

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

Monday 18 May 2020

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.

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	
Section B	
TOTAL	



J U N 2 0 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

There is a general trend for an increase in ionisation energy across Period 3.
Give **one** example of an element that deviates from this trend.

Explain why this deviation occurs.

[3 marks]Element Aluminium (Al)

Explanation The outer electron in aluminium is in a 3p sub-shell
(orbital), which is higher in energy than the 3s sub-shell.
It is also slightly more shielded by the 3s electrons, so less energy is
needed to remove it than to remove the 3s electron from magnesium.

0 1 . 2

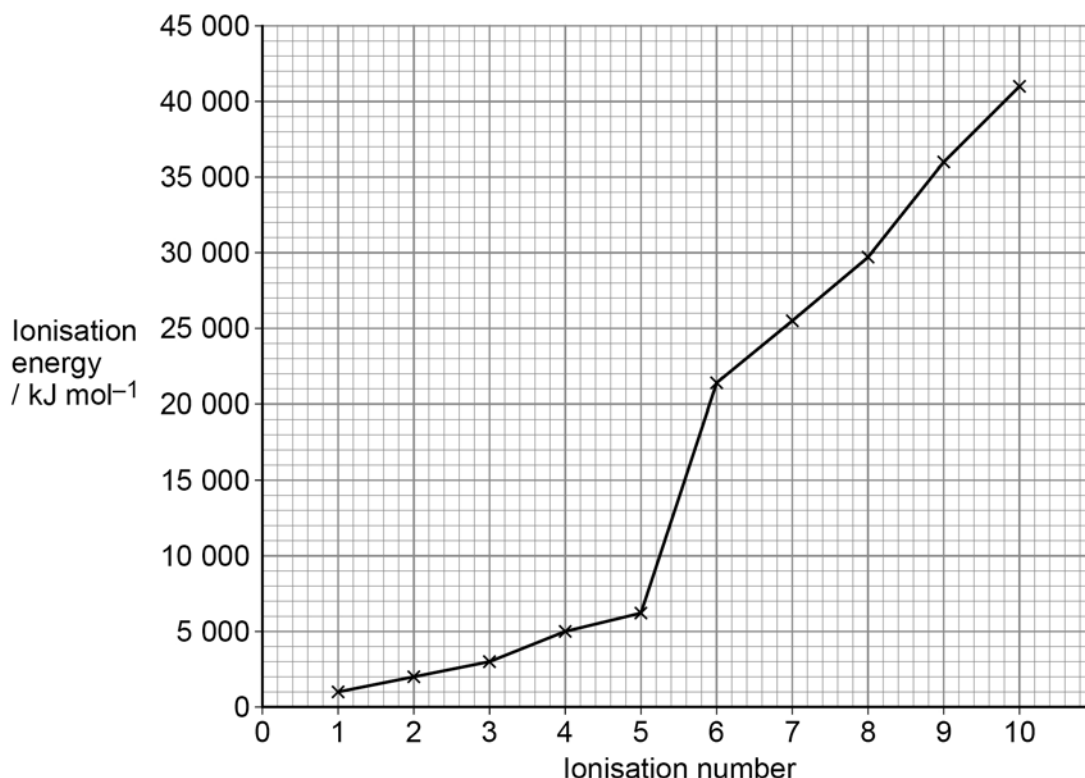
Give an equation, including state symbols, to represent the process that occurs when
the **third** ionisation energy of sodium is measured.

[1 mark]

0 1 . 3

Figure 1 shows the successive ionisation energies of a Period 3 element, X.

Figure 1



Identify element X.

Explain your choice.

[3 marks]

Element Phosphorus (P)

Explanation There is a large jump in ionisation energy between the 5th and the 6th ionisation energies.

This is because the 6th electron is removed from the second (principal) energy level (2p), which is closer to the nucleus and less shielded than the third energy level.

