Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

1410U30-1

Z22-1410U30-1

THURSDAY, 9 JUNE 2022 – AFTERNOON

CHEMISTRY – A2 unit 3
Physical and Inorganic Chemistry

1 hour 45 minutes

	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**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid. You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.
Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) 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 **Q.8**(c).

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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]

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(b) Write an ionic equation for the reaction. [1]

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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]

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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]

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(b) Suggest a rate-determining step for this reaction. [1]

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4. State what is meant by the term 'standard electrode potential'. Include the conditions required. [2]

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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]

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6. Write the expression for the ionic product of water, K_w. [1]

7. Give a reason why the entropy of Hg(l) is greater than that of Au(s). [1]

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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]

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(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.

$$Na(s) + \tfrac{1}{2}Cl_2(g) \longrightarrow NaCl(s) \qquad \Delta_f H^{\theta} = -411\ kJ\ mol^{-1}$$

Some standard enthalpy changes are given in the table.

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

(i) State the enthalpy of atomisation of chlorine. [1]

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(ii) Use the standard enthalpy changes to find the standard enthalpy change of lattice formation of sodium chloride. [3]

Standard enthalpy change of lattice formation = ... kJ mol^{-1}

(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]

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(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. 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. [6 QER]

Formula of tachyhydrite .....

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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]

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(b) Explain why iron has more than one common oxidation state in its compounds. [1]

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(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]

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(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]

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(ii) Suggest how you would select an appropriate wavelength to find the concentration of $[Fe(H_2O)_6]^{3+}$ in the equilibrium mixture. [1]

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(iii) Write an expression for the equilibrium constant K_c for this equilibrium, giving its unit. [2]

Unit .....

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(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. [4]

Mass = ... g

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

(i) Give the formula of the precipitate and its colour. [1]

Formula .....

Colour .....

(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. [2]

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

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(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]

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

(i) Write an equation for this process. [1]

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(ii) Explain why CO is a good reducing agent. [1]

