

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 _____

A-level CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 5 June 2018

Afternoon

Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Booklet, 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 the 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.
- 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 105.

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



J U N 1 8 7 4 0 5 1 0 1

Answer **all** questions in the spaces provided.

0 1

This question is about lattice enthalpies.

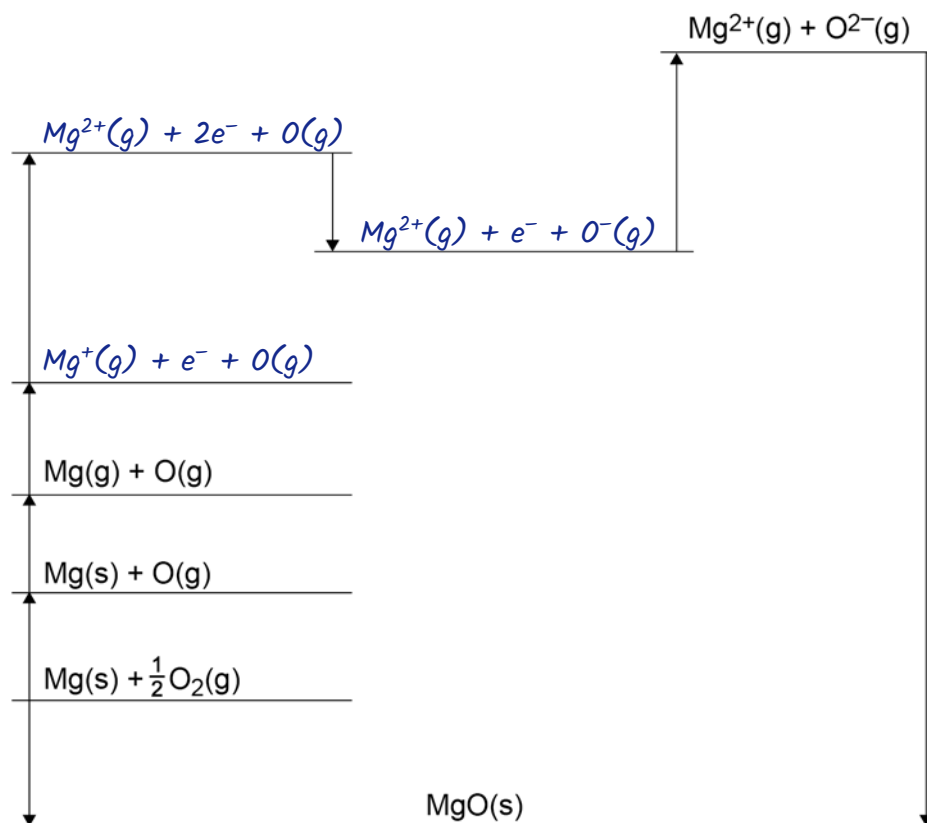
0 1 . 1

Figure 1 shows a Born–Haber cycle for the formation of magnesium oxide.

Complete **Figure 1** by writing the missing symbols on the appropriate energy levels.

[3 marks]

Figure 1



0 1 . 2 Table 1 contains some thermodynamic data.

Table 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation for magnesium oxide	-602
Enthalpy of atomisation for magnesium	+150
First ionisation energy for magnesium	+736
Second ionisation energy for magnesium	+1450
Bond dissociation enthalpy for oxygen	+496
First electron affinity for oxygen	-142
Second electron affinity for oxygen	+844

Calculate a value for the enthalpy of lattice formation for magnesium oxide.

[3 marks]

$$\Delta H_f(\text{MgO}) = \Delta H_{at}(\text{Mg}) + \frac{1}{2}\Delta H_{BDE}(\text{O}_2) + IE_1 + IE_2 + EA_1 + EA_2 + \Delta H_{LF}$$

$$-602 = 150 + (\frac{1}{2} \times 496) + 736 + 1450 + (-142) + 844 + \Delta H_{LF}$$

$$-602 = 3286 + \Delta H_{LF}$$

$$\Delta H_{LF} = -602 - 3286 = -3888 \text{ kJ mol}^{-1}$$

Enthalpy of lattice formation -3888 kJ mol^{-1}

6

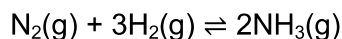
Turn over for the next question

Turn over ►



0 2

Nitrogen and hydrogen were mixed in a 1:3 mole ratio and left to reach equilibrium in a flask at a temperature of 550 K. The equation for the reaction between nitrogen and hydrogen is shown.



