GCE A LEVEL

1410U30-1

THURSDAY, 9 JUNE 2022 – AFTERNOON

CHEMISTRY – A2 UNIT 3

PHYSICAL AND INORGANIC CHEMISTRY

1 hour 45 minutes plus your additional time allowance

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
SECTION A	1. to 7.	10	
SECTION B	8.	14	
	9.	20	
	10.	12	
	11.	24	
	Total	80	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:

- **calculator;**
- **DATA BOOKLET supplied by WJEC.**

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

Answer ALL questions in SECTION A.
Answer ALL questions in SECTION B.

Write your answers in the spaces provided.
If you run out of space, use the additional pages at the back of the booklet taking care to number the question(s) correctly.

Candidates are advised to allocate their time appropriately between SECTION A (10 MARKS) and SECTION B (70 MARKS).

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part – question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in question 8 (c).

SECTION A

ANSWER ALL QUESTIONS.

1. Addition of aqueous lead(II) nitrate to aqueous potassium iodide causes a precipitate to form.

(a) Give the colour of the precipitate.

_____

[1 mark]

(b) Write an ionic equation for the reaction.

_____

_____

[1 mark]

2. Addition of excess hydrochloric acid to aqueous copper(II) sulfate causes the solution to turn green.

Give the formula of the copper – containing species present.

_____

[1 mark]

3. The rate equation for the decomposition of N_2O_5 to form O_2 and NO_2 is first order overall.

(a) Write the rate equation for this reaction.

_____

_____

[1 mark]

(b) Suggest a rate – determining step for this reaction.

_____

_____

[1 mark]

4. State what is meant by the term ‘standard electrode potential’. Include the conditions required.

_____

_____

_____

_____

_____

_____

[2 marks]

5. Phosphorus is able to form two different chlorides, PCl_3 and PCl_5. Nitrogen is only able to form one chloride, NCl_3.

Explain this difference.

_____

_____

_____

_____

_____

[1 mark]

6. Write the expression for the ionic product of water, K_W.

[1 mark]

7. Give a reason why the entropy of Hg(l) is greater than that of Au(s).

_____

_____

_____

_____

[1 mark]

(Total for SECTION A = 10 marks)

SECTION B

ANSWER ALL QUESTIONS.

8. The Mohs scale measures the hardness of different materials and runs from 1 to 10, with 10 being the hardest. A fingernail is rated as 2.5 on the Mohs scale so any material that can be scratched with a fingernail has a hardness of less than 2.5

Graphite and the minerals halite and tachyhydrite, can all be scratched with a fingernail.

(a) The hardness value of graphite is approximately 1.5

Describe the structure of graphite and explain why it is soft.

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 8 continued

8. (b) Halite is the mineral name for rock salt. It contains sodium chloride.

The equation corresponding to the standard enthalpy change of formation of sodium chloride is as follows.

$$Na(s) + \frac{1}{2} Cl_2(g) \longrightarrow NaCl(s)$$

$$\Delta_f H^{\theta} = -411 \text{ kJ mol}^{-1}$$

Some standard enthalpy changes are given in the table below.

Enthalpy term	Standard molar enthalpy change (kJ mol^{-1})
first ionisation energy of sodium	494
electron affinity of chlorine	−364
bond energy of Cl_2	242
enthalpy of atomisation of sodium	109

continued on the next page . . .

Question 8 (b) continued

8. (b) (i) State the enthalpy of atomisation of chlorine.

_____

[1 mark]

(ii) Use the standard enthalpy changes to find the standard enthalpy change of lattice formation of sodium chloride.

Space for working

Standard enthalpy change of lattice formation

= _____ kJ mol^{-1}

[3 marks]

continued on the next page . . .

Question 8 (b) continued

8. (b) (iii) A student suggests that the entropy change for the formation of sodium chloride must be positive as the reaction occurs easily.

Is the student correct? Justify your answer.

_____

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 8 continued

8. (c) Tachyhydrite is a soft, soluble mineral that has a general formula of $A_aB_bX_c.dH_2O$.

A and B represent two different s – block metal ions, with X representing an anion.

Use ALL the following data to find the identity of all the ions present and to find the formula of tachyhydrite.

A, B AND X ARE NOT THE CHEMICAL SYMBOLS OF THE ELEMENTS PRESENT.