So X has 5 electrons in its outer shell (Group 5), and the Period 3 element in Group 5 is phosphorus.

7

Turn over for the next question

Turn over ►



0 2

This question is about a titration.

A student dissolves an unknown mass of sodium hydroxide in water to make 200 cm³ of an aqueous solution.

A 25.0 cm³ sample of this sodium hydroxide solution is placed in a conical flask and is titrated with 0.150 mol dm⁻³ sulfuric acid.

The equation for this reaction is shown.

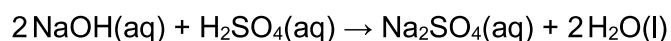


Table 1 shows the results of the titrations.

Table 1

Titration	Rough	1	2	3
Final reading / cm ³	20.75	40.35	21.05	40.60
Initial reading / cm ³	0.00	20.75	1.20	21.05
Titre / cm ³	20.75	19.60	19.85	19.55

0 2 . 1

Calculate the mass of sodium hydroxide used to make the original solution.

[5 marks]

$$\text{Mean titre (concordant 1 and 3)} = (19.60 + 19.55) \div 2 = 19.575 \text{ cm}^3$$

$$n(\text{H}_2\text{SO}_4) = 0.150 \times 19.575 \div 1000 = 2.936 \times 10^{-3} \text{ mol}$$

$$n(\text{NaOH}) \text{ in } 25.0 \text{ cm}^3 = 2 \times 2.936 \times 10^{-3} = 5.873 \times 10^{-3} \text{ mol}$$

$$n(\text{NaOH}) \text{ in } 200 \text{ cm}^3 = 5.873 \times 10^{-3} \times (200 \div 25.0) = 0.04698 \text{ mol}$$

$$\text{mass} = n \times M_r = 0.04698 \times 40.0 = 1.879 \text{ g}$$

Mass of sodium hydroxide 1.88 g



0 2 . 2

The student uses a funnel to fill the burette with sulfuric acid before starting the titration. After filling, the student forgets to remove the funnel from the top of the burette.

Suggest why this might affect the titre volume recorded.

[1 mark]

Drops of acid left in the funnel could drip into the burette during the titration, making the reading on the burette lower, so the titre recorded would not be the true volume added (too small).

0 2 . 3

State **one** advantage of using a conical flask rather than a beaker for the titration.

[1 mark]

There is less chance of splashing or losing any of the solution when the flask is swirled.

7

Turn over for the next question

Turn over ►



0 3

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

0 3 . 1

Define the term relative atomic mass.

[2 marks]

*The (weighted) average mass of an atom of an element, compared to
1/12th of the mass of an atom of carbon-12.*

0 3 . 2

A sample of krypton is ionised using electron impact.

The mass spectrum of this sample of krypton has four peaks.

Table 2 shows data from this spectrum.

Table 2

<i>m/z</i>	82	83	84	86
Relative intensity	6	1	28	8

Calculate the relative atomic mass (A_r) of this sample of krypton.

Give your answer to 1 decimal place.

[2 marks]

$$\begin{aligned}
 A_r &= [(82 \times 6) + (83 \times 1) + (84 \times 28) + (86 \times 8)] \\
 &\quad \div (6 + 1 + 28 + 8) \\
 &= 3615 \div 43 = 84.07
 \end{aligned}$$

 A_r 84.1


0 3 . 3

In a TOF mass spectrometer, ions are accelerated to the same kinetic energy (KE).

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}

In a TOF mass spectrometer, each $^{84}\text{Kr}^+$ ion is accelerated to a kinetic energy of 4.83×10^{-16} J and the time of flight is 1.72×10^{-5} s

Calculate the length, in metres, of the TOF flight tube.