0 2 . 1

When equilibrium was reached, the total pressure in the flask was 150 kPa and the mole fraction of $\text{NH}_3(\text{g})$ in the mixture was 0.80

Calculate the partial pressure of each gas in this equilibrium mixture.

[3 marks]

mole fraction $\text{NH}_3 = 0.80$, so $\text{N}_2 + \text{H}_2 = 0.20$, in a 1:3 ratio

mole fraction $\text{N}_2 = 0.25 \times 0.20 = 0.05$, $\text{H}_2 = 0.75 \times 0.20 = 0.15$

pp = mole fraction $\times$ total pressure (150 kPa)

Partial pressure of nitrogen $0.05 \times 150 = 7.5$ kPa

Partial pressure of hydrogen $0.15 \times 150 = 22.5$ kPa

Partial pressure of ammonia $0.80 \times 150 = 120$ kPa

0 2 . 2

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

[1 mark]

$$K_p = \frac{(p\text{NH}_3)^2}{(p\text{N}_2) \times (p\text{H}_2)^3}$$



0 2 . 3

In a different equilibrium mixture, under different conditions, the partial pressures of the gases are shown in **Table 2**.

Table 2

Gas	Partial pressure / kPa
N ₂	1.20×10^2
H ₂	1.50×10^2
NH ₃	1.10×10^3

Calculate the value of the equilibrium constant (K_p) for this reaction and give its units. **[2 marks]**

$$K_p = \frac{(1.10 \times 10^3)^2}{(1.20 \times 10^2) \times (1.50 \times 10^2)^3}$$

$$= 1.21 \times 10^6 \div 4.05 \times 10^8 = 2.99 \times 10^{-3}$$

$$\text{units: } \text{kPa}^2 \div (\text{kPa} \times \text{kPa}^3) = \text{kPa}^{-2}$$

$$K_p \underline{2.99 \times 10^{-3}} \quad \text{Units } \underline{\text{kPa}^{-2}}$$

0 2 . 4

The enthalpy change for the reaction is -92 kJ mol^{-1}

State the effect, if any, of an increase in temperature on the value of K_p for this reaction.

Justify your answer.

[3 marks]

Effect on K_p Decreases

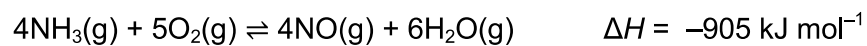
Justification The forward reaction is exothermic (ΔH is negative), so
when the temperature increases the equilibrium shifts to the left, in the
endothermic direction, to reduce the temperature (oppose the increase in
temperature). So the partial pressure of NH₃ falls and K_p decreases.

Turn over ►



0 3

The equation for the reaction between ammonia and oxygen is shown.



Some standard entropies are given in **Table 3**.

Table 3

Gas	$S^\circ / \text{J K}^{-1} \text{mol}^{-1}$
$\text{NH}_3(\text{g})$	193
$\text{O}_2(\text{g})$	205
$\text{NO}(\text{g})$	211
$\text{H}_2\text{O}(\text{g})$	189

0 3 . 1

Calculate the entropy change for the reaction between ammonia and oxygen.

[2 marks]

$$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$$

$$= [(4 \times 211) + (6 \times 189)] - [(4 \times 193) + (5 \times 205)]$$

$$= 1978 - 1797$$

$$= +181 \text{ J K}^{-1} \text{mol}^{-1}$$

Entropy change +181 J K⁻¹ mol⁻¹



03.2

Calculate a value for the Gibbs free-energy change (ΔG), in kJ mol^{-1} , for the reaction between ammonia and oxygen at 600°C

(If you were unable to obtain an answer to Question 03.1, you should assume that the entropy change is $211 \text{ J K}^{-1} \text{ mol}^{-1}$. This is **not** the correct answer.)

[2 marks]

$$\Delta G = \Delta H - T\Delta S, \quad T = 600 + 273 = 873 \text{ K}, \quad \Delta S = 0.181 \text{ kJ K}^{-1} \text{ mol}^{-1}$$

$$\Delta G = -905 - (873 \times 181 \times 10^{-3}) = -905 - 158 = -1063$$

$$\Delta G \underline{\hspace{1cm} -1063 \hspace{1cm}} \text{ kJ mol}^{-1}$$

03.3

The reaction between ammonia and oxygen was carried out at a higher temperature.

