (8490 to 27 100), so the 7th electron is removed from the second (2p) shell, which is closer to the nucleus and has less shielding.



0 2

This question is about the elements in Group 2.

0 2 . 1

Describe the structure and bonding in magnesium.

[2 marks]

A giant lattice of positive Mg^{2+} ions (cations) surrounded by a sea of delocalised electrons (metallic bonding).

Strong electrostatic attraction between the Mg^{2+} ions and the delocalised electrons.

0 2 . 2

State the trend in the atomic radius of the elements down Group 2 from Mg to Ba

Give a reason for this trend.

[2 marks]

Trend *Atomic radius increases down the group.*

Reason *The number of electron energy levels (shells) increases down the group, so the outer electrons are further from the nucleus.*

0 2 . 3

Give an equation, including state symbols, for the reaction of magnesium with steam.

State **two** observations for this reaction.

[3 marks]

Equation



Observation 1 *A bright white light (flame) is seen.*

Observation 2 *A white powder (ash) is formed.*

Question 2 continues on the next page

Turn over ►



0 2 . 4

The sulfates of the elements in Group 2 from Mg to Ba have different solubilities.

State the formula of the least soluble of these sulfates.

Give a use for this sulfate.

[2 marks]

Formula BaSO_4

Use Barium meal, for X-rays of internal organs (the digestive system).

0 2 . 5

A sample of strontium is made up of only three isotopes: ^{86}Sr , ^{87}Sr and ^{88}Sr

This sample contains 83.00% by mass of ^{88}Sr

This sample of strontium has $A_r = 87.73$

Calculate the percentage abundance of each of the other two isotopes in this sample.

[4 marks]

Let abundance of $^{87}\text{Sr} = x \%$

so abundance of $^{86}\text{Sr} = 100 - 83.00 - x = (17.00 - x) \%$

$$87.73 = [(88 \times 83.00) + (87 \times x) + (86 \times (17.00 - x))] \div 100$$

$$8773 = 7304 + 87x + 1462 - 86x$$

$$8773 = 8766 + x$$

$$x = 7.00$$

$$^{87}\text{Sr} = 7.00 \% \quad \text{and} \quad ^{86}\text{Sr} = 17.00 - 7.00 = 10.00 \%$$

$$\% \text{ abundance } ^{87}\text{Sr} = \underline{7.00 \%}$$

$$\% \text{ abundance } ^{86}\text{Sr} = \underline{10.00 \%}$$



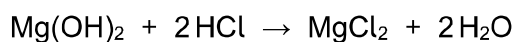
0 2 . 6

$\text{Mg}(\text{OH})_2$ is used as an antacid to treat indigestion.

A student does an experiment to determine the percentage by mass of $\text{Mg}(\text{OH})_2$ in an indigestion tablet.

40.0 cm³ of 0.200 mol dm⁻³ HCl (an excess) is added to 0.200 g of a powdered tablet. The mixture is swirled thoroughly.

All of the $\text{Mg}(\text{OH})_2$ reacts with HCl as shown.



The amount of HCl remaining after this reaction is determined by titration with 0.100 mol dm⁻³ NaOH

29.25 cm³ of 0.100 mol dm⁻³ NaOH are needed.

Calculate the percentage by mass of $\text{Mg}(\text{OH})_2$ in the indigestion tablet.

[6 marks]

$$n(\text{HCl}) \text{ added} = 0.200 \times 40.0 \div 1000 = 0.00800 \text{ mol}$$

$$n(\text{NaOH}) = 0.100 \times 29.25 \div 1000 = 0.002925 \text{ mol}$$

$$\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}, \text{ so } n(\text{HCl}) \text{ remaining} = 0.002925 \text{ mol}$$

$$n(\text{HCl}) \text{ reacted with } \text{Mg}(\text{OH})_2 = 0.00800 - 0.002925 = 0.005075 \text{ mol}$$

$$n(\text{Mg}(\text{OH})_2) = 0.005075 \div 2 = 0.0025375 \text{ mol}$$

$$M_r(\text{Mg}(\text{OH})_2) = 24.3 + 2(16.0 + 1.0) = 58.3$$

$$\text{mass of } \text{Mg}(\text{OH})_2 = 0.0025375 \times 58.3 = 0.148 \text{ g}$$

$$\% \text{ by mass} = (0.148 \div 0.200) \times 100 = 74.0 \%$$

Percentage by mass 74.0 %

19

Turn over ►



0 3

A student uses this method to prepare a standard solution of sodium carbonate.

