OXFORD

INTERNATIONAL
AQA EXAMINATIONS

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I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert
- 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. Use pencil only for drawing.
- 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.
- All working must be shown.
- 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).
- 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.

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

Do not write outside the box

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

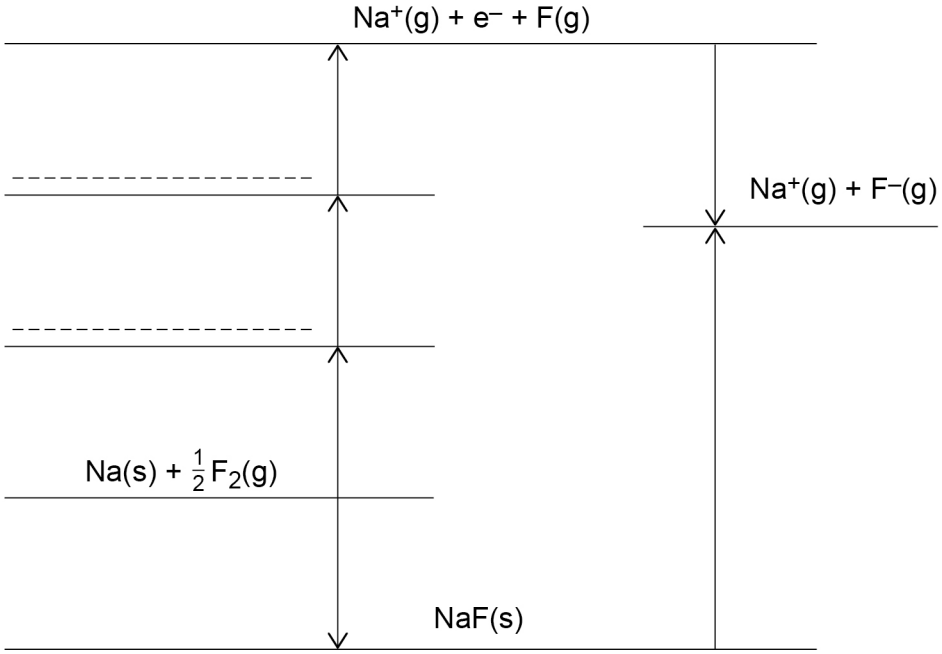
0 1 This question is about sodium fluoride.

0 1 . 1 **Figure 1** shows an incomplete Born–Haber cycle for the formation of sodium fluoride.

Complete **Figure 1** by writing the formulas, including state symbols, of the appropriate species on the two dotted lines.

[2 marks]

Figure 1



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0 1 . 2 **Table 1** shows some thermodynamic data.

Table 1

	$\Delta H^{\ominus}$ / kJ mol^{-1}
$Na(s) \rightarrow Na(g)$	+109
$Na(g) \rightarrow Na^{+}(g) + e^{-}$	+494
$F_2(g) \rightarrow 2F(g)$	+158
$F(g) + e^{-} \rightarrow F^{-}(g)$	–348
$NaF(s) \rightarrow Na^{+}(g) + F^{-}(g)$	+902

Use **Figure 1** and the values given in **Table 1** to calculate a value for the enthalpy of formation of sodium fluoride.

[2 marks]

Enthalpy of formation _____ kJ mol^{-1}

0 1 . 3 State why the theoretical enthalpy of lattice dissociation for sodium fluoride in a data book is less endothermic than the experimental value calculated using a Born–Haber cycle.

[1 mark]

_____

_____

Turn over ►

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0 1 . 4 How does the value for the enthalpy of lattice dissociation for sodium chloride compare with the value for the enthalpy of lattice dissociation for sodium fluoride?

[1 mark]

Tick (✓) **one** box.

The value for sodium chloride is more endothermic. ☐

The values for sodium chloride and for sodium fluoride are the same. ☐

The value for sodium chloride is less endothermic. ☐

0 1 . 5 An equation for the process that happens when sodium fluoride dissolves in water is shown.

$$NaF(s) + aq \rightarrow Na^+(aq) + F^-(aq)$$

Table 2 shows some thermodynamic data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation for NaF(s)	+902
Enthalpy of hydration for $Na^+(g)$	–406
Enthalpy of hydration for $F^-(g)$	–506

Use the data in **Table 2** to calculate the enthalpy of solution for sodium fluoride.

[2 marks]

Enthalpy of solution _____ kJ mol^{-1}

8

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 2 Lithium carbonate decomposes as shown.

$$Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$$

The Gibbs free-energy change, ΔG, varies with temperature as shown

$$\Delta G = \Delta H - T\Delta S$$

Table 3 shows how the value for ΔG for the decomposition of lithium carbonate varies with temperature.