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

[4 marks]

$$m \text{ of one ion} = (84 \div 1000) \div 6.022 \times 10^{23} = 1.395 \times 10^{-25} \text{ kg}$$

$$KE = \frac{1}{2}mv^2 \text{ so } v^2 = 2KE \div m$$

$$v^2 = (2 \times 4.83 \times 10^{-16}) \div 1.395 \times 10^{-25} = 6.925 \times 10^9$$

$$v = \sqrt{6.925 \times 10^9} = 83\,218 \text{ m s}^{-1}$$

$$d = v \times t = 83\,218 \times 1.72 \times 10^{-5} = 1.43 \text{ m}$$

Length of flight tube 1.43 m

8

Turn over for the next question

Turn over ►



0 4

This question is about enthalpy changes.

0 4 . 1

State the meaning of the term enthalpy change as applied to a chemical reaction.

[1 mark]

The heat energy change (measured) at constant pressure.

0 4 . 2

A student determines the enthalpy change for the reaction between calcium carbonate and hydrochloric acid.



The student follows this method:

- measure out 50 cm³ of 1.00 mol dm⁻³ aqueous hydrochloric acid using a measuring cylinder and pour the acid into a 100 cm³ glass beaker
- weigh out 2.50 g of solid calcium carbonate on a watch glass and tip the solid into the acid
- stir the mixture with a thermometer
- record the maximum temperature reached.

The student uses the data to determine a value for the enthalpy change.

Explain how the experimental method and use of apparatus can be improved to provide more accurate data.

Describe how this data from the improved method can be used to determine an accurate value for the temperature change.

[6 marks]

Improving the apparatus: measure the 50 cm³ of acid with a burette (or pipette) instead of a measuring cylinder, as it is more accurate.

Use a polystyrene cup with a lid instead of a glass beaker (or insulate the beaker) to reduce heat loss to the surroundings.

Reweigh the watch glass after tipping the calcium carbonate into the acid, so the exact mass of solid added is found by difference.

Use powdered calcium carbonate so the reaction is faster and the maximum temperature is reached more quickly, so less heat is lost.

Temperature measurements: measure and record the temperature of the



acid every minute for a few minutes (e.g. 4 minutes) before adding the solid, to get a steady initial temperature.

Add the calcium carbonate at a recorded time (e.g. at 4 minutes) and stir. Then measure and record the temperature at regular intervals (e.g. every minute) for at least 8 minutes after the addition, until a steady cooling trend is observed.

Determining ΔT : plot a graph of temperature (y-axis) against time (x-axis). Draw a best-fit line through the readings before addition and a best-fit line through the cooling readings after the maximum.

Extrapolate the cooling line back to the time of addition. ΔT is the difference between the extrapolated temperature and the initial temperature at the time of addition. This corrects for heat lost to the surroundings while the reaction was happening.

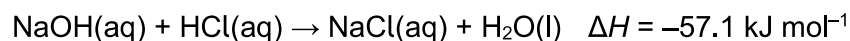
Question 4 continues on the next page

Turn over ►



0 4 . 3

In a different experiment 50.0 cm³ of 0.500 mol dm⁻³ aqueous hydrochloric acid are reacted with 50.0 cm³ of 0.500 mol dm⁻³ aqueous sodium hydroxide.



The initial temperature of each solution is 18.5 °C

Calculate the maximum final temperature of the reaction mixture.

Assume that the specific heat capacity of the reaction mixture, $c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$

Assume that the density of the reaction mixture = 1.00 g cm⁻³

[5 marks]

$$n(\text{HCl}) = n(\text{NaOH}) = 50.0 \times 0.500 \div 1000 = 0.0250 \text{ mol}$$

$$q = -\Delta H \times n = 57.1 \times 0.0250 = 1.4275 \text{ kJ} = 1427.5 \text{ J}$$

$$q = mc\Delta T, \text{ mass of mixture} = 100 \text{ cm}^3 \times 1.00 = 100 \text{ g}$$

$$\Delta T = q \div mc = 1427.5 \div (100 \times 4.18) = 3.4 \text{ }^\circ\text{C}$$

$$\text{Final temperature} = 18.5 + 3.4 = 21.9 \text{ }^\circ\text{C}$$

Final temperature 21.9 °C

0 4 . 4

Suggest how, without changing the apparatus, the experiment in Question 04.3 could be improved to reduce the percentage uncertainty in the temperature change.