1. Weigh a clean, dry, empty container on a balance that reads to 2 decimal places.
2. Add about 2.5 g of solid sodium carbonate to the container.
3. Tip the solid into a beaker.
4. Add approximately 100 cm³ of distilled water to the beaker and stir until all the solid has dissolved.
5. Pour the solution into a 250 cm³ volumetric flask.
6. Add distilled water until the top of the meniscus is level with the graduation mark.

0 3 . 1

Suggest **three** improvements to this method.

[3 marks]

- 1 *Weigh by difference: reweigh the empty container after tipping the solid out, and record all masses to 2 decimal places.*
- 2 *Wash the container and the beaker (and stirring rod) with distilled water and add all the washings to the volumetric flask.*
- 3 *Use a dropper near the mark so the bottom of the meniscus is on the line, then stopper and invert the flask several times to mix.*

0 3 . 2

A different student uses the correct method to prepare 250 cm³ of sodium carbonate solution in a volumetric flask. The uncertainty for the volumetric flask is ± 0.20 cm³

Calculate the percentage uncertainty in the volume of this sodium carbonate solution.

[1 mark]

$$(0.20 \div 250) \times 100$$

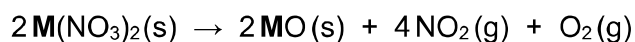
Percentage uncertainty 0.080 %

4



0 4

M is a Group 2 metal that forms the nitrate $M(NO_3)_2$
0.320 g of $M(NO_3)_2$ is heated strongly and decomposes completely.



The mixture of gases formed has a volume of 225 cm³ at 450 °C and 101 000 Pa

Determine the M_r of $M(NO_3)_2$

Identify **M**.

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[5 marks]

$$V = 225 \text{ cm}^3 = 225 \times 10^{-6} \text{ m}^3 \quad T = 450 + 273 = 723 \text{ K}$$

$$n(\text{gas}) = pV \div RT = (101\,000 \times 225 \times 10^{-6}) \div (8.31 \times 723) \\ = 22.725 \div 6008.13 = 3.78 \times 10^{-3} \text{ mol}$$

2 mol $M(NO_3)_2$ gives 5 mol of gas (4 NO_2 + 1 O_2)

$$n(M(NO_3)_2) = 3.782 \times 10^{-3} \times 2/5 = 1.513 \times 10^{-3} \text{ mol}$$

$$M_r = \text{mass} \div n = 0.320 \div 1.513 \times 10^{-3} = 211.5$$

$$M_r(NO_3)_2 \text{ part} = 2 \times (14.0 + 3 \times 16.0) = 124.0$$

$$A_r(M) = 211.5 - 124.0 = 87.5, \text{ which matches strontium (87.6)}$$

M_r of $M(NO_3)_2$ 211.5

Identity of **M** Strontium, Sr

5

Turn over ►



0	5
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This question is about the shapes of molecules.

Discuss the difference between the shapes of CF_4 and XeF_4

In your answer you should:

- name the shape of each molecule
- explain the shape of each molecule
- explain the bond angle(s) in each molecule.

[6 marks]

CF_4 is tetrahedral and XeF_4 is square planar.

CF_4 : the carbon atom has four bonding pairs of electrons and no lone pairs. Electron pairs repel each other equally and arrange themselves to be as far apart as possible to minimise repulsion, so the four bonding pairs point to the corners of a tetrahedron and the $\text{F}-\text{C}-\text{F}$ bond angle is 109.5° .

XeF_4 : the xenon atom has four bonding pairs and two lone pairs of electrons (six electron pairs in total), so the electron pairs are arranged octahedrally.

