

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

AS CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

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.

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**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Section B	
TOTAL	



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

Section A

Answer **all** questions in this section.

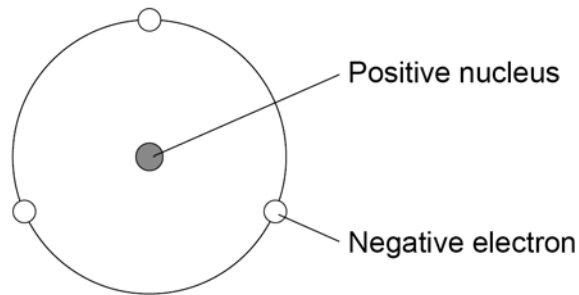
0 1

This question is about atomic structure.

0 1 . 1

Figure 1 is a model proposed by Rutherford to show the structure of an atom.

Figure 1



State **two** features of the current model that are not shown in the Rutherford model.

[2 marks]

Feature 1 of the current model The current model includes neutrons and protons in the nucleus (Rutherford's has neither).

Feature 2 of the current model The current model shows electrons in different energy levels / orbitals (shells), e.g. the first energy level holds only 2 electrons.



0 1 . 2

A sample of tin is analysed in a time of flight mass spectrometer. The sample is ionised by electron impact to form $1+$ ions.

Table 1 shows data about the four peaks in this spectrum.

Table 1

m/z	Percentage abundance
112	22.41
114	11.78
117	34.97
120	To be determined

Give the symbol, including mass number, of the ion that reaches the detector first.

Calculate the relative atomic mass of tin in this sample.
Give your answer to 1 decimal place.

[4 marks]

Lightest ion has the smallest m/z so it is fastest and arrives first.

Symbol of ion $^{112}\text{Sn}^+$

$$\% \text{ abundance of } ^{120}\text{Sn} = 100 - (22.41 + 11.78 + 34.97) = 30.84 \%$$

$$\text{RAM} = \frac{(112 \times 22.41) + (114 \times 11.78) + (117 \times 34.97) + (120 \times 30.84)}{100}$$

$$= (2509.92 + 1342.92 + 4091.49 + 3700.80) \div 100$$

$$= 11645.13 \div 100 = 116.4513$$

$$= 116.5 \text{ (1 d.p.)}$$

Relative atomic mass 116.5

6

Turn over ►



0 2

This question is about magnesium and its compounds.

0 2 . 1

State **one** observation when magnesium reacts with steam.

Give an equation, including state symbols, for this reaction.

[2 marks]

Observation *A bright white light (glow) is seen and a white powder / solid (MgO) forms.*

Equation



0 2 . 2

Describe the bonding in magnesium.

[2 marks]

Metallic bonding: a lattice of positive Mg^{2+} ions and delocalised electrons (the two outer shell electrons of each Mg atom are delocalised).

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

0 2 . 3

Explain, in terms of structure and bonding, why magnesium chloride has a high melting point.

[3 marks]

Magnesium chloride has a giant ionic lattice of Mg^{2+} and Cl^- ions.

There are strong electrostatic forces of attraction between the oppositely charged Mg^{2+} and Cl^- ions,

so a lot of energy is needed to overcome these attractions, giving a high melting point.

0 2 . 4

Give **one** medical use for magnesium hydroxide.

[1 mark]

As an antacid for indigestion relief, to neutralise excess stomach acid (milk of magnesia).



0 3

This question is about redox reactions.

0 3 . 1

State, in terms of electrons, the meaning of the term oxidising agent.

[1 mark]

An oxidising agent is an electron acceptor (it gains electrons).

0 3 . 2

 $\text{Cr}_2\text{O}_7^{2-}$ can oxidise SO_3^{2-} in acidic conditions to form Cr^{3+} and SO_4^{2-} Deduce a half-equation for the oxidation of SO_3^{2-} to SO_4^{2-} Deduce a half-equation for the reduction of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} Deduce the overall equation for the oxidation of SO_3^{2-} by $\text{Cr}_2\text{O}_7^{2-}$

[3 marks]

Half-equation for the oxidation of SO_3^{2-} to SO_4^{2-} Half-equation for the reduction of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} 

Overall equation



4

Turn over for the next question

Turn over ►



0 4

This question is about the identification of ions in unknown solutions.

A student completes a number of test-tube reactions on solutions **A**, **B** and **C**.

Table 2 shows the student's observations.