Table 3

***T* / K**	**ΔG / kJ mol^{-1}**
300	177
600	128
900	80
1200	31
1500	–18

0 2 . 1 Use the data in **Table 3** and the grid on page 7 to plot a graph of ΔG (*y*-axis) against temperature.

[2 marks]

0 2 . 2 Use the gradient of your graph to deduce the entropy change (ΔS) for this reaction.

State the units.

[3 marks]

ΔS _____

Units _____

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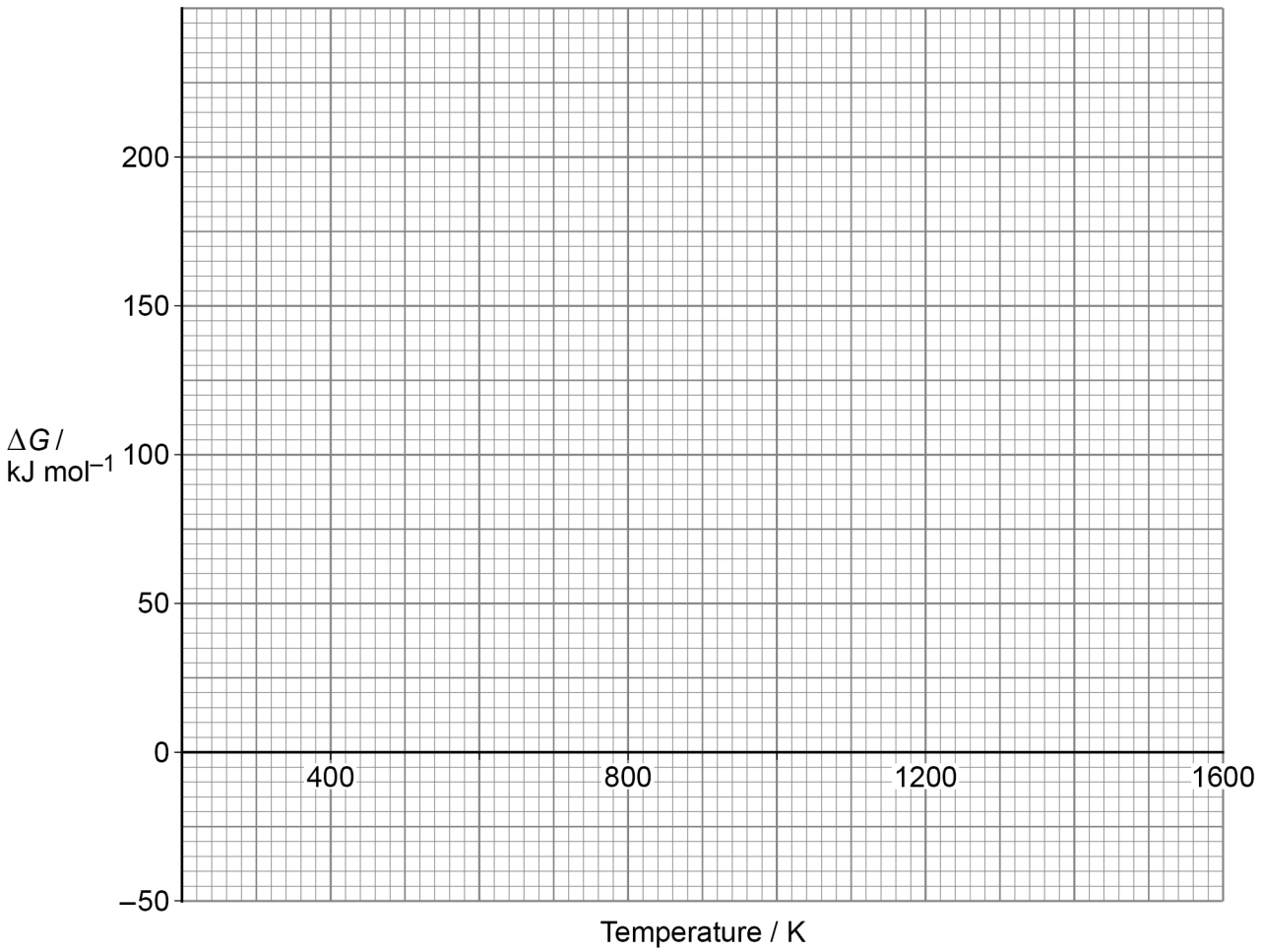

0 2 . 3 Use your graph to deduce the temperature, in K, at which the reaction becomes feasible.