Lone pairs repel more strongly than bonding pairs, so the two lone pairs position themselves as far apart as possible, opposite each other (180° apart), above and below the plane.

This leaves the four bonding pairs (the four F atoms) in one plane around the Xe atom, giving a square planar shape with $\text{F}-\text{Xe}-\text{F}$ bond angles of 90° .

So the difference in shape is caused by the two lone pairs on Xe: CF_4 has no lone pairs and a bond angle of 109.5° , while XeF_4 has two lone pairs and a bond angle of 90° .



[illegible]

6



0 6

This question is about halogens and halide ions.

0 6 . 1

Explain why the electronegativity of the halogens decreases down the group.

[2 marks]

Down the group the atoms are larger with more shells and more shielding, so the bonding pair of electrons is further from the nucleus. So there is weaker attraction between the nucleus and the bonding pair of electrons.

Concentrated sulfuric acid reacts with solid sodium chloride and with solid sodium bromide.

0 6 . 2

State **one** similarity in, and **one** difference between, these reactions.

[2 marks]

Similarity *Both form misty white fumes of a hydrogen halide (HCl and HBr) in an acid-base reaction.*

Difference *Only with bromide is there a redox reaction: Br⁻ ions are oxidised, giving red-brown Br₂ fumes and SO₂.*

0 6 . 3

Solid sodium iodide reacts with concentrated sulfuric acid to form hydrogen sulfide.

Give a half-equation to show the oxidation of iodide ions.

Give a half-equation to show the reduction of concentrated sulfuric acid to hydrogen sulfide.

Use your half-equations to deduce an overall equation for this reaction.

[3 marks]

Half-equation 1



Half-equation 2



Overall equation



Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

Turn over ►



0 7

This question is about time of flight (TOF) mass spectrometry.

0 7 . 1

Compound **X** is dissolved in a polar, volatile solvent and is ionised by electrospray ionisation.

Each ion is accelerated so that it has a kinetic energy of $1.36 \times 10^{-16} \text{ J}$

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$
where:

KE = kinetic energy / J

m = mass / kg

v = speed / m s^{-1}

The time of flight along the 0.750 m flight tube is $2.48 \times 10^{-5} \text{ s}$

Determine the mass, in g, of one mole of **X**.

The Avogadro constant, $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

[5 marks]

$$v = d \div t = 0.750 \div 2.48 \times 10^{-5} = 30\,241.9 \text{ m s}^{-1}$$

$$m = 2KE \div v^2 = (2 \times 1.36 \times 10^{-16}) \div (30\,241.9)^2 \\ = 2.974 \times 10^{-25} \text{ kg}$$

$$m = 2.974 \times 10^{-25} \times 1000 = 2.974 \times 10^{-22} \text{ g}$$

$$\text{mass of 1 mol of ions} = 2.974 \times 10^{-22} \times 6.022 \times 10^{23} = 179.1 \text{ g}$$

Electrospray ionisation adds H^+ ; ions are XH^+ , so subtract 1

$$\text{mass of one mole of X} = 179.1 - 1 = 178.1 \text{ g}$$

Mass of one mole of **X** 178.1 g



A mixture of gases is analysed using TOF mass spectrometry.
The mixture contains argon, carbon dioxide, nitrogen and oxygen.
The mixture is ionised by electron impact.

0 7 . 2 State the meaning of the term electron impact ionisation.

[1 mark]

High energy electrons from an electron gun are fired at the sample and knock out an electron from each molecule or atom, forming $1+$ ions.

0 7 . 3 Identify the ion formed from this mixture that reaches the detector last.

Justify your answer.

[2 marks]

Ion that reaches detector last *CO_2^+*

Justification *CO_2^+ has the highest mass to charge ratio ($m/z = 44$), so it travels the slowest and takes longest to reach the detector.*

0 7 . 4 State how the ions are detected, and how the abundance of each ion is measured, in a TOF mass spectrometer.