Table 2

	Test 1	Test 2	Test 3
	Add H ₂ SO ₄ (aq)	Warm with NaOH(aq)	Add acidified AgNO ₃ (aq)
A	white precipitate	no visible change	no visible change
B	effervescence	a gas is formed that turns damp red litmus blue	effervescence
C	no visible change	no visible change	off-white precipitate

0 4 . 1

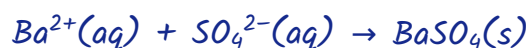
Suggest the identity of the positive ion in solution **A**.

Give the simplest ionic equation for the formation of the white precipitate in **Test 1** for solution **A**.

[2 marks]

Identity of positive ion in **A** Ba²⁺ (barium ion)

Ionic equation



0 4 . 2

Different gases are formed when solution **B** reacts in **Test 1** and in **Test 2**.

Suggest the identity of each gas.

Give the simplest ionic equation for the formation of the gas in **Test 2**.

[2 marks]

Gas formed in **Test 1** Carbon dioxide, CO₂

Gas formed in **Test 2** Ammonia, NH₃

Ionic equation for the formation of the gas in **Test 2**



0 4 . 3

The student thinks that solution **C** contains either chloride ions or bromide ions.

Describe a further test, or tests, to show whether solution **C** contains chloride or bromide ions.

[3 marks]

Add dilute ammonia solution to the off-white precipitate formed with acidified silver nitrate.

If the precipitate dissolves in dilute ammonia, chloride ions are present (AgCl is soluble in dilute NH_3).

If the precipitate does not dissolve in dilute ammonia, then bromide ions are present. (It would dissolve in concentrated ammonia, confirming AgBr .)

7

Turn over for the next question

Turn over ►



0 5

This question is about chlorine.

0 5 . 1

Chlorine has a low boiling point because the forces between the molecules are weak.

Explain how these forces arise between molecules of chlorine.

[3 marks]

Electrons are constantly moving randomly within each Cl_2 molecule, so at any instant the electron density can be uneven, creating a temporary dipole ($\delta+$ at one end, $\delta-$ at the other) in one molecule.

This temporary dipole induces a dipole in a neighbouring Cl_2 molecule.

These temporary (induced) dipoles attract each other, the $\delta+$ end of one molecule attracting the $\delta-$ end of the next. These are van der Waals (London) forces.

0 5 . 2

Give an equation for the reaction of chlorine with water.

Give a reason why chlorine is added to drinking water.

[2 marks]

Equation



Reason *It kills bacteria / microorganisms (pathogens), so it sterilises the water.*

0 5 . 3

Chlorine reacts with cold, aqueous sodium hydroxide in the manufacture of bleach.

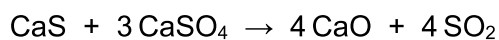
Give an equation for this reaction.

[1 mark]



0 6

Calcium sulfide reacts with calcium sulfate as shown.



2.50 g of calcium sulfide are heated with 9.85 g of calcium sulfate until there is no further reaction.

Show that calcium sulfate is the limiting reagent in this reaction.

Calculate the mass, in g, of sulfur dioxide formed.

$$M_r(\text{CaS}) = 72.2$$

$$M_r(\text{CaSO}_4) = 136.2$$

[5 marks]

$$n(\text{CaS}) = 2.50 \div 72.2 = 0.0346 \text{ mol}$$

$$n(\text{CaSO}_4) = 9.85 \div 136.2 = 0.0723 \text{ mol}$$

3 mol of CaSO_4 are needed for each 1 mol of CaS , so to react all the CaS would need $3 \times 0.0346 = 0.104 \text{ mol } \text{CaSO}_4$, but only 0.0723 mol is present. $n(\text{CaSO}_4)$ is less than $3 \times n(\text{CaS})$, so CaSO_4 is the limiting reagent.

$$n(\text{SO}_2) = n(\text{CaSO}_4) \times 4/3 = 0.0723 \times 4/3 = 0.0964 \text{ mol}$$

$$M_r(\text{SO}_2) = 32.1 + 2(16.0) = 64.1$$

$$\text{mass of } \text{SO}_2 = 0.0964 \times 64.1 = 6.18 \text{ g}$$

Mass of sulfur dioxide 6.18 g

5

Turn over for the next question

Turn over ►



0 7

This question is about combustion.

0 7 . 1

State the meaning of the term standard enthalpy of combustion.