Explain how this change affects the value of ΔG for the reaction.

[2 marks]

ΔG becomes more negative (less positive).

This is because the entropy change is positive, so as T increases the

$T\Delta S$ term gets bigger, so $-T\Delta S$ becomes more negative while ΔH stays

the same.

Question 3 continues on the next page

Turn over ►



0 3 . 4

Platinum acts as a heterogeneous catalyst in the reaction between ammonia and oxygen. It provides an alternative reaction route with a lower activation energy.

Describe the stages of this alternative route.

[3 marks]

The reactants (NH_3 and O_2) are adsorbed onto the platinum surface at the active sites.

Bonds in the reactants are weakened / broken, and the reaction occurs on the surface, with new bonds made on the surface.

The products (NO and H_2O) are then desorbed from the platinum surface, freeing the active sites.

0 3 . 5

Deduce the change in oxidation state of nitrogen, when NH_3 is oxidised to NO

[1 mark]

-3 to +2 (an increase of 5)

0 3 . 6

When ammonia reacts with oxygen, nitrous oxide (N_2O) can be produced instead of NO

Give an equation for this reaction.

[1 mark]



0	4
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This question is about s-block metals.

0	4	.	1
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Give the full electron configuration for the calcium ion, Ca^{2+}

[1 mark]



0	4	.	2
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Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

[2 marks]

*In Ca^+ the electron removed is from the 4s orbital (4th energy level),
whereas in K^+ it is removed from the 3p orbital (3rd energy level).
So the electron removed from Ca^+ is further from the nucleus and
experiences more shielding, so it is less strongly attracted and less
energy is needed.*

0	4	.	3
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Identify the s-block metal that has the highest first ionisation energy.

[1 mark]

Beryllium (Be)

0	4	.	4
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Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

[1 mark]



Question 4 continues on the next page

Turn over ►



0 4 . 5

A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.

The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.

Show by calculation which reagent is in excess.

Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

[3 marks]

Ionic equation $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$

$$n(\text{BaCl}_2) = (6 \div 1000) \times 0.25 = 1.5 \times 10^{-3} \text{ mol}$$

$$n(\text{Na}_2\text{SO}_4) = (8 \div 1000) \times 0.15 = 1.2 \times 10^{-3} \text{ mol}$$

1:1 ratio, so BaCl_2 is in excess by $3 \times 10^{-4} \text{ mol}$

Reagent in excess Barium chloride (BaCl_2)

Total volume of other reagent 10 cm^3 of $0.15 \text{ mol dm}^{-3} \text{ Na}_2\text{SO}_4$

Volume of Na_2SO_4 needed to react with all $1.5 \times 10^{-3} \text{ mol BaCl}_2 = 1.5 \times$

$10^{-3} \div 0.15 = 0.010 \text{ dm}^3 = 10 \text{ cm}^3$ of sodium sulfate solution, so the

filtrate contains only NaCl .



0 4 . 6

A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr , ^{87}Sr and ^{88}Sr

In this sample, the ratio of abundances of the isotopes ^{86}Sr : ^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.

Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

[4 marks]

Why isotopes of strontium have identical chemical properties

All the isotopes have the same electron configuration (the same number of electrons and of outer shell electrons), and chemical properties depend on the electrons.

Let abundance of ^{86}Sr = x % and ^{87}Sr = x %, so ^{88}Sr = (100 - 2x) %

$$[86x + 87x + 88(100 - 2x)] \div 100 = 87.7$$

$$173x + 8800 - 176x = 8770$$

$$3x = 30, \text{ so } x = 10 \%$$

$$\text{abundance of } ^{88}\text{Sr} = 100 - (2 \times 10) = 80.0 \%$$

Percentage abundance of ^{88}Sr 80.0 %

0 4 . 7

A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba , ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

[1 mark]

$^{138}\text{Ba}^+$

Turn over ►



0 4 . 8

A $^{137}\text{Ba}^+$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of $3.65 \times 10^{-16} \text{ J}$
This ion takes $2.71 \times 10^{-5} \text{ s}$ to reach the detector.

