Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

S25-1410U30-1

1410U30-1

TUESDAY, 10 JUNE 2025 – MORNING

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 6.	10	
Section B	7.	16	
	8.	13	
	9.	19	
	10.	22	
	Total	80	

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ADDITIONAL MATERIALS

- A calculator, pencil and ruler
- **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.

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 **Q9**(b)(iii).

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SECTION A

Answer **all** questions.

1. Complete the Arrhenius equation below. [1]

k = ...

2. Give a reason why $SiCl_4$ reacts vigorously with water whilst CCl_4 does not. [1]

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3. Many reactions use heterogeneous catalysts.

(a) State what is meant by the term heterogeneous in this context. [1]

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(b) Give an example of a heterogeneous catalyst and the reaction it catalyses. [1]

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4. Ethanedioic acid, $(COOH)_2$, can be oxidised by acidified manganate(VII) ions.

Use the half-equations below to write the ionic equation for the reaction. [1]

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

$$(COOH)_2 \longrightarrow 2CO_2 + 2H^+ + 2e^- \times 5$$

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5. A metal halide gives a lilac flame test and the addition of concentrated sulfuric acid causes it to release coloured fumes and a smell of rotten eggs.

Identify the metal halide, giving reasons for your answer. [2]

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6. (a) Give the observation(s) expected when aqueous sodium hydroxide is added gradually to aqueous chromium(III) chloride until the sodium hydroxide is in excess. [1]

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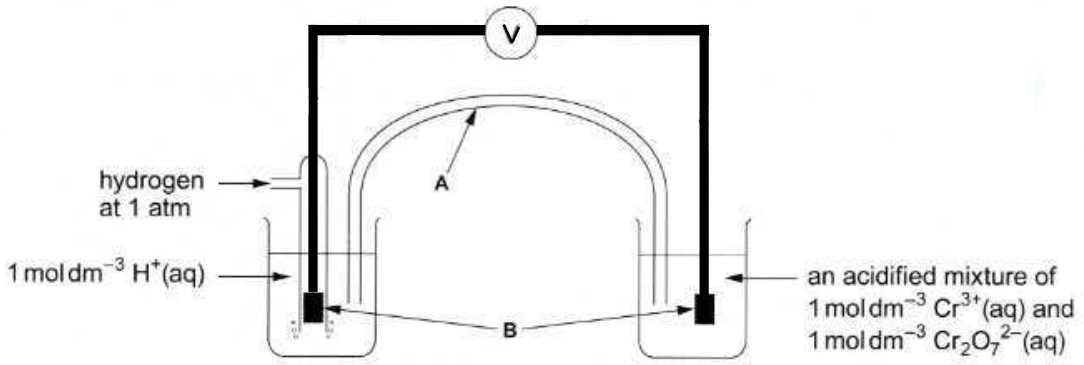
(b) The diagram shows the apparatus used to measure the standard electrode potential for the half-equation:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O \qquad E^\theta = +1.33\,V$$



(i) Name parts **A** and **B**. [1]

A .....

B .....

(ii) **Label the diagram** to show the direction of flow of electrons in the wire. [1]

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SECTION B

Answer **all** questions.

7. (a) Metal nitrates containing Group 2 metals decompose upon heating.

$$2M(NO_3)_2(s) \longrightarrow 2MO(s) + 4NO_2(g) + O_2(g)$$

Metal nitrate	Standard enthalpy change of reaction / kJ mol^{-1}	Standard entropy change of reaction / J K^{-1} mol^{-1}
$Mg(NO_3)_2$	444	411
$Ca(NO_3)_2$		379
$Ba(NO_3)_2$	936	397

(i) Give a reason why all the entropy changes are positive. [1]

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(ii) The minimum temperature for decomposition of calcium nitrate is 1500 °C.

Find the standard enthalpy change for this reaction. [3]

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

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(iii) Treatment of aqueous barium nitrate with sulfuric acid produces a white precipitate of barium sulfate, whilst addition of the same acid to aqueous magnesium nitrate does not give a precipitate.

I. Write the ionic equation for the formation of the precipitate, including state symbols. [1]

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II. Use the data below to explain why barium sulfate is insoluble in water whilst magnesium sulfate is soluble. [3]

	Standard enthalpy change / kJ mol^{-1}
Lattice breaking enthalpy of $MgSO_4$	2833
Lattice breaking enthalpy of $BaSO_4$	2474
Hydration enthalpy of Mg^{2+} ion	–1920
Hydration enthalpy of Ba^{2+} ion	–1360
Hydration enthalpy of SO_4^{2-} ion	–1059

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(b) Ammonium nitrate is a soluble salt. Suggest the pH of an aqueous solution of ammonium nitrate, giving a reason for your answer. [2]

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(c) Aqueous lead(II) nitrate forms precipitates when a variety of aqueous solutions are added.