[2 marks]

*The enthalpy change when one mole of a substance is burned**completely in oxygen,**with all reactants and products in their standard states, under standard**conditions (100 kPa and a stated temperature, usually 298 K).*

0 7 . 2

A student does an experiment to determine the enthalpy of combustion of propan-1-ol ($\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$, $M_r = 60.0$).

Combustion of 0.497 g of propan-1-ol increases the temperature of 150 g of water from 21.2 °C to 35.1 °C

Calculate a value, in kJ mol^{-1} , for the enthalpy of combustion of propan-1-ol in this experiment.The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

[3 marks]

$$\Delta T = 35.1 - 21.2 = 13.9 \text{ }^\circ\text{C} (= 13.9 \text{ K})$$

$$q = mc\Delta T = 150 \times 4.18 \times 13.9 = 8715.3 \text{ J} = 8.7153 \text{ kJ}$$

$$n(\text{propan-1-ol}) = 0.497 \div 60.0 = 0.00828 \text{ mol}$$

$$\Delta H = -q \div n = -8.7153 \div 0.00828$$

$$= -1052.6 = -1050 \text{ kJ mol}^{-1} (3 \text{ s.f.})$$

Enthalpy of combustion -1050 kJ mol^{-1} 

0 7 . 3

The enthalpy of combustion determined experimentally is less exothermic than that calculated using enthalpies of formation.

Give **one** possible reason for this, other than heat loss.

[1 mark]

Incomplete combustion of the propan-1-ol (some forms carbon monoxide / soot instead of CO₂).

6

Turn over for the next question

Turn over ►



0 8

A student is provided with a 5.60 g sample of ethanoic acid (CH_3COOH) contaminated with sodium ethanoate (CH_3COONa).

The student dissolves the sample in deionised water and makes the volume up to 200 cm^3

The student removes 25.0 cm^3 samples of the solution and titrates them with $0.350 \text{ mol dm}^{-3}$ sodium hydroxide solution.

Table 3 shows the results of these titrations.

Table 3

	Rough	1	2	3
Final volume / cm^3	20.85	41.10	20.50	40.80
Initial volume / cm^3	0.00	20.85	0.00	20.50
Titre / cm^3	20.85	20.25	20.50	20.30

0 8 . 1

Use the results in **Table 3** to calculate the mean titre value.

Use the mean titre to calculate the percentage by mass of sodium ethanoate in the original sample.

[6 marks]

Concordant titres: 20.25 and 20.30

$$\text{mean} = (20.25 + 20.30) \div 2 = 20.275$$

Mean titre value 20.275 cm^3



$$n(\text{NaOH}) = 0.350 \times 20.275 \div 1000 = 7.09625 \times 10^{-3} \text{ mol}$$



$$n(\text{CH}_3\text{COOH}) \text{ in } 25.0 \text{ cm}^3 = 7.09625 \times 10^{-3} \text{ mol}$$

$$n(\text{CH}_3\text{COOH}) \text{ in } 200 \text{ cm}^3 = 7.09625 \times 10^{-3} \times 8 = 0.05677 \text{ mol}$$

$$\text{mass of CH}_3\text{COOH} = 0.05677 \times 60.0 = 3.4062 \text{ g}$$

$$\text{mass of CH}_3\text{COONa} = 5.60 - 3.4062 = 2.1938 \text{ g}$$

$$\% \text{ CH}_3\text{COONa} = (2.1938 \div 5.60) \times 100 = 39.2 \%$$

Percentage by mass 39.2 %

0 8 . 2

The student rinses the burette with deionised water before filling with sodium hydroxide solution.

State and explain the effect, if any, that this rinsing will have on the value of the titre.

[2 marks]

The titre value would increase (be larger).

This is because the water left in the burette dilutes the sodium

hydroxide solution, so it is more dilute and a larger volume is needed to neutralise the acid.

8

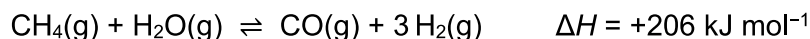
Turn over for the next question

Turn over ►



0 9

Hydrogen can be prepared on an industrial scale using the reversible reaction between methane and steam.



The reaction is done at a temperature of 800 °C and a low pressure of 300 kPa in the presence of a nickel catalyst.

Explain, in terms of equilibrium yield and cost, why these conditions are used.