$$KE = \frac{1}{2}mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{speed (m s}^{-1}\text{)}$$

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

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

[5 marks]

$$\text{mass of one ion, } m = (137 \times 10^{-3}) \div (6.022 \times 10^{23}) = 2.275 \times 10^{-25} \text{ kg}$$

$$v^2 = 2KE \div m = (2 \times 3.65 \times 10^{-16}) \div (2.275 \times 10^{-25}) = 3.2088 \times 10^9$$

$$v = \sqrt{2KE \div m} = \sqrt{3.2088 \times 10^9} = 5.6646 \times 10^4 \text{ m s}^{-1}$$

$$v = d \div t, \text{ so } d = v \times t$$

$$d = 5.6646 \times 10^4 \times 2.71 \times 10^{-5} = 1.535 \text{ m}$$

$$= 1.54 \text{ m (3 s.f.)}$$

Length of flight tube 1.54 m

18



0 5

Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

0 5 . 1

State the meaning of the term strong acid.

[1 mark]

An acid that completely dissociates (ionises) in aqueous solution to form H^+ ions.

0 5 . 2

In an experiment, 10.35 cm^3 of $0.100 \text{ mol dm}^{-3}$ hydrochloric acid are added to 25.0 cm^3 of $0.150 \text{ mol dm}^{-3}$ barium hydroxide solution.

Calculate the pH of the solution that forms at 30°C

$K_w = 1.47 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 30°C

Give your answer to 2 decimal places.

[6 marks]

$$n(\text{HCl}) = 10.35 \times 10^{-3} \times 0.100 = 1.035 \times 10^{-3} \text{ mol}$$

$$n(\text{Ba}(\text{OH})_2) = 25.0 \times 10^{-3} \times 0.150 = 3.75 \times 10^{-3} \text{ mol}$$

$$n(\text{OH}^-) = 2 \times 3.75 \times 10^{-3} = 7.50 \times 10^{-3} \text{ mol}$$

$$\text{excess } n(\text{OH}^-) = 7.50 \times 10^{-3} - 1.035 \times 10^{-3} = 6.465 \times 10^{-3} \text{ mol}$$

$$\text{total volume} = 10.35 + 25.0 = 35.35 \text{ cm}^3$$

$$[\text{OH}^-] = 6.465 \times 10^{-3} \div 35.35 \times 10^{-3} = 0.182885 \text{ mol dm}^{-3}$$

$$[\text{H}^+] = K_w \div [\text{OH}^-] = 1.47 \times 10^{-14} \div 0.182885$$

$$= 8.0378 \times 10^{-14} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(8.0378 \times 10^{-14}) = 13.09$$

pH 13.09

Turn over ►



0 5 . 3 The pH of water at 30 °C is 6.92

Give the reason why water is neutral at this temperature.

[1 mark]

Because $[H^+] = [OH^-]$ in pure water.

0 5 . 4 Identify the oxide that could react with water to form a solution with pH = 2

Tick (✓) **one** box.

[1 mark]

Al₂O₃

☐

Na₂O

☐

SiO₂

☐

SO₂

☒

0 5 . 5

Give the expression for the acid dissociation constant (K_a) for ethanoic acid (CH_3COOH).

[1 mark]

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

0 5 . 6

A buffer solution contains 0.025 mol of sodium ethanoate dissolved in 500 cm³ of 0.0700 mol dm⁻³ ethanoic acid at 25 °C
A sample of 5.00 cm³ of 2.00 mol dm⁻³ hydrochloric acid is added to this buffer solution.

Calculate the pH of the solution formed.

For ethanoic acid, $K_a = 1.76 \times 10^{-5}$ mol dm⁻³ at 25 °C

[5 marks]

$$n(\text{HCl}) \text{ added} = 5.00 \times 10^{-3} \times 2.00 = 0.0100 \text{ mol}$$

$$n(\text{CH}_3\text{COOH}) = 500 \times 10^{-3} \times 0.0700 = 0.0350 \text{ mol}$$



$$n(\text{CH}_3\text{COO}^-) = 0.025 - 0.0100 = 0.015 \text{ mol}$$

$$n(\text{CH}_3\text{COOH}) = 0.0350 + 0.0100 = 0.045 \text{ mol}$$

$$[\text{H}^+] = K_a \times [\text{CH}_3\text{COOH}] \div [\text{CH}_3\text{COO}^-] \text{ (volumes cancel)}$$