Complete the table to give the observations, if any, when the solutions below are added to aqueous lead(II) nitrate. [2]

Solution added	Observation(s)
sulfuric acid	.....
potassium iodide	.....

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(d) Metal nitrates are often found in rocks mixed with materials such as limestone. A student is provided with a rock which contains a mixture of sodium nitrate and calcium carbonate. Heating the rock causes both substances to decompose according to the following equations.

$$2NaNO_3(s) \longrightarrow 2NaNO_2(s) + O_2(g)$$

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

The boiling temperatures of the gases produced are as follows.

Substance	O_2	CO_2
Boiling temperature/K	90	195

A sample of 81.3 g of the rock was heated until both substances decomposed completely. The volume of gas produced was measured at 1 atm pressure at two different temperatures.

Temperature/K	Volume of gas produced/cm^3
200	1.193×10^4
100	1.028×10^3

Find the percentage by mass of calcium carbonate in the rock. [4]

Percentage calcium carbonate = ... %

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8. (a) When chlorine gas reacts with concentrated aqueous sodium hydroxide solution, it produces sodium chloride, sodium chlorate(V) and water.

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

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(ii) Use oxidation states to show why this reaction can be described as disproportionation. [2]

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(b) Chlorate(I) ions can oxidise bromide ions according to the following equation.

$$ClO^-(aq) + Br^-(aq) \longrightarrow Cl^-(aq) + BrO^-(aq)$$

(i) One method of studying the rate of this reaction is by sampling and quenching.

State how you would quench the samples. [1]

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(ii) The reaction is first order with respect to each reactant therefore second order overall.

A student states that this means that successive half-life values for each reactant will be constant. Is the student correct?

Give a reason for your answer. [1]

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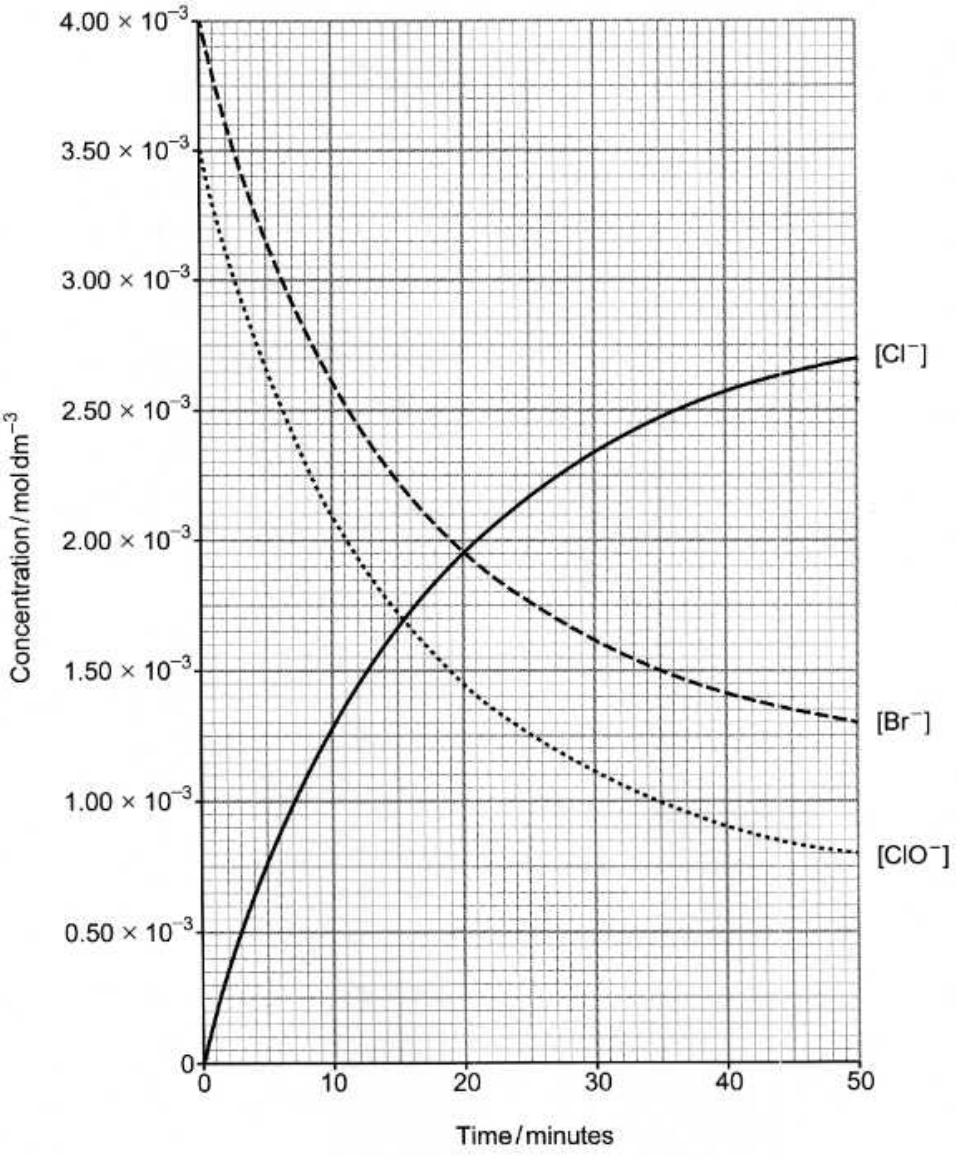
(iii) A student follows the progress of the reaction at a temperature of 298 K.