[6 marks]

Temperature: the forward reaction is endothermic ($\Delta H = +206 \text{ kJ mol}^{-1}$). A high temperature shifts the position of equilibrium to the right (to the endothermic side) to oppose the increase in temperature and absorb the heat, so the equilibrium yield of hydrogen increases. A high temperature also increases the rate.

However, high temperatures are costly because a lot of energy (fuel) is needed to produce them, so 800 °C is a compromise between a high yield and the energy cost.

Pressure: there are 4 moles of gas on the right-hand side and only 2 moles of gas on the left-hand side. A low pressure shifts the position of equilibrium to the right, the side with more moles of gas, to oppose the decrease in pressure, so the equilibrium yield of hydrogen increases. A low pressure is also cheap, because less energy is needed for compressors and the plant does not need expensive thick-walled pipes and vessels, so the cost is low.

Catalyst: the nickel catalyst has no effect on the position of equilibrium, so it has no effect on the equilibrium yield. It speeds up the forward and reverse reactions equally by providing an alternative route with a lower activation energy.

Adding a catalyst allows a lower temperature to be used while still



having an acceptable rate, so less energy is needed and this lowers the cost.

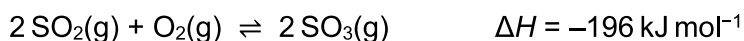
Do not write
outside the
box

Turn over ►



1 0

Sulfur dioxide reacts with oxygen to form sulfur trioxide.



1 0 . 1

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

[1 mark]

$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

1 0 . 2

A mixture of sulfur dioxide and oxygen is allowed to reach equilibrium in a container of volume 1800 cm^3 at temperature T .At equilibrium, the mixture contains 0.176 mol of sulfur dioxide and 0.461 mol of sulfur trioxide.At temperature T the equilibrium constant, $K_c = 15.0 \text{ mol}^{-1} \text{ dm}^3$

Calculate the amount, in moles, of oxygen at equilibrium.

[3 marks]

$$V = 1800 \text{ cm}^3 = 1.80 \text{ dm}^3$$

$$[\text{SO}_2] = 0.176 \div 1.80 = 0.0978 \text{ mol dm}^{-3}$$

$$[\text{SO}_3] = 0.461 \div 1.80 = 0.256 \text{ mol dm}^{-3}$$

$$[\text{O}_2] = [\text{SO}_3]^2 \div (K_c \times [\text{SO}_2]^2) = 0.256^2 \div (15.0 \times 0.0978^2)$$

$$= 0.0656 \div 0.1434 = 0.457 \text{ mol dm}^{-3}$$

$$n(\text{O}_2) = 0.457 \times 1.80 = 0.823 \text{ mol}$$

Amount of oxygen 0.823 mol

1 0 . 3

At a different temperature, a mixture contains
 0.025 mol of sulfur dioxide
 0.049 mol of oxygen
 0.034 mol of sulfur trioxide.

The total pressure of the mixture in a 3500 cm³ reaction vessel is 255 kPa

Use the data to calculate the temperature, in °C, of the mixture.

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

[5 marks]

$$pV = nRT \text{ so } T = pV \div nR$$

$$n = 0.025 + 0.049 + 0.034 = 0.108 \text{ mol}$$

$$p = 255 \text{ kPa} = 255\,000 \text{ Pa}$$

$$V = 3500 \text{ cm}^3 = 3500 \times 10^{-6} \text{ m}^3 = 0.0035 \text{ m}^3$$

$$T = (255\,000 \times 0.0035) \div (8.31 \times 0.108) = 892.5 \div 0.89748$$

$$= 994.5 \text{ K}$$

$$T \text{ in } ^\circ\text{C} = 994.5 - 273 = 721 \text{ } ^\circ\text{C}$$

Temperature 721 °C

9

Turn over for Section B

Turn over ►



Section B

Answer **all** questions in this section.Only **one** answer per question is allowed.

For each answer 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.

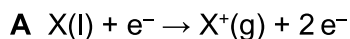
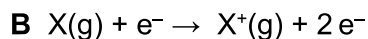
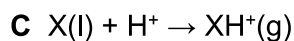
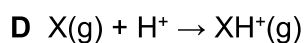
You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

1 1

In a time of flight mass spectrometer, molecule X is ionised using electrospray ionisation.

What is the equation for this ionisation?