$$= 1.76 \times 10^{-5} \times 0.045 \div 0.015 = 5.28 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(5.28 \times 10^{-5}) = 4.28$$

pH 4.28

15

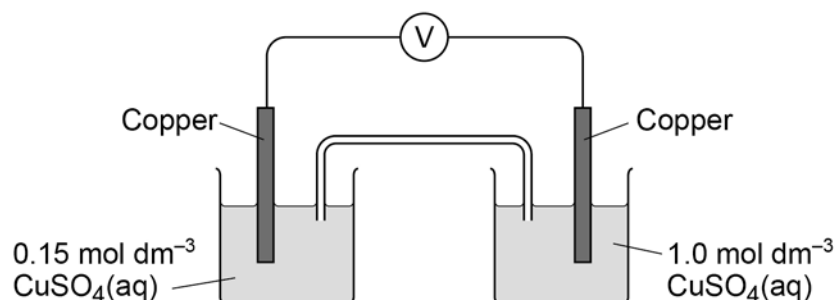
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0 6

A student set up the cell shown in **Figure 2**.

Figure 2



The student recorded an initial voltage of +0.16 V at 25 °C

0 6 . 1

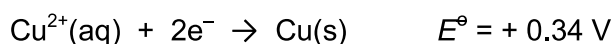
Explain how the salt bridge provides an electrical connection between the two solutions.

[1 mark]

The salt bridge contains mobile ions (e.g. K^+ and NO_3^-), which move through it between the two solutions, carrying the charge and completing the circuit.

0 6 . 2

The standard electrode potential for the Cu^{2+}/Cu electrode is



Calculate the electrode potential of the left-hand electrode in **Figure 2**.

[1 mark]

Electrode potential +0.18 V

0 6 . 3

Both electrodes contain a strip of copper metal in a solution of aqueous Cu^{2+} ions.

State why the left-hand electrode does **not** have an electrode potential of +0.34 V

[1 mark]

Because the concentration of Cu^{2+} ions is not 1.0 mol dm^{-3} (it is 0.15 mol dm^{-3}), so it is not a standard electrode.



0 6 . 4

Give the conventional representation for the cell in **Figure 2**.
Include all state symbols.

[1 mark]



0 6 . 5

When the voltmeter is replaced by a bulb, the EMF of the cell in **Figure 2** decreases over time to 0 V

Suggest how the concentration of copper(II) ions in the left-hand electrode changes when the bulb is alight.

Give **one** reason why the EMF of the cell decreases to 0 V

[2 marks]

Change in concentration of copper(II) ions in the left-hand electrode

The concentration of Cu^{2+} ions increases, because Cu is oxidised to Cu^{2+} at the left-hand electrode.

Reason why the EMF decreases to 0 V *The concentrations of Cu^{2+} ions in the two solutions become equal (the same), so the two electrode potentials become the same and there is no potential difference.*

6

Turn over for the next question

Turn over ►



0 7 . 1

When anhydrous aluminium chloride reacts with water, solution **Y** is formed that contains a complex aluminium ion, **Z**, and chloride ions.

Give an equation for this reaction.

[1 mark]



0 7 . 2

Give an equation to show how the complex ion **Z** can act as a Brønsted–Lowry acid with water.

[1 mark]



0 7 . 3

Describe **two** observations you would make when an excess of sodium carbonate solution is added to solution **Y**.

Give an equation for the reaction. In your equation, include the formula of each complex aluminium species.

[3 marks]

Observation 1 A white precipitate forms.

Observation 2 Effervescence (bubbles of gas, CO₂).

Equation



07.4

Aqueous potassium hydroxide is added, until in excess, to solution Y.

Describe **two** observations you would make.

For each observation give an equation for the reaction that occurs.

In your equations, include the formula of each complex aluminium species.

[4 marks]

Observation 1 A white precipitate forms.

Equation 1



Observation 2 The white precipitate dissolves in excess KOH to form a colourless solution.

Equation 2



9

Turn over for the next question

Turn over ►



0 8

This question is about sodium and some of its compounds.