She obtains the results shown in the graph.



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I. Use the concentration of chloride ions to find the initial rate of the reaction. [2]

Rate = ... $mol\,dm^{-3}\,min^{-1}$

II. Find the value of the rate constant for the reaction, giving its unit. [4]

k = ...

Unit .....

III. Another student chooses to plot the concentration of bromate(I) ions formed instead of the concentration of chloride ions formed.

State the differences in their graphs, if any, giving a reason for your answer. [2]

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Examine only

9. Ethanoic acid can be produced in a reaction between iodomethane and carbon monoxide, followed by treatment with water.

$$CH_3I + CO \longrightarrow CH_3COI \qquad \text{Reaction 1}$$

$$CH_3COI + H_2O \longrightarrow CH_3COOH + HI \qquad \text{Reaction 2}$$

(a) Use data from one of the tables below to calculate the **more accurate** value of the standard enthalpy change for reaction 1. Give a reason for your choice of data. [3]

Bond	Bond energy / kJ mol^{-1}
C — H	413
C — C	346
C — I	240
C = O	745
C ≡ O in carbon monoxide	1072

Substance	Standard enthalpy change of formation / kJ mol^{-1}
CH_3I	–14
CO	–111
CH_3COI	–162

Enthalpy change for reaction 1 = ... kJ mol^{-1}

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(b) Reaction 2 produces a mixture of the weak acid CH_3COOH and the strong acid HI.

(i) Suggest what effect the presence of HI will have on the dissociation of CH_3COOH in this mixture compared to an aqueous solution containing only CH_3COOH. Give your reasoning. [2]

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(ii) Calculate the pH of an aqueous solution of the strong acid HI of concentration $0.250\,mol\,dm^{-3}$. [2]

pH = ...

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(iii) A student is given 100 cm^3 of a solution of ethanoic acid of concentration 0.100 mol dm^{-3} and wishes to produce a buffer solution of pH 4.45. He has access to the full range of chemicals in a laboratory.

Describe how the buffer solution could be formed, calculating the amounts of any other substances required. Explain how the buffer solution works to keep the pH of the solution constant.

[6 QER]

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(c) The complex $[Ru(CO)_2(P(CH_3)_3)_2CH_3I]$ catalyses the reaction of iodomethane with carbon monoxide. One stage in the process is the reversible reaction below, with five of the ligands shown as L.

$$[RuL_5CH_3] + CO \rightleftharpoons [RuL_5COCH_3]$$

The values of the equilibrium constant for this process at different temperatures in methylbenzene solvent are listed in the table.

Temperature / °C	K_c / mol^{-1} dm^3
34	1220
42	694
49	406
56	290
64	196
74	120

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(i) Suggest what information this table allows us to deduce about the energy changes during this reversible reaction. [2]

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(ii) A solution containing a mixture of complex $[RuL_5CH_3]$ of concentration 1.25×10^{-3} mol dm^{-3} and carbon monoxide of concentration 7.55×10^{-4} mol dm^{-3} is placed in a sealed tube, heated to a set temperature and the mixture allowed to reach equilibrium. The equilibrium mixture contains 1.37×10^{-4} mol dm^{-3} of $[RuL_5COCH_3]$.

Find the value of K_c and hence suggest the temperature used for the experiment. [4]

K_c = ... mol^{-1} dm^3

Temperature = ... °C

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10. Copper is present in a range of alloys, including those listed below.

Alloy	Typical copper content (% by mass)	Other element(s) present
brass	65-95	zinc
cupronickel	60-90	nickel
bronze	85-90	tin
electrum	6-25	gold silver
leaded tin bronze	70-85	tin lead

One method of finding the copper content of an alloy is by treating the alloy with concentrated hydrochloric acid in the presence of air to form a solution containing metal ions and diluting this to a known volume. This solution can then be analysed by titration.