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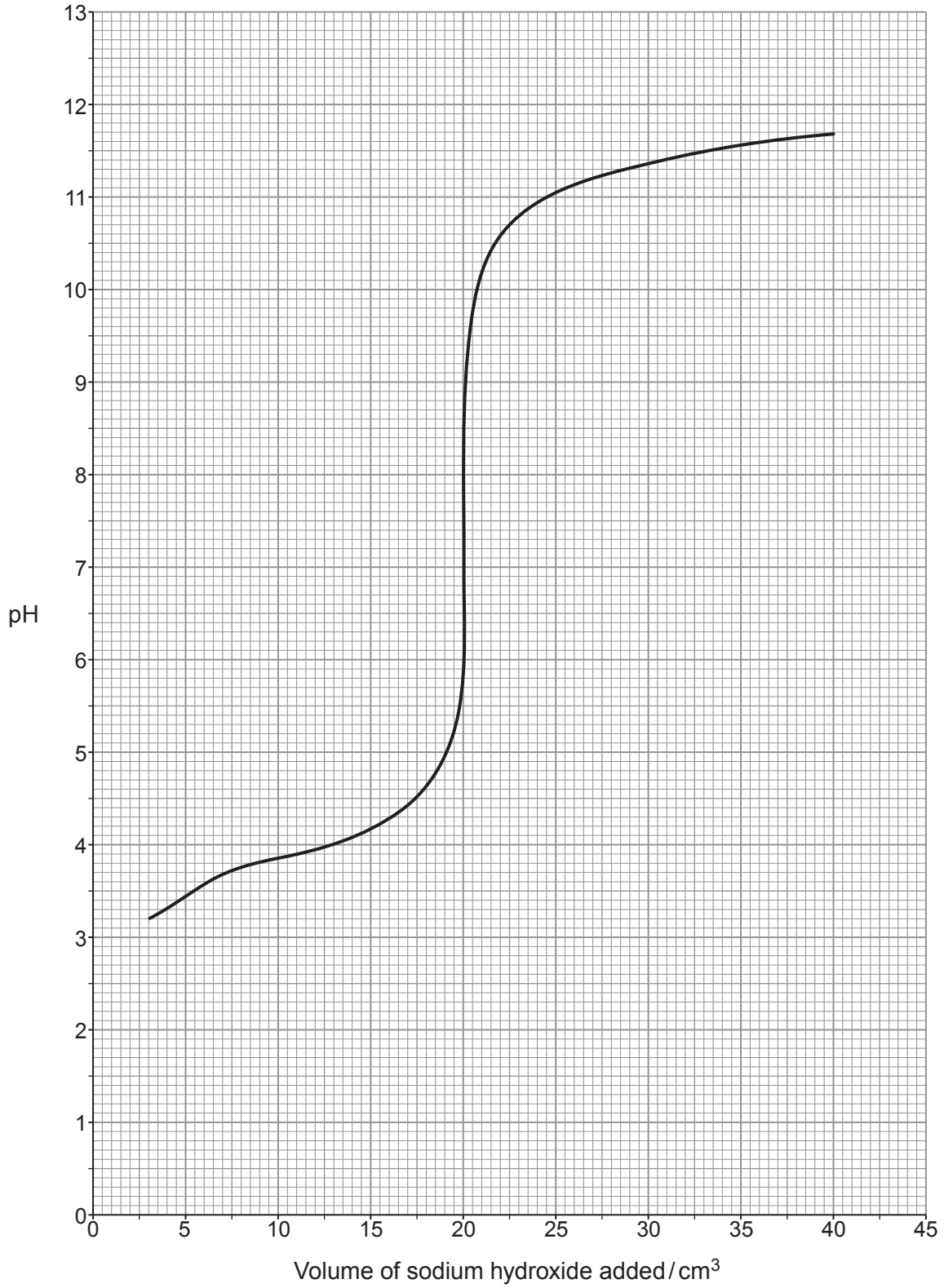
Turn over.

10. 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. The initial pH value is missing from the graph.



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(a) Several indicators are listed in the table.

Identify **all** the indicator(s) which are appropriate for this titration. Give a reason for your choice(s). [2]

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

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(b) Calculate the concentration of the HA solution. [2]

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

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(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. [4]

You **must** show your working.

pH after addition of 10.0 cm^3 = ...

Initial pH = ...

(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]

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Examiner only

(e) Some data regarding the dissociation of another weak acid, HX, at two different temperatures are given in the table.

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

	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	

Find temperature *T* and hence explain in terms of equilibrium why the percentage dissociation is different at this temperature. [3]

T = ... K

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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.

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

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.

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

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.

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

(i) Calculate the mean volume of sodium thiosulfate solution used. [1]

Mean volume = ... cm^3

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(ii) Find the concentration of sodium chlorate(I) in the initial bleach sample. [3]

Concentration = ... mol dm^{-3}

(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. [1]

Concentration = ... % w/v

(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]

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Examiner only

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

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

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

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	

(i) I. Find the orders of reaction with respect to chlorate(V) and bromide ions. [2]

You **must** show your working.

Order with respect to chlorate(V) ions .....

Order with respect to bromide ions .....

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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. [2]

Initial rate = ... mol dm^{-3} s^{-1}

(ii) Chemists often use an approximate rule that the rate of a reaction doubles when the temperature is increased by 10 °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}. [3]

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Examiner only

(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]

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(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.

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 °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.

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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. [4]

You **must** show your working and give your answers to **appropriate** numbers of significant figures.

Moles of CO_2 using Joe's method = ... mol

Moles of CO_2 using Heledd's method = ... mol

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II. Suggest, from the data provided, which of the two methods will give better results. Give a reason for your suggestion. [1]

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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]

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(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]

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END OF PAPER

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