



GCE A LEVEL

1410U30-1

MONDAY, 12 JUNE 2023 – MORNING

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.	13	
	10.	18	
	11.	11	
	12.	14	
	Total	80	

(Turn over)

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 9 (a).

SECTION A

ANSWER ALL QUESTIONS.

1. Addition of aqueous lead nitrate to aqueous potassium iodide causes a precipitate to form. Write an ionic equation for the formation of the precipitate, including state symbols.

[1 mark]

2. Look at the table for Question 2 in the separate Diagram Booklet.

Use the data shown in the table to explain why silver chloride is insoluble in water.

[2 marks]

(Turn over)

3. A white crystalline solid gives a red colour in a flame test and addition of concentrated sulfuric acid to the solid gives purple fumes and a smell of rotten eggs.

Name the ions present, giving your reasons.

[2 marks]

4. Aluminium chloride forms Al_2Cl_6 dimers using coordinate bonding. Explain why the coordinate bonds form.

[2 marks]

(Turn over)

5. Addition of ammonia solution to aqueous copper(II) sulfate causes a pale blue precipitate to form followed by a coloured solution when excess ammonia solution is added.

Give the colour of the solution formed.

[1 mark]

6. The Haber process uses a heterogeneous catalyst.

State what is meant by the term 'heterogeneous' in this context.

[1 mark]

7. Hexagonal boron nitride is sometimes called white graphite. Give ONE difference between the physical properties of hexagonal boron nitride and graphite.

[1 mark]

(Total for SECTION A = 10 marks)

SECTION B

- 8. When performing redox titrations the concentration of one solution is found by reaction with another solution of known concentration. Some oxidising agents are classed as primary standards as their concentrations can be calculated precisely from the mass used. Other oxidising agents need to be standardised by reaction with solutions of known concentration before use.**

continued on the next page . . .

Question 8 continued

8. (a) Potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$, is a primary standard. Calculate the concentration of a solution of potassium dichromate made from 5.00 g of potassium dichromate in 250 cm^3 of deionised water.

Space for working:

concentration = _____ mol dm^{-3}

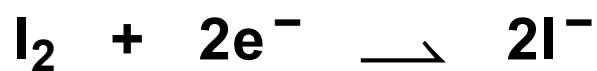
[2 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (b) Sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, can be standardised using potassium dichromate. To do this, acidified potassium dichromate is used to oxidise iodide ions to iodine molecules and the sodium thiosulfate is then used to reduce the iodine formed.



- (i) Write the half-equation for acidified dichromate ions acting as an oxidising agent.

[1 mark]

continued on the next page . . .

(Turn over)

Question 8 (b) continued

8. (b) (ii) Write an equation for the oxidation of iodide ions to iodine molecules using acidified dichromate.
-
-

[1 mark]

- (iii) Excess $\text{KI}(\text{aq})$ was added to 25.0 cm^3 of the aqueous potassium dichromate from part (a) with a small amount of dilute acid. This produced iodine. Aqueous sodium thiosulfate was added from a burette and 24.30 cm^3 of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ was needed for complete reaction with the iodine.

continued on the next page . . .

(Turn over)

Question 8 (b) (iii) continued

8. (b) (iii) I. The titration used an indicator.
Name the indicator used.

[1 mark]

- II. Calculate the concentration of
the aqueous sodium thiosulfate.

Space for working:

concentration = _____ mol dm⁻³

[3 marks]

(Turn over)

Question 8 continued

8. (c) Addition of aqueous sodium hydroxide to the solution of potassium dichromate causes a colour change.

State the colour change and explain why this is not a redox reaction.

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (d) Look at the equation and table for Question 8 (d) in the separate Diagram Booklet.

Heating solid potassium dichromate can cause it to decompose releasing oxygen gas.