[1 mark]

_____ K

6

Turn over for the next question

Do not write outside the box

0 3 This question is about the elements in Period 3 and their compounds.

0 3 . 1 Give **two** observations made when sodium reacts with oxygen.

Write an equation for this reaction.

[3 marks]

Observation 1 _____

_____

Observation 2 _____

_____

Equation

_____

0 3 . 2 Draw the structure of the compound (M_r = 267.0) formed when aluminium reacts with chlorine.

Show each covalent bond as a line (—) and each co-ordinate bond as an arrow (⟶).

[2 marks]

Do not write outside the box

0 3 . 3 Write an equation for the reaction of phosphorus(V) oxide with water.

Draw the structure of the phosphorus-containing compound formed.

[2 marks]

Equation

_____

Structure

0 3 . 4 A 0.750 g sample of silicon tetrachloride reacts with an excess of water to form an acidic solution.

$$SiCl_4(l) + 2\,H_2O(l) \rightarrow SiO_2(s) + 4\,HCl(aq)$$

Calculate the volume, in cm^3, of 0.500 mol dm^{-3} aqueous sodium hydroxide needed to neutralise the acidic solution formed.

[3 marks]

Volume _____ cm^3

Do not write outside the box

0 3 . 5 **Table 4** shows the melting points of silicon dioxide and silicon tetrachloride.

Table 4

	Melting point / K
Silicon dioxide	1986
Silicon tetrachloride	204

Explain, in terms of structure and bonding, why the melting points of silicon dioxide and silicon tetrachloride are different.

[4 marks]

14

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Turn over for the next question

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0 4 This question is about hydrated ammonium iron(II) sulfate, $(NH_4)_2SO_4.FeSO_4.xH_2O$ where *x* is a whole number.

0 4 . 1 A student determines the number of moles of water of crystallisation in hydrated ammonium iron(II) sulfate. The value of *x* can be calculated using the results from a titration of an acidified solution of ammonium iron(II) sulfate with potassium manganate(VII).

Method

- Dissolve 6.615 g of hydrated ammonium iron(II) sulfate in sulfuric acid and make the solution up to 250 cm^3
- Transfer a 25.0 cm^3 portion of this solution to a conical flask.
- Add 0.0150 mol dm^{-3} potassium manganate(VII) solution from a burette until the mixture in the conical flask just becomes pink.
- Repeat the titration until concordant results are obtained.

The student calculates the mean titre of the potassium manganate(VII) solution to be 22.50 cm^3

Use the data to calculate the value of *x* in hydrated ammonium iron(II) sulfate.

M_r of $(NH_4)_2SO_4.FeSO_4$ = 284.0

[5 marks]

Value of *x* _____

Do not write outside the box

0 4 . 2 State why the mixture in the conical flask becomes pink when the end point of the titration is reached.

[1 mark]

_____

_____

0 4 . 3 One reagent can be used to show that a solution of ammonium iron(II) sulfate contains both NH_4^+ ions and Fe^{2+} ions.

Identify this reagent.

Give the observation(s) that would be made with this reagent that shows the presence of each cation.

[3 marks]

Reagent _____

_____

Observation to show the presence of NH_4^+ ions _____

_____

Observation to show the presence of Fe^{2+} ions _____

_____

9

Turn over for the next question

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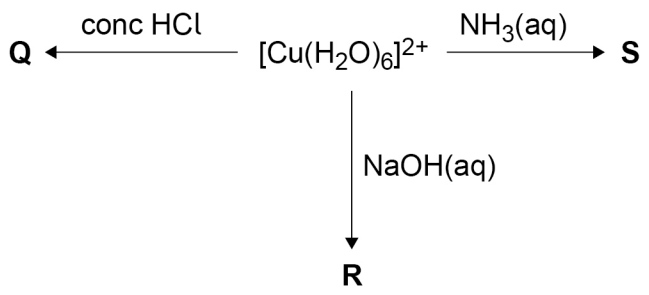
0 5 Some reactions involving aqueous copper(II) complex ions are shown.



0 5 . 1 State the meaning of the term complex ion.

[1 mark]

_____

_____

0 5 . 2 Aqueous copper(II) ions react with an excess of concentrated hydrochloric acid to form a solution containing complex ion **Q**.

Write an equation for the reaction.

Give a reason why there is a colour change in this reaction.

[2 marks]

Equation

_____

Reason _____

_____

_____

Do not write outside the box

0 5 . 3 Aqueous copper(II) ions react with aqueous sodium hydroxide to form complex **R**.

State what would be observed.