[2 marks]

How ions are detected *The positive ions hit the detector and each ion gains an electron, which generates a current.*

How abundance is measured *The abundance of each ion is proportional to the size of the current produced.*

10

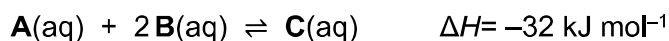
Turn over for the next question

Turn over ►



0 8

This question is about the equilibrium mixture formed when **A** and **B** react.



0 8 . 1

A solution containing 0.60 mol of **A** is added to a solution containing 0.60 mol of **B**.
The amount of **C** formed at equilibrium is 0.28 mol

Deduce the amounts, in moles, of **A** and **B** in this mixture at equilibrium.

[2 marks]

A + 2B ⇌ C: 0.28 mol C formed uses 0.28 mol A and 0.56 mol B

A at equilibrium = 0.60 - 0.28 = 0.32 mol

B at equilibrium = 0.60 - (2 × 0.28) = 0.04 mol

Amount of **A** 0.32 mol

Amount of **B** 0.04 mol

0 8 . 2

Give an expression for the equilibrium constant (K_c) for this reaction.

[1 mark]

$$K_c = \frac{[C]}{[A][B]^2}$$



0 8 . 3

The temperature of the equilibrium mixture is decreased.

Predict the effect, if any, on the value of K_c
Give a reason for your prediction.

[3 marks]

Prediction The value of K_c increases.

Reason The forward reaction is exothermic, so the equilibrium shifts to the right, in the exothermic direction, to increase the temperature and oppose the decrease.

0 8 . 4

In another mixture at equilibrium

[A] = 0.48 mol dm⁻³

[C] = 0.62 mol dm⁻³

For this reaction, the equilibrium constant $K_c = 7.8 \text{ mol}^{-2} \text{ dm}^6$

Calculate [B] at equilibrium.

Give your answer to the appropriate number of significant figures.

[3 marks]

$$K_c = [C] \div ([A][B]^2), \text{ so } [B]^2 = [C] \div ([A] \times K_c)$$

$$[B]^2 = 0.62 \div (0.48 \times 7.8) = 0.62 \div 3.744 = 0.1656$$

$$[B] = \sqrt{0.1656} = 0.4069 \text{ mol dm}^{-3}$$

$$= 0.41 \text{ mol dm}^{-3} \text{ (2 s.f., as the data are given to 2 s.f.)}$$

[B] 0.41 mol dm⁻³

9

Turn over ►



Section B

Answer **all** questions in this section.Only **one** answer per question is **allowed**.For each question **completely fill** in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this **will** not be marked.
Do **not** use additional sheets for this working.

0

9

Which atom contains the most neutrons?

[1 mark]

A ^{54}Cr ☐B ^{55}Mn ☐C ^{57}Fe ☒D ^{58}Ni ☐

Use this information for Questions 10 and 11.

A student completes a titration to determine the concentration of ethanoic acid in vinegar.

25.0 cm³ of vinegar are transferred to a conical flask using a pipette.
A few drops of phenolphthalein are added to the conical flask.
Sodium hydroxide solution is added from a burette to the conical flask.
The titration is repeated until concordant results are obtained.

1	0
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Which suggestion improves the accuracy of the titres?

[1 mark]

- A** Rinsing the conical flask with vinegar between each titration. ☐
- B** Rinsing the conical flask with sodium hydroxide solution between each titration. ☐
- C** Rinsing the conical flask with water between each titration. ☒
- D** Not rinsing the conical flask between each titration. ☐

1	1
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Which suggestion decreases the percentage uncertainty in the mean titre?

[1 mark]

- A** Use a more dilute solution of sodium hydroxide in the burette. ☒
- B** Use a more dilute solution of vinegar. ☐
- C** Rinse the inside of the conical flask with distilled water during each titration. ☐
- D** Rinse the tip of the burette with distilled water near the end point in each titration. ☐

1	2
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Which reaction has the highest percentage atom economy for the production of hydrogen?