[1 mark]

Increase the concentration of both solutions (using the same volumes),
so the temperature change is larger.



0 5

This question is about Group 2 elements and their compounds.

0 5 . 1

Explain why the melting point of magnesium is higher than the melting point of sodium.

[2 marks]

Mg²⁺ ions have a higher charge than Na⁺ ions and are smaller, and Mg has more delocalised electrons (two per atom) than Na.

So there is a stronger attraction between the positive ions and the delocalised sea of electrons, so magnesium has stronger metallic bonding which needs more energy to break.

0 5 . 2

Give an equation to show how magnesium is used as the reducing agent in the extraction of titanium.

Explain, in terms of oxidation states, why magnesium is the reducing agent.

[2 marks]

Equation



Explanation

The oxidation state of Mg increases from 0 to +2, so magnesium loses electrons (is oxidised), while titanium is reduced from +4 to 0 and gains these electrons. Mg donates electrons, so it is the reducing agent.

Question 5 continues on the next page

Turn over ►



0 5 . 3

State what is observed when dilute aqueous sodium hydroxide is added to separate solutions of magnesium chloride and barium chloride.

[2 marks]

Observation with magnesium chloride White precipitate forms

Observation with barium chloride No visible change (stays colourless)

6

0 6

This question is about shapes of molecules and ions.

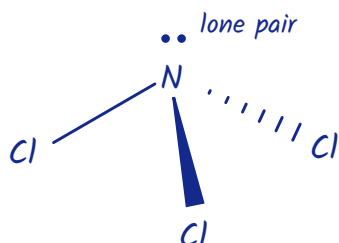
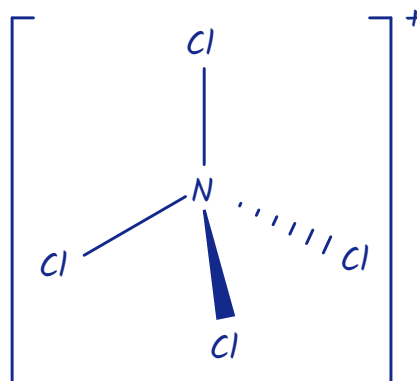
Draw the shape of NCl_3 and of NCl_4^+

Include any lone pairs of electrons that influence the shape.

Name the shape of NCl_3

State and explain the bond angle in NCl_4^+

[5 marks]

Shape of NCl_3 Shape of NCl_4^+ 

Name of shape of NCl_3 Pyramidal (trigonal pyramidal)

Bond angle in NCl_4^+ 109.5°

Explanation of bond angle in NCl_4^+ There are 4 bonding pairs and no lone pairs of electrons around the N.

The electron pairs repel equally and get as far apart as possible, so the shape is tetrahedral with a bond angle of 109.5° .

5

Turn over for the next question

Turn over ►



0 7

This question is about Group 7 elements and their compounds.

0 7 . 1

Chlorine is used to treat water even though it is toxic to humans.

Give **one** reason why water is treated with chlorine.

Explain why chlorine is added to water even though it is toxic.

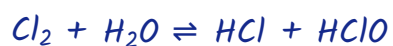
Give an equation for the reaction of chlorine with cold water.

[3 marks]

Reason To kill bacteria (microorganisms), sterilising / disinfecting the water.

Explanation The health benefit of killing harmful bacteria outweighs the risk, because chlorine is only used in very small quantities (low concentrations).

Equation



0 7 . 2

Solid sodium iodide reacts with concentrated sulfuric acid to form iodine and sulfur in a redox reaction.