A flame test on a sample of tachyhydrite gives a brick – red flame with no indication of any other colour. Addition of dilute sulfuric acid to a solution of tachyhydrite causes the solution to go cloudy. With concentrated sulfuric acid, misty fumes are released from the solid, however there is no colour change.

continued on the next page . . .

Question 8 (c) continued

Addition of aqueous silver nitrate to a solution of tachyhydrite causes a precipitate to form.

Tachyhydrite has an M_r of approximately 518. On heating to constant mass the solid loses 41.75% of its initial mass.

Formula of tachyhydrite _____

[6 marks QER]

(Total for Question 8 = 14 marks)

9. Iron is an example of a transition element. It has two main oxidation states in its compounds.

(a) Write the electronic structure of an Fe^{2+} ion and use it to show why iron is classed as a transition element.

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 9 continued

9. (b) Explain why iron has more than one common oxidation state in its compounds.

_____

_____

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 9 continued

9. (c) In very acidic solutions, Fe^{3+} forms $[Fe(H_2O)_6]^{3+}$.

Draw the structure of the $[Fe(H_2O)_6]^{3+}$ ion.

[1 mark]

continued on the next page . . .

Question 9 continued

9. (d) In solutions with pH values between 1 and 3, the following equilibrium occurs.

$$[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$$

The concentrations of $[Fe(H_2O)_6]^{3+}$ and $[Fe(H_2O)_5(OH)]^{2+}$ present can be studied using colorimetry.

(i) Explain why the complex ions $[Fe(H_2O)_6]^{3+}$ and $[Fe(H_2O)_5(OH)]^{2+}$ are not the same colour.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 9 (d) continued

9. (d) (ii) Suggest how you would select an appropriate wavelength to find the concentration of $[Fe(H_2O)_6]^{3+}$ in the equilibrium mixture.

_____

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 9 (d) continued

9. (d) (iii) Write an expression for the equilibrium constant K_c for this equilibrium, giving its unit.

Space for working

Unit _____

[2 marks]

continued on the next page . . .

Question 9 (d) continued

9. (d) (iv) A known mass of iron(III) chloride, $FeCl_3.6H_2O$ (M_r 270.4) is dissolved in $1.00\ dm^3$ of dilute hydrochloric acid. At equilibrium the pH of the solution is 1.55 and the concentration of $[Fe(H_2O)_5(OH)]^{2+}$ is $0.103\ mol\ dm^{-3}$. The numerical value of K_c under these conditions is 4.03×10^{-3}.

Find the mass of $FeCl_3.6H_2O$ used to make the solution.

Space for working

continued on the next page . . .

Space for working continued

Mass = _____ g

[4 marks]

continued on the next page . . .

Question 9 continued

9. (e) At higher pH values, solutions containing hydrated Fe^{3+} ions form a precipitate.

(i) Give the formula of the precipitate and its colour.

Formula _____

Colour _____

[1 mark]

continued on the next page . . .

Question 9 (e) continued

9. (e) (ii) Aqueous iron(II) compounds form a precipitate of a different colour with aqueous sodium hydroxide. In a test tube, the precipitate can change colour on standing.

Use the standard electrode potential values below to explain this change.

	Standard electrode potential, E^{θ} / V
$Fe^{3+} + e^{-} \rightleftharpoons Fe^{2+}$	+0.77
$O_2 + 4H^{+} + 4e^{-} \rightleftharpoons 2H_2O$	+1.23

[2 marks]

9. (e) (iii) A student states that it would be incorrect to use the standard electrode potential for the oxygen half – cell as the solution will be alkaline. State, giving a reason, the effect an alkaline solution will have on the value of the electrode potential of the oxygen half – cell.

[2 marks]

continued on the next page . . .

Question 9 continued

9. (f) In a blast furnace Fe_2O_3 is reduced by CO to form iron metal.

(i) Write an equation for this process.

_____

_____

[1 mark]

(ii) Explain why CO is a good reducing agent.

_____

_____

_____

[1 mark]

(Total for Question 9 = 20 marks)

10. Look at the diagram for Question 10 in the separate Diagram Booklet.
The diagram shows a titration curve.

A student used a solution of weak acid HA in a titration. A $25.0\,cm^3$ sample of the acid was titrated against a sodium hydroxide solution of concentration $0.250\,mol\,dm^{-3}$ giving the pH titration curve shown in the diagram. The initial pH value is missing from the graph.

continued on the next page . . .