0 8 . 1

Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

[6 marks]

Sodium has metallic bonding. It is a giant metallic lattice of positive Na^+ ions surrounded by a sea of delocalised electrons, and the bonding is the electrostatic attraction between the positive ions and the delocalised electrons. Each Na atom only donates one electron and Na^+ is relatively large, so this attraction is relatively weak.

Sodium bromide and sodium iodide have ionic bonding. They are giant ionic lattices, in which there are strong electrostatic attractions between oppositely charged ions (Na^+ and Br^- , or Na^+ and I^-) in all directions throughout the lattice.

NaBr has a higher melting point than Na because the ionic bonds in NaBr are stronger than the metallic bonds in Na: the attraction between the oppositely charged ions is stronger than the attraction between the Na^+ ions and the delocalised electrons, so more energy is needed to overcome it.

NaBr has a higher melting point than NaI because the Br^- ion is smaller than the I^- ion (both have the same charge). So the Br^- ion can get closer to the Na^+ ions, and there is stronger attraction between the oppositely charged ions in NaBr than in NaI . More energy is needed to break the ionic bonds in the NaBr lattice.

So the stronger the bonding in the giant lattice, the higher the melting point, giving the order $\text{NaBr} > \text{NaI} > \text{Na}$.



[illegible]

0 8 . 2

When 250 mg of sodium were added to 500 cm³ of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.

Calculate the volume, in cm³, of the gas formed at 101 kPa

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

[6 marks]

Equation $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$

$$\text{mass of Na} = 250 \text{ mg} = 0.250 \text{ g}$$

$$n(\text{Na}) = 0.250 \div 23.0 = 0.0109 \text{ mol } (1.087 \times 10^{-2})$$

$$n(\text{H}_2) = 0.01087 \div 2 = 5.435 \times 10^{-3} \text{ mol}$$

$$T = 25 + 273 = 298 \text{ K}, \quad P = 101 \text{ kPa} = 101\,000 \text{ Pa}$$

$$pV = nRT, \text{ so } V = nRT \div p$$

$$V = (5.435 \times 10^{-3} \times 8.31 \times 298) \div 101\,000$$

$$= 1.33 \times 10^{-4} \text{ m}^3$$

$$= 1.33 \times 10^{-4} \times 10^6 = 133 \text{ cm}^3$$

Volume 133 cm³

0 8 . 3

Calculate the concentration, in mol dm⁻³, of sodium ions in the solution produced in the reaction in Question 08.2.

[1 mark]

$$[\text{Na}^+] = 0.01087 \div (500 \times 10^{-3}) = 0.0217 \text{ mol dm}^{-3}$$

Concentration 0.0217 mol dm⁻³



0 8 . 4

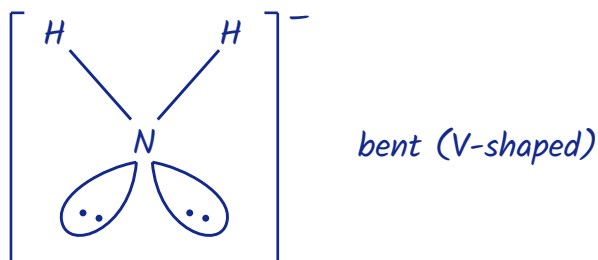
Sodium reacts with ammonia to form the compound NaNH_2 that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

Predict the bond angle.
Justify your prediction.

[4 marks]

Shape

Bond angle 104.5°

Justification There are 4 electron pairs around N (2 bonding pairs and 2 lone pairs), and these electron pairs repel each other to be as far apart as possible.

Lone pair/lone pair repulsion is greater than lone pair/bonding pair repulsion, which is greater than bonding pair/bonding pair repulsion, so the bond angle is reduced from 109.5° to 104.5°.

17

Turn over for the next question

Turn over ►



0 9

This question is about vanadium compounds and ions.

0 9 . 1

Use data from **Table 4** to identify the species that can be used to reduce VO_2^+ ions to VO^{2+} in aqueous solution and no further.
Explain your answer.