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

Give a half-equation to show the conversion of sulfuric acid to sulfur.

Give an overall equation for this redox reaction.

Identify one other sulfur-containing reduction product formed when solid sodium iodide reacts with concentrated sulfuric acid.

[4 marks]

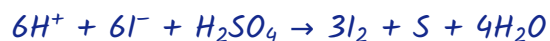
Half-equation for the conversion of iodide ions to iodine



Half-equation for the conversion of sulfuric acid to sulfur



Overall equation



Other sulfur-containing reduction product

Hydrogen sulfide, H_2S

Question 7 continues on the next page

Turn over ►



A student completes an experiment to determine the percentage by mass of sodium chloride in a mixture of sodium chloride and sodium iodide.

The student uses this method.

- 600 mg of the mixture are dissolved in water to form a solution.
- An excess of aqueous silver nitrate is added to the solution. This forms a precipitate containing silver chloride and silver iodide.
- Excess dilute ammonia solution is then added to the precipitate. The silver chloride dissolves.
- The silver iodide is filtered off from the solution, and is then washed and dried.

The mass of the silver iodide obtained is 315 mg

0 7 . 3 Silver nitrate is added to the solution.

Suggest why an excess is used.

[1 mark]

To make sure that all of the halide ions (both the chloride and the iodide ions) are precipitated, so they are all removed from the solution.

0 7 . 4 Calculate the amount, in moles, of silver iodide obtained.

$M_r(\text{AgI}) = 234.8$

[1 mark]

$$n(\text{AgI}) = \text{mass} \div M_r = 0.315 \text{ g} \div 234.8$$

$$= 1.34 \times 10^{-3} \text{ mol}$$

Amount of silver iodide 1.34×10^{-3} mol



07.5

Calculate, using your answer to Question **07.4**, the mass, in grams, of sodium iodide in the mixture.

$$M_r(\text{NaI}) = 149.9$$

[1 mark]

$$n(\text{NaI}) = n(\text{AgI}) = 1.34 \times 10^{-3} \text{ mol}$$

$$\text{mass of NaI} = 1.34 \times 10^{-3} \times 149.9 = 0.201 \text{ g}$$

Mass of sodium iodide 0.201 g

07.6

Calculate, using your answer to Question **07.5**, the percentage by mass of sodium chloride in the mixture.

[2 marks]

$$\text{mass of NaCl} = 600 - 201 = 399 \text{ mg}$$

$$\% \text{ NaCl} = (399 \div 600) \times 100 = 66.5\%$$

Percentage of sodium chloride 66.5%

12

Turn over for the next question

Turn over ►



0 8

This question is about a volatile liquid, **A**.

0 8 . 1

A student does an experiment to determine the relative molecular mass (M_r) of liquid **A** using the apparatus shown in **Figure 2**.

The student injects a sample of **A** into a gas syringe in an oven.

At the temperature of the oven, liquid **A** vaporises.