Question 10 (a) continued

10. (a) Several indicators are listed in the table below. Identify ALL the indicator(s) which are appropriate for this titration. Give a reason for your choice(s).

Indicator	pH range
methyl orange	3.1 – 4.4
bromocresol purple	5.2 – 6.8
bromothymol blue	6.0 – 7.6
naphtholphthalein	7.3 – 8.7
cresolphthalein	8.2 – 10.1

[2 marks]

continued on the next page . . .

Question 10 continued

10. (b) Calculate the concentration of the HA solution.

Space for working

Concentration = _____ $mol\,dm^{-3}$

[2 marks]

continued on the next page . . .

Question 10 continued

10. (c) Find the pH of the mixture after addition of $10.0\ cm^3$ of sodium hydroxide solution and hence calculate the initial pH of the HA solution.

You MUST show your working.

Space for working

pH after addition of $10.0\ cm^3$ = _____

continued on the next page . . .

Space for working continued

Initial pH = _____

[4 marks]

continued on the next page . . .

Question 10 continued

10. (d) HA is a weak acid and so it can be used to make a buffer solution.
Suggest ONE important use for buffer solutions.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 10 continued

10. (e) **Look at the table for question 10 (e) in the separate Diagram Booklet.**

Some data regarding the dissociation of another weak acid, HX,

at two different temperatures are given in the table.

$$HX \rightleftharpoons H^+ + X^-$$

Find temperature *T* and hence explain in terms of equilibrium why the percentage dissociation is different at this temperature.

Space for working

continued on the next page . . .

Space for working continued

T **= _____ K**

[3 marks]

(Total for Question 10 = 12 marks)

11. Chlorine can form a range of oxyanions with chlorine present in oxidation states including +1, +5 and +7.

(a) Chlorate(I) ions, ClO^-, are commonly present in household bleaches.
These ions can oxidise iodide ions to iodine.

$$ClO^- + 2I^- + H_2O \rightarrow I_2 + Cl^- + 2OH^-$$

Dewi took a $25.0\ cm^3$ sample of a household bleach and diluted it to form $250\ cm^3$ of solution in a standard volumetric flask. Four $25.0\ cm^3$ portions of the diluted solution were measured and placed in separate conical flasks and a spatula of solid potassium iodide was added to each. Each portion was titrated against standard sodium thiosulfate solution from a burette.

continued on the next page . . .

Question 11 (a) continued

$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$$

Dewi had access to five concentrations of sodium thiosulfate:

$2.00\ mol\ dm^{-3}$, $1.00\ mol\ dm^{-3}$, $0.500\ mol\ dm^{-3}$, $0.200\ mol\ dm^{-3}$ and $0.0500\ mol\ dm^{-3}$.

He selected the $0.500\ mol\ dm^{-3}$ solution and his results are shown in the table provided for Question 11 (a) in the separate Diagram Booklet.

continued on the next page . . .

Question 11 (a) continued

11. (a) (i) Calculate the mean volume of sodium thiosulfate solution used.

Space for working

Mean volume = _____ cm^3

[1 mark]

continued on the next page . . .

Question 11 (a) continued

11. (a) (ii) Find the concentration of sodium chlorate(I) in the initial bleach sample.

Space for working

Concentration = _____ **$mol\,dm^{-3}$**

[3 marks]

continued on the next page . . .

Question 11 (a) continued

11. (a) (iii) **Bleach concentrations are often quoted on labels as % w/v, that is the mass of sodium chlorate(I) dissolved in $100\ cm^3$ of water.**

Calculate the % w/v concentration of sodium chlorate(I) in this bleach.

Space for working

Concentration = _____% w/v

[1 mark]

continued on the next page . . .

Question 11 (a) continued

11. (a) (iv) The teacher tells Dewi that he has selected an inappropriate concentration of sodium thiosulfate solution.

Suggest which concentration of sodium thiosulfate he should have chosen.
Give TWO reasons for your answer.

_____

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 11 continued

11. (b) Chlorate(V) anions, ClO_3^-, are strong oxidising agents and can oxidise bromide ions in acid solution to form bromine and chloride ions.

$$ClO_3^- + 6Br^- + 6H^+ \rightarrow Cl^- + 3Br_2 + 3H_2O$$

The initial rate of this reaction was measured at a temperature of $298\ K$ using different concentrations of reactants.

Look at the table for Question 11 (b) in the separate Diagram Booklet.
The data for these experiments are shown in the table.

continued on the next page . . .