[1 mark]

- A** $\text{LiH} + \text{H}_2\text{O} \rightarrow \text{LiOH} + \text{H}_2$ ☐
- B** $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$ ☐
- C** $2\text{Al} + 3\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2$ ☐
- D** $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ ☒

Turn over for the next question

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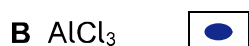


1 3

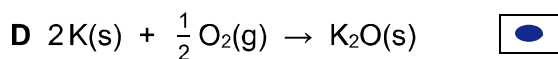
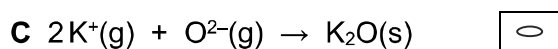
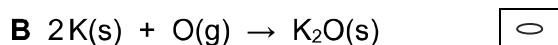
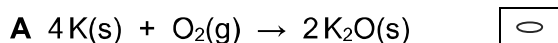
Which molecule has a permanent dipole?

[1 mark]**1 4**

Which molecule can accept an electron pair during the formation of a coordinate bond?

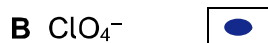
[1 mark]**1 5**

Which reaction has an enthalpy change equal to the standard enthalpy of formation of potassium oxide?

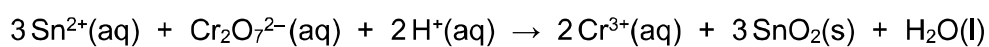
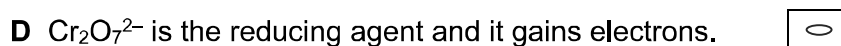
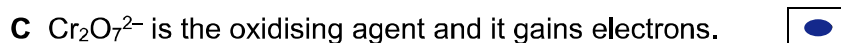
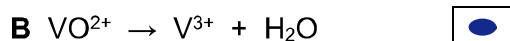
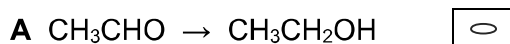
[1 mark]

1 6

In which species is chlorine in its highest oxidation state?

[1 mark]**1 7**

Which statement about this redox reaction is correct?

**[1 mark]****1 8**Which incomplete half-equation is balanced by adding two H^+ ions and one electron to the left-hand side?**[1 mark]****Turn over for the next question****Turn over ►**

Use this information for Questions 19 to 23.

A student completes some test-tube reactions on five solutions, **P**, **Q**, **R**, **S** and **T**. The student completes each test on separate samples of each solution. Observations are shown in the table.

Solution	Test 1 Add a few drops of $\text{H}_2\text{SO}_4(\text{aq})$	Test 2 Add $\text{HNO}_3(\text{aq})$ then a few drops of $\text{AgNO}_3(\text{aq})$	Test 3 Add a few drops of $\text{NaOH}(\text{aq})$	Test 4 Add a few drops of $\text{Cl}_2(\text{aq})$
P	White precipitate	Cream precipitate	No visible change	Orange solution
Q	Effervescence	Effervescence and white precipitate	No visible change	No visible change
R	No visible change	No visible change	White precipitate	No visible change
S	White precipitate		No visible change	Dark brown solution
T	No visible change	White precipitate	White precipitate	No visible change

Use the information in the table to answer Questions 19 to 23.

1 9

Which solution contains carbonate ions?

[1 mark]

A Solution **P** ☐

B Solution **Q** ☒

C Solution **R** ☐

D Solution **S** ☐

2 0

What could be the identity of the compound in solution **P**?

[1 mark]

A MgBr_2 ☐

B BaBr_2 ☒

C MgCl_2 ☐

D BaCl_2 ☐



2 1What observation is expected in **Test 2** for solution **S**?**[1 mark]**

- A** No visible change ☐
- B** Effervescence ☐
- C** White precipitate ☐
- D** Pale yellow precipitate ☒

2 2In **Test 2**, the mixture formed by solution **S** is filtered.

Which substance is present in the filtrate?

[1 mark]

- A** AgBr ☐
- B** AgI ☐
- C** Ba(NO₃)₂ ☒
- D** Mg(NO₃)₂ ☐

2 3What could be the identity of the compound in solution **T**?**[1 mark]**

- A** MgCl₂ ☒
- B** BaCl₂ ☐
- C** MgBr₂ ☐
- D** BaBr₂ ☐

15**END OF QUESTIONS**

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