Figure 2

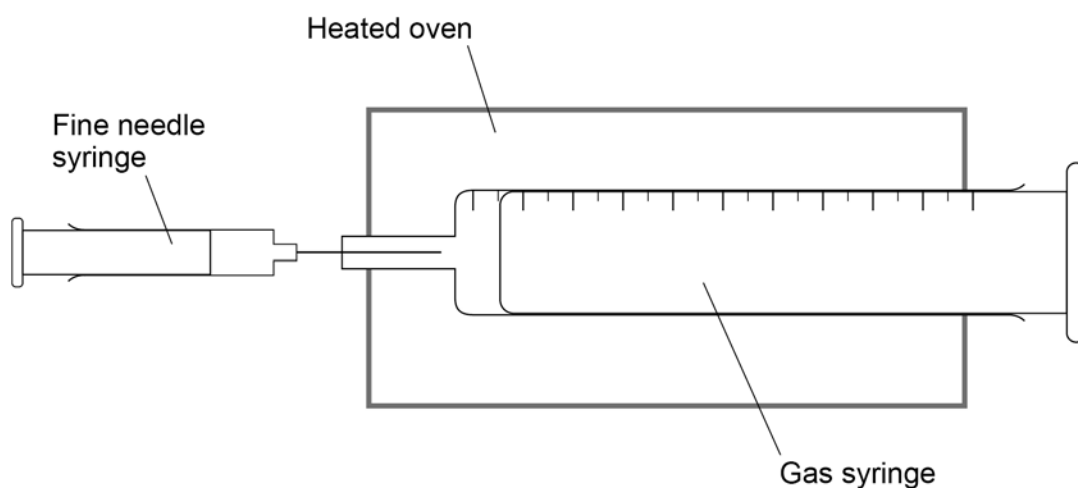


Table 3 shows the student's results.

Table 3

Mass of fine needle syringe and contents before injecting	11.295 g
Mass of fine needle syringe and contents after injecting	10.835 g
Volume reading on gas syringe before injecting	0.0 cm ³
Volume reading on gas syringe after injecting	178.0 cm ³
Pressure of gas in syringe	100 kPa
Temperature of oven	120 °C



Calculate the M_r of **A**.

Give your answer to 3 significant figures.

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

[4 marks]

$$pV = nRT \text{ so } n = pV \div RT$$

$$p = 100 \text{ kPa} = 100\,000 \text{ Pa}; \quad V = 178.0 \text{ cm}^3 = 178.0 \times 10^{-6} \text{ m}^3$$

$$T = 120 + 273 = 393 \text{ K}$$

$$n = (100\,000 \times 178.0 \times 10^{-6}) \div (8.31 \times 393) = 5.45 \times 10^{-3} \text{ mol}$$

$$\text{mass of A} = 11.295 - 10.835 = 0.460 \text{ g}$$

$$M_r = \text{mass} \div n = 0.460 \div 5.45 \times 10^{-3} = 84.4$$

M_r 84.4

0 8 . 2

The student noticed that some of the liquid injected into the gas syringe did **not** vaporise.

Explain the effect that this has on the M_r calculated by the student.

[2 marks]

The calculated M_r would be greater (higher) than the actual value.

The mass recorded would be higher than the mass of gas actually in the syringe, and a lower volume of gas would be recorded, so fewer moles are calculated. $M_r = \text{mass} \div \text{moles}$, so dividing by too small a number of moles gives too large an M_r .

Question 8 continues on the next page

Turn over ►



Table 3 is repeated here.

Table 3

Mass of fine needle syringe and contents before injecting	11.295 g
Mass of fine needle syringe and contents after injecting	10.835 g
Volume reading on gas syringe before injecting	0.0 cm ³
Volume reading on gas syringe after injecting	178.0 cm ³
Pressure of gas in syringe	100 kPa
Temperature of oven	120 °C

0 8 . 3

Each reading on the balance used to record the mass of the fine needle syringe and contents had an uncertainty of ± 0.001 g

Calculate the percentage uncertainty in the mass of liquid **A** injected in this experiment.

[1 mark]

$$\text{mass of A} = 11.295 - 10.835 = 0.460 \text{ g (two readings)}$$

$$\% \text{ uncertainty} = (2 \times 0.001) \div 0.460 \times 100$$

$$= 0.435\%$$

Percentage uncertainty 0.435%

7



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.

0 9

Which atom has the smallest number of neutrons?

[1 mark]

A ^3H ☐B ^4He ☐C ^5He ☐D ^4Li ☒

1 0

Which species contains bonds that have different polarities?

[1 mark]

A NH_4^+ ☐B CCl_4 ☐C CH_3Cl ☒D H_3O^+ ☐

Turn over ►



1 1

Which compound has hydrogen bonding?