Table 4

Electrode half-equation	$E^\ominus / \text{V}$
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00
$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.34
$\text{Cl}_2(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76

[2 marks]

Reagent Fe^{2+} (e.g. iron(II) sulfate solution)

Explanation $E^\ominus$ for $\text{Fe}^{3+}/\text{Fe}^{2+}$ (+0.77 V) is less positive than $E^\ominus$ for $\text{VO}_2^+/\text{VO}^{2+}$ (+1.00 V), so Fe^{2+} reduces VO_2^+ , but more positive than $E^\ominus$ for $\text{VO}^{2+}/\text{V}^{3+}$ (+0.34 V), so it cannot reduce VO^{2+} further.

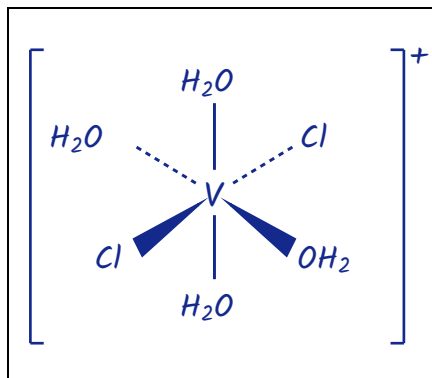
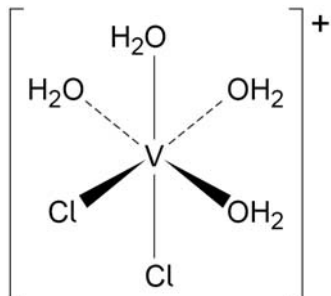
0 9 . 2

Give the oxidation state of vanadium in $[\text{VO}(\text{H}_2\text{O})_5]^{2+}$ **[1 mark]**+4

0 9 . 3 The $[\text{V}(\text{H}_2\text{O})_4\text{Cl}_2]^+$ ion exists as two isomers. One isomer is shown.

Draw the structure of the other isomer and state the type of isomerism.

[2 marks]



Type of isomerism Cis-trans (geometric / E-Z stereo) isomerism

0 9 . 4 Heating NH_4VO_3 produces vanadium(V) oxide, water and one other product.

Give an equation for the reaction.

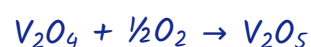
[1 mark]



0 9 . 5 Vanadium(V) oxide is the catalyst used in the manufacture of sulfur trioxide.

Give **two** equations to show how the catalyst is used and regenerated.

[1 mark]



Turn over ►



1 0 . 1

A student added 627 mg of hydrated sodium carbonate ($\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$) to 200 cm^3 of $0.250 \text{ mol dm}^{-3}$ hydrochloric acid in a beaker and stirred the mixture. After the reaction was complete, the resulting solution was transferred to a volumetric flask, made up to 250 cm^3 with deionised water and mixed thoroughly. Several 25.0 cm^3 portions of the resulting solution were titrated with $0.150 \text{ mol dm}^{-3}$ aqueous sodium hydroxide. The mean titre was 26.60 cm^3 of aqueous sodium hydroxide.

Calculate the value of x in $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$

Show your working.

Give your answer as an integer.

[7 marks]

$$n(\text{HCl}) \text{ added} = 200 \times 10^{-3} \times 0.250 = 0.0500 \text{ mol}$$

$$n(\text{NaOH}) \text{ in titration} = 26.60 \times 10^{-3} \times 0.150 = 3.99 \times 10^{-3} \text{ mol}$$

$$\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}, \text{ so } n(\text{HCl}) \text{ in } 25.0 \text{ cm}^3 = 3.99 \times 10^{-3} \text{ mol}$$

$$\text{excess HCl in } 250 \text{ cm}^3 = 3.99 \times 10^{-3} \times 10 = 3.99 \times 10^{-2} \text{ mol}$$

$$n(\text{HCl}) \text{ reacted with } \text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O} = 0.0500 - 0.0399 = 0.0101 \text{ mol}$$



$$n(\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}) = 0.0101 \div 2 = 5.05 \times 10^{-3} \text{ mol}$$

$$\text{mass} = 627 \text{ mg} = 0.627 \text{ g}$$

$$M_r = 0.627 \div 5.05 \times 10^{-3} = 124.2$$

$$M_r(\text{Na}_2\text{CO}_3) = 106.0, \text{ so } x\text{H}_2\text{O} = 124.2 - 106.0 = 18.2$$

$$x = 18.2 \div 18.0 = 1.01, \text{ so } x = 1$$



Value of x 1

$\frac{\quad}{7}$

END OF QUESTIONS

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