Write an equation for the reaction.

[2 marks]

Observation _____

Equation

_____

0 5 . 4 Aqueous copper(II) ions react with an excess of aqueous ammonia to form a solution containing complex ion **S**.

State what would be observed when aqueous ammonia is added dropwise, until in excess, to a solution containing aqueous copper(II) ions.

Write an equation for the overall reaction.

[3 marks]

Observations _____

_____

_____

Equation

_____

8

Turn over for the next question

Do not write outside the box

0 6 This question is about transition metal complex ions.

0 6 . 1 An octahedral complex absorbs light with a wavelength (λ) of 535 nm because of d–d electron transitions.

The energy difference (ΔE) between the ground state and the excited state of the d electrons is

$$\Delta E = \frac{hc}{\lambda}$$

Planck constant, $h = 6.63 \times 10^{-34}$ J s
Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}

Calculate the energy difference, in J, between the d orbitals.
Assume that the light is absorbed only in d–d electron transitions.

[2 marks]

Energy difference _____ J

0 6 . 2 State **two** changes that could be made to a transition metal ion in solution that would influence the ability of the transition metal ion to change from a higher to a lower oxidation state.

[2 marks]

1 _____

2 _____

Do not write outside the box

0 6 . 3 Ethane-1,2-diamine ($H_2NCH_2CH_2NH_2$) can act as a bidentate ligand.
When an excess of ethane-1,2-diamine is added to a solution containing $[Co(NH_3)_6]^{2+}$ ions, all the ammonia ligands are replaced.

Write an equation for this reaction.

Explain the chelate effect in terms of the entropy change and the enthalpy change in this reaction.

[5 marks]

Equation

Explanation

Question 6 continues on the next page

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0 6 . 4 The complex ion $[Co(H_2O)_2(C_2O_4)_2]^{2-}$ exists in three isomeric forms.
It exhibits both *cis-trans* and optical isomerism.

Draw the structure of **one** of the optical isomers.

[1 mark]

10

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Turn over for the next question

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0 7 This question is about electrochemical cells.

Table 5 shows some standard electrode potential data.

Table 5

Electrode half-equation	$E^{\ominus}$ / V
$2\,BrO_3^-(aq) + 12\,H^+(aq) + 10\,e^- \rightarrow Br_2(aq) + 6\,H_2O(l)$	+1.52
$Br_2(aq) + 2\,e^- \rightarrow 2\,Br^-(aq)$	+1.07
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	+0.34
$Fe^{2+}(aq) + 2\,e^- \rightarrow Fe(s)$	−0.44

0 7 . 1 Identify the species in **Table 5** that can oxidise iron to iron(II) ions with no further reaction.

Deduce an overall equation for this reaction.

[2 marks]

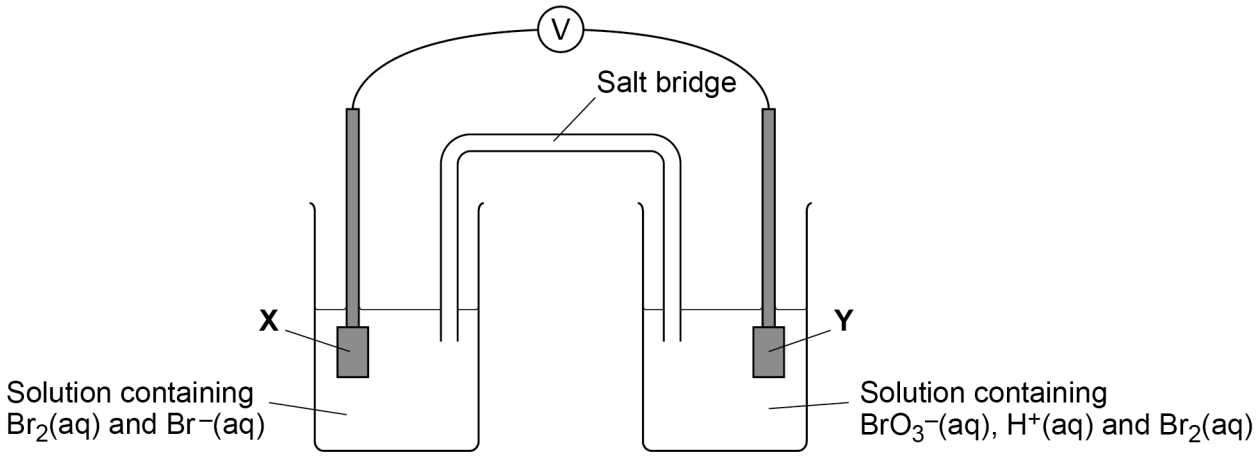
Species _____

Equation

_____

Figure 2 shows an electrochemical cell.