(a) The class teacher notes that this method would not be suitable for analysing electrum or leaded tin bronze.

Suggest how the method could be changed to allow for the analysis of electrum and leaded tin bronze. Give your reasoning. [2]

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(b) Several of the metals added to copper to form these alloys are amphoteric.

Identify **one** amphoteric metal from the table and state what is meant by the term amphoteric. [2]

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(c) A 1.72 g sample of an alloy was used to make 250 cm^3 of an aqueous solution containing copper and other metal ions. Samples of 25.0 cm^3 of the solution were measured out and the copper ions reacted with excess iodide ions to form iodine.

The iodine was titrated using sodium thiosulfate solution of concentration 0.0500 mol dm^{-3}. The mean volume of sodium thiosulfate needed for complete reaction was 33.05 cm^3.

(i) Write the equations for the following reactions:

- $Cu^{2+}(aq)$ with $I^-(aq)$
- $I_2(aq)$ with $S_2O_3^{2-}(aq)$

Hence show that 1 mol of $S_2O_3^{2-}(aq)$ is equivalent to 1 mol of $Cu^{2+}(aq)$ in the titration. [3]

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(ii) Find the percentage by mass of copper in the alloy and hence identify which alloy(s) could be present in the sample. [4]

Percentage copper = ... %

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Examiner only

(d) (i) Aqueous solutions formed from copper(II) compounds contain $[Cu(H_2O)_6]^{2+}$ ions.

Explain why these solutions are pale blue. [3]

(ii) Copper(I) compounds are often white solids. Give a reason why these compounds are not coloured. [1]

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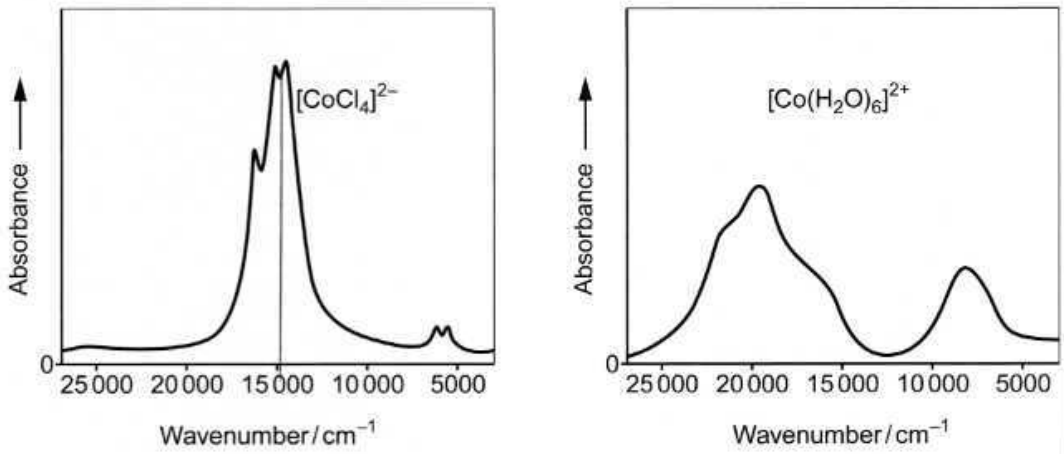
(iii) Many metal complexes change colour when a new ligand is added. The absorption spectra of two cobalt(II) complexes are given below.



Suggest which wavenumber, in cm^{-1}, should be used to study the conversion of $[Co(H_2O)_6]^{2+}$ into $[CoCl_4]^{2-}$. Give a reason for your selection. [2]

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Examiner only

(e) The standard electrode potentials for some reactions of copper and thallium ions are given below.

Half-equation	Standard electrode potential, E^{θ}/V
$Tl^{3+} + 2e^- \rightleftharpoons Tl^+$	+1.25
$Cu^+ + e^- \rightleftharpoons Cu$	+0.52
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.16
$Tl^+ + e^- \rightleftharpoons Tl$	−0.34

(i) When copper(I) ions are formed in solution, the reaction below occurs.

$$2Cu^+ \longrightarrow Cu^{2+} + Cu$$

Use the standard electrode potential values to explain why this reaction occurs. [2]

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(ii) I. Copper(I) ions can act as a reducing agent. Identify the final thallium containing species formed when copper(I) ions reduce thallium(III) ions.

Use the standard electrode potential values to explain your answer. [2]

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II. A student suggests that the more stable oxidation state of thallium can be predicted from its position in the Periodic Table.

Suggest, giving a reason, which oxidation state of thallium will be more stable. [1]

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END OF PAPER

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