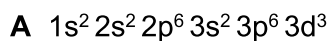
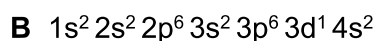
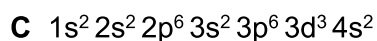
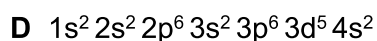
[1 mark]

☐☐☐☒

1 2

What is the electron configuration of V^{2+} in the ground state?

[1 mark]

☒☐☐☐

1 3

Which molecule is **not** able to form a co-ordinate bond with another species?

[1 mark]

A BH_3 ☐B CH_4 ☒C NH_3 ☐D H_2O ☐

1 4

Which species has a square planar shape?

[1 mark]

A NH_4^+ ☐B SF_4 ☐C XeF_4 ☒D PCl_4^+ ☐

1 5

Which bond has the most unsymmetrical electron distribution?

[1 mark]

A H-O ☒B H-S ☐C H-N ☐D H-P ☐

Turn over for the next question

Turn over ►



1 6

Which compound contains a chlorine atom with an oxidation state of +4?

[1 mark]**A** KClO_4 ☐**B** CCl_4 ☐**C** ClO_2 ☒**D** ClO_2F ☐**1 7**

Which element is classified as a d block element?

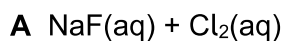
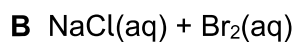
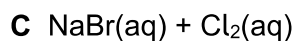
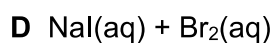
[1 mark]**A** Antimony☐**B** Molybdenum☒**C** Strontium☐**D** Uranium☐**1 8**

Which element in Period 3 has the highest melting point?

[1 mark]**A** Aluminium☐**B** Silicon☒**C** Sodium☐**D** Sulfur☐

1 9

Which pair of solutions, when mixed, reacts to form a dark brown solution?

[1 mark]☐☐☐☒**2 0**

Some solid sodium halides are reacted with concentrated sulfuric acid.

Which solid sodium halide does **not** produce a sulfur-containing gas as one of the products?**[1 mark]**☒☐☐☐**Turn over for the next question****Turn over ►**

2 1Which atom has one more proton and two more neutrons than $^{31}_{15}\text{P}$?**[1 mark]**☐☐☐☒**2 2**

What is a use for barium sulfate?

[1 mark]**A** In agriculture to act as a fertiliser☐**B** In agriculture to neutralise acidic soil☐**C** In medicine to produce an X-ray image☒**D** In medicine as an antacid to treat indigestion☐**2 3**

Which ion has the largest radius?

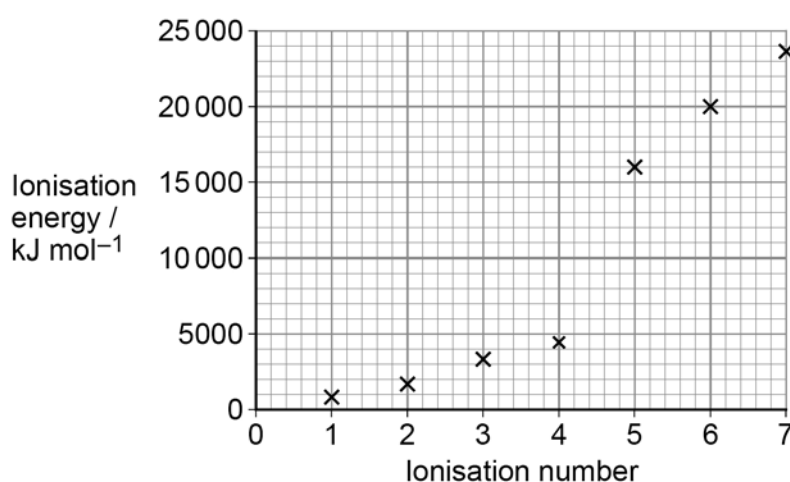
[1 mark]☐☐☐☒

2 4

Which element has a first ionisation energy lower than that of sulfur?

[1 mark]**A** Chlorine☐**B** Oxygen☐**C** Phosphorus☐**D** Selenium☒**2 5**

The first seven successive ionisation energies for element Z are shown.



What is element Z?

[1 mark]**A** Carbon☐**B** Nitrogen☐**C** Silicon☒**D** Phosphorus☐**15****END OF QUESTIONS**

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

[illegible]

Do not write
outside the
box

[illegible]

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2021 AQA and its licensors. All rights reserved.



2 8



2 1 6 A 7 4 0 4 / 1