Question 11 (b) continued

11. (b) (i) I. Find the orders of reaction with respect to chlorate(V) and bromide ions. You MUST show your working.

Space for working

Order with respect to

chlorate(V) ions _____

Order with respect to

bromide ions _____

[2 marks]

continued on the next page . . .

Question 11 (b) (i) continued

11. (b) (i) II. The student finds that the rate of reaction is proportional to $[H^+]^3$. This is described as third order with respect to hydrogen ions.

Find the expected initial rate for experiment 4.

Space for working

Initial rate = _____ $mol\,dm^{-3}\,s^{-1}$

[2 marks]

continued on the next page . . .

Question 11 (b) continued

11. (b) (ii) **Chemists often use an approximate rule that the rate of a reaction doubles when the temperature is increased by $10^{\circ}C$.**

Show that this rule is true if this reaction is warmed from $298\,K$ to $308\,K$. The activation energy for the reaction is $52.8\,kJ\,mol^{-1}$.

Space for working

[3 marks]

Question 11 continued

11. (c) The acid formed from chlorate(VII) ions is commonly called perchloric acid, $HClO_4$.

It is a very strong acid and is commonly classed as a superacid as it is a stronger acid than sulfuric acid.

(i) State how the K_a value of a stronger acid will compare with that of a weaker acid, giving a reason.

_____

_____

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 11 (c) continued

11. (c) (ii) The concentration of $25.0\ cm^3$ of an aqueous solution of perchloric acid can be found by adding an excess of calcium carbonate and then measuring the amount of carbon dioxide gas released.

This can be done by either:

- **measuring the volume of the gas released using a gas syringe, or**
- **measuring the mass lost as the carbon dioxide is released by placing the reaction flask on a digital balance.**

continued on the next page . . .

Question 11 (c) (ii) continued

Joe uses the first method to study his sample of perchloric acid and finds that the reaction releases $87\ cm^3$ of carbon dioxide at $30^\circ C$ and $1\ atm$ pressure.

Heledd uses the second method and finds that the mixture loses a total of $0.1533\ g$ during the reaction.

continued on the next page . . .

Question 11 (c) (ii) continued

11. (c) (ii) I. Find the number of moles of carbon dioxide released in each experiment and hence state whether the two solutions provided to Joe and Heledd are of the same concentration.

You MUST show your working and give your answers to APPROPRIATE numbers of significant figures.

Space for working

continued on the next page . . .

Space for working continued

Moles of CO_2 using Joe's method

= _____ mol

Moles of CO_2 using Heledd's method

= _____ mol

_____

_____

[4 marks]

continued on the next page . . .

Question 11 (c) (ii) continued

11. (c) (ii) II. Suggest, from the data provided, which of the two methods will give better results. Give a reason for your suggestion.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 11 (c) (ii) continued

11. (c) (ii) III. Isha suggests using excess magnesium in place of calcium carbonate for Joe and Heledd's experiments. This will produce hydrogen gas in place of carbon dioxide. Explain which of the two methods will suffer the greater loss in accuracy.

[2 marks]

continued on the next page . . .

Question 11 (c) continued

11. (c) (iii) One common salt of perchloric acid is ammonium perchlorate.

Suggest a pH value for a solution of ammonium perchlorate.
Give a reason for your answer.

[2 marks]

(Total for Question 11 = 24 marks)

TOTAL SECTION B = 70 MARKS

END OF PAPER

TOTAL 80 MARKS

Question number	Additional pages, if required. Write the question number(s) in the left - hand margin.

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THURSDAY, 9 JUNE 2022 – AFTERNOON