[1 mark]**A** NaH☐**B** NH₃☒**C** HI☐**D** SiH₄☐**1 2**

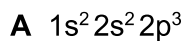
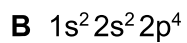
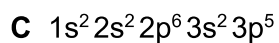
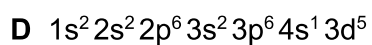
Which reaction has an enthalpy change equal to the standard enthalpy of formation of lithium fluoride?

[1 mark]**A** $\text{Li(g)} + \frac{1}{2}\text{F}_2\text{(g)} \rightarrow \text{LiF(s)}$ ☐**B** $\text{Li}^+\text{(g)} + \text{F}^-\text{(g)} \rightarrow \text{LiF(s)}$ ☐**C** $\text{Li}^+\text{(aq)} + \text{F}^-\text{(aq)} \rightarrow \text{LiF(s)}$ ☐**D** $\text{Li(s)} + \frac{1}{2}\text{F}_2\text{(g)} \rightarrow \text{LiF(s)}$ ☒**1 3**NO₂⁻ ions can be reduced in acidic solution to NO
How many electrons are gained when each NO₂⁻ ion is reduced?**[1 mark]****A** 1☒**B** 2☐**C** 3☐**D** 4☐

1 4

Which is the electron configuration of an atom with **only two** unpaired electrons?

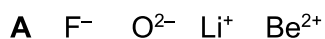
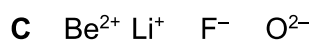
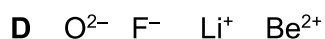
[1 mark]

☐☒☐☐

1 5

Which represents the correct order of increasing radius of the ions?

[1 mark]

☐☐☒☐

1 6

Which compound contains a co-ordinate bond?

[1 mark]

☐☐☐☒

Turn over ►



1 7

Which property increases down Group 7?

[1 mark]**A** ability to oxidise a given reducing agent☐**B** boiling point☒**C** electronegativity☐**D** first ionisation energy☐**1 8**

Which of these elements has the highest melting point?

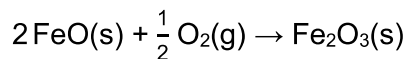
[1 mark]**A** Argon☐**B** Chlorine☐**C** Silicon☒**D** Sulfur☐**1 9**Which statement is **not** always correct for a reaction at equilibrium? $\text{reactants} \rightleftharpoons \text{products}$ **[1 mark]****A** The concentrations of the reactants and products are equal.☒**B** The equilibrium can be achieved starting from the reactants.☐**C** The equilibrium can be achieved starting from the products.☐**D** The rate of the forward reaction is equal to the rate of the reverse reaction.☐

2 0

Two reactions of iron with oxygen are shown.



What is the enthalpy change, in kJ mol^{-1} , for this reaction?

**[1 mark]****A** +550☐**B** -278☒**C** -1094☐**D** -1372☐**2 1**

Which compound contains chlorine in an oxidation state of +1?

[1 mark]**A** Cl_2O ☒**B** KClO_3 ☐**C** ClF_3 ☐**D** CCl_4 ☐

Turn over for the next question

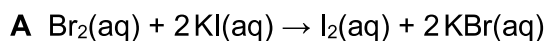
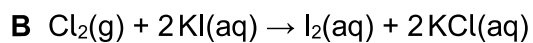
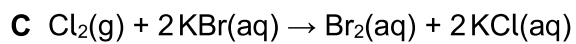
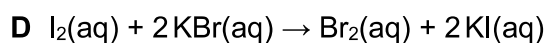
Turn over ►



2	2
---	---

Which equation shows a redox reaction that does **not** occur?

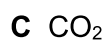
[1 mark]

☐☐☐☒

2	3
---	---

Which molecule has a permanent dipole?

[1 mark]

☐☐☐☒

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]

*Do not write
outside the
box*

[illegible]

[illegible]

[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 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 © 2020 AQA and its licensors. All rights reserved.



3 2



2 0 6 A 7 4 0 4 / 1