Figure 2



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0 7 . 2 Use data from **Table 5** to calculate the EMF of the cell in **Figure 2**.

Deduce the overall redox equation for the reaction.

[3 marks]

EMF _____

Equation

_____

0 7 . 3 State why a salt bridge is needed.

Identify a salt to use in the salt bridge for this electrochemical cell.

[2 marks]

Why salt bridge is needed _____

_____

Identity of salt _____

0 7 . 4 Identify a material used for electrodes **X** and **Y** in **Figure 2**.

Give a reason for using this material.

[2 marks]

Material _____

Reason _____

_____

0 7 . 5 What is the effect on the EMF of the cell if the surface area of both electrodes is doubled?

[1 mark]

Tick (✓) **one** box.

EMF is increased by a factor of 4 ☐

EMF is increased by a factor of 2 ☐

EMF is unchanged. ☐

10

Do not write outside the box

0 8 This question is about pH.

0 8 . 1 Define the term pH.

[1 mark]

_____

0 8 . 2 A 20.0 cm^3 sample of 0.115 mol dm^{-3} hydrochloric acid is diluted with deionised water to form 145 cm^3 of solution.

Calculate the pH of the solution formed.

Give your answer to 2 decimal places.

[3 marks]

pH _____

Do not write outside the box

0 8 . 3 Water dissociates as shown.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

At 45 °C, the ionic product of water (K_w) has a value of 4.02×10^{-14} mol^2 dm^{-6}

Calculate the pH of water at 45 °C

Give your answer to 2 decimal places.

[2 marks]

pH _____

0 8 . 4 Calculate the pH of 0.175 mol dm^{-3} aqueous butanoic acid ($CH_3CH_2CH_2COOH$) at 25 °C

For butanoic acid at 25 °C, the acid dissociation constant, $K_a = 1.51 \times 10^{-5}$ mol dm^{-3}

Give your answer to 2 decimal places.

[3 marks]

pH _____

Do not write outside the box

0 8 . 5 Aqueous sodium hydroxide is added to 25.0 cm^3 of aqueous butanoic acid ($CH_3CH_2CH_2COOH$) in a titration.

Figure 3 shows how the pH of the solution changes.

Figure 3

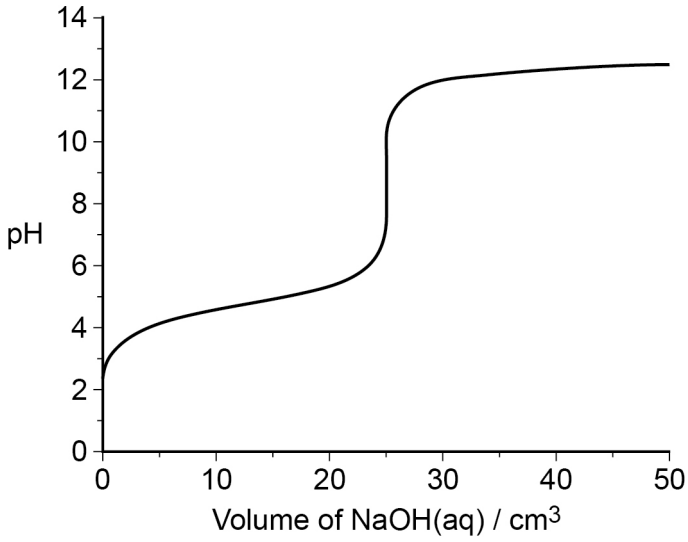

Table 6 shows the pH ranges of some indicators.

Table 6

Indicator	**pH range**
Thymol blue	1.2–2.8
Methyl orange	3.1–4.4
Thymolphthalein	9.3–10.5
Indigo carmine	11.6–14.0

Use **Table 6** to identify the most suitable indicator for this titration.

[1 mark]

Do not write outside the box

0 8 . 6 Butanoic acid ($CH_3CH_2CH_2COOH$) and sodium butanoate ($CH_3CH_2CH_2COONa$) are mixed at 25 °C to form a buffer solution with pH = 4.50

Calculate the mass, in grams, of sodium butanoate that should be added to 50.0 cm^3 of 0.175 mol dm^{-3} aqueous butanoic acid to prepare this buffer solution.

For butanoic acid at 25 °C, the acid dissociation constant, $K_a = 1.51 \times 10^{-5}$ mol dm^{-3}

[5 marks]

Mass of sodium butanoate _____ g

15

END OF QUESTIONS

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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