CHEMISTRY – A2 UNIT 3

PHYSICAL AND INORGANIC CHEMISTRY

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

Diagram Booklet

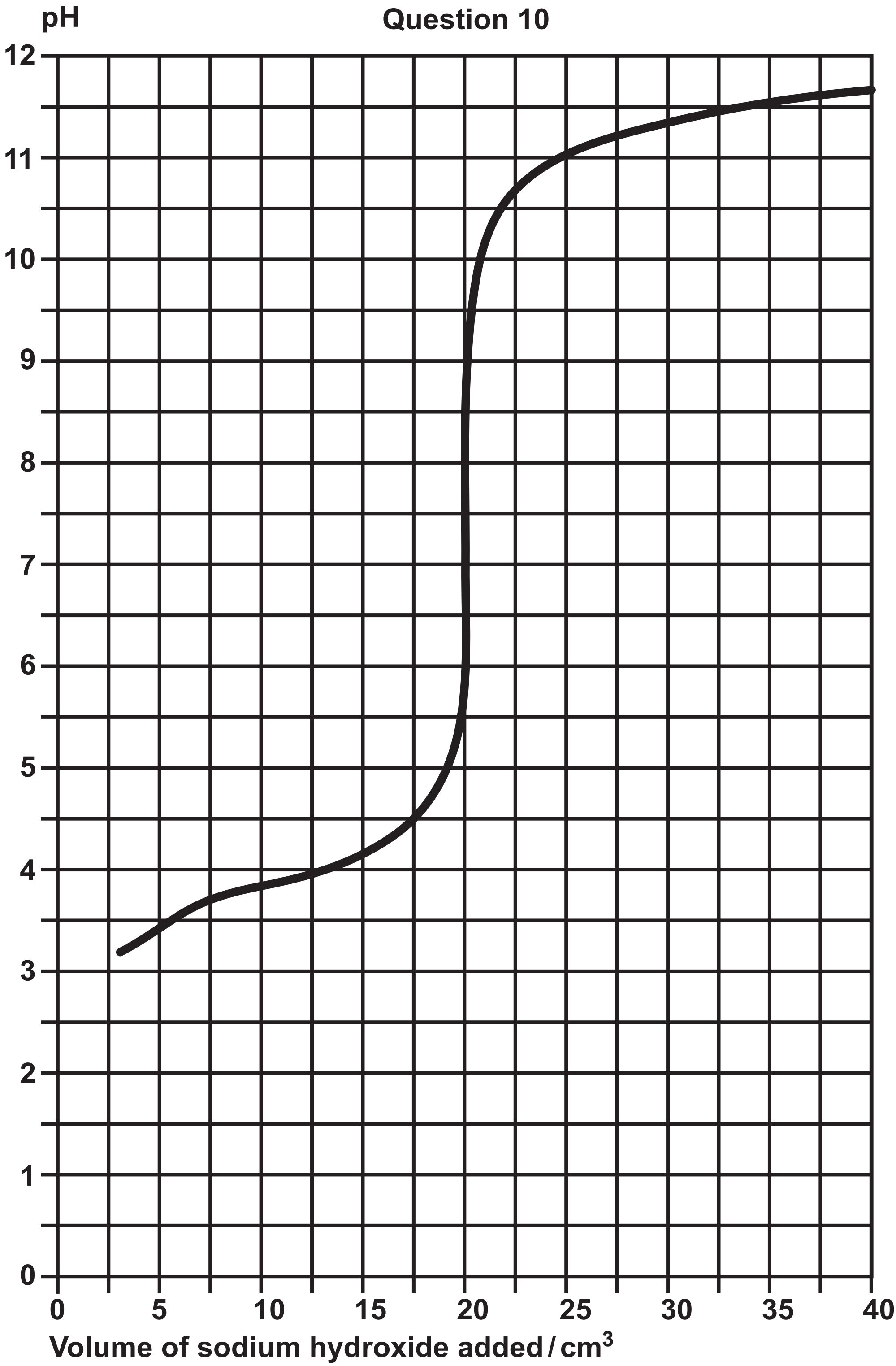
Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

Question 10


pH
12
11
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
Volume of sodium hydroxide added / cm3

Question 10 (e)

Table

	HX at 298 K	HX at temperature *T*
Percentage dissociated	3.9	3.4
ΔG for acid dissociation / kJ mol^{-1}	15.9	16.7
ΔH for acid dissociation / kJ mol^{-1}	– 10.0	
ΔS for acid dissociation / J K^{-1} mol^{-1}	– 87.0	

Question 11 (a)

Table

	1	2	3	4
Volume of $Na_2S_2O_3$ solution / cm^3	6.45	6.40	6.50	6.45

Question 11 (b)

Table

Experiment	Concentration of ClO_3^- / mol dm^{-3}	Concentration of Br^- / mol dm^{-3}	pH	Initial rate / mol dm^{-3} s^{-1}
1	0.30	0.20	0	3.06×10^{-7}
2	0.60	0.20	0	6.12×10^{-7}
3	0.30	0.60	0	9.18×10^{-7}
4	0.30	0.60	1	