- (i) Calculate the standard enthalpy change of formation of potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$

Space for working:

$$\Delta_f H^\theta = \underline{\hspace{2cm}} \text{ kJ mol}^{-1}$$

[2 marks]

(Turn over)

Question 8 (d) continued

8. (d) (ii) Calculate the minimum temperature required for this reaction.

Space for working:

minimum temperature = _____ K

[2 marks]

(Total for Question 8 = 14 marks)

(Turn over)

9. (a) The elements of the **p** – block show a variety of oxidation states within the same group, whilst some elements of the **d** – block can show an even wider range of oxidation states.

- Some oxides of group 4 have an oxidation state of **+4** such as **CO₂** , **SiO₂** and **PbO₂** and others have an oxidation state of **+2** such as **CO** and **PbO**. There is no stable oxide with the formula **SiO**.
- Some chlorides of group 5 have a **+5** oxidation state such as **PCl₅** and some have an oxidation state of **+3** such as **NCl₃** and **PCl₃**
There is no stable chloride with the formula **NCl₅**

continued on the next page . . .

(Turn over)

Question 9 continued

9. (b) Tin(II) ions, Sn^{2+} (aq), can be used as reducing agents for a range of metal ions. In one study of the reduction of Pt^{4+} ions to Pt^{2+} ions in an acid solution, the reaction was found to be first order with respect to both Pt^{4+} and Sn^{2+} with a rate constant of $895 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ at 297 K.

(i) Write a rate equation for this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (b) continued

- 9. (b) (ii) A student suggests studying this reaction using sampling and quenching with samples taken every 30 seconds for 5 minutes. Explain why this would not be an appropriate sampling interval.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 continued

- 9. (c) (i) A second student decides to use colorimetry to study the rate of this reaction. Explain what the student should consider when choosing an appropriate wavelength of light for their colorimetry experiment.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (c) continued

9. (c) (ii) The value of the rate constant was measured at five different temperatures to attempt to find the activation energy.

$$\ln k = \ln A - (E_a / RT)$$

Look at the diagram for Question 9 (c) (ii) in the separate Diagram Booklet.

The diagram shows the graph that was plotted of ($\ln k$) against ($1 / \text{Temperature}$).

Find the activation energy of the reaction.

Space for working:

activation energy, $E_a =$ _____ kJ mol^{-1}
[3 marks]

(Total for Question 9 = 13 marks)

(Turn over)

10. Oxygen forms several molecular compounds of formula X_2O . These include compounds with fluorine and chlorine.

(a) Look at the table for Question 10 (a) in the separate Diagram Booklet.

Some thermodynamic data for F_2O and Cl_2O are given in the table.

A student examines the data and states that there is sufficient information to find the minimum temperature for decomposition of F_2O to its elements but not for Cl_2O .

Is the student correct?

Justify your answer.

(Turn over)

[3 marks]

10. (b) F_2O is a strong oxidising agent and can oxidise Xe to XeF_4 whilst releasing oxygen gas.

(i) Write an equation for this process.

[1 mark]

(ii) Show that the xenon is oxidised in the process.

[1 mark]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (c) F_2O reacts slowly with water to produce HF , a weak acid.



A small amount of F_2O is added to 400 cm^3 of water at 15°C and it reacts completely. The reaction produces 82 cm^3 of oxygen gas at this temperature and 1 atm pressure.

continued on the next page . . .

Question 10 (c) continued

10. (c) (i) Calculate the concentration of the HF solution formed.

Space for working:

concentration = _____ mol dm⁻³

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (c) continued

10. (c) (ii) Calculate the pH of the HF solution formed.

$$K_a (\text{HF}) = 6.6 \times 10^{-4} \text{ mol dm}^{-3}$$

Space for working:

pH = _____

[3 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (d) Cl_2O can react with water in a reversible reaction.



This reaction can occur in non – aqueous solvents and in a particular solvent the value of the equilibrium constant, K_{C} , at 273 K is 5.0 and it has no units.

- (i) Write an expression for the equilibrium constant K_{C} .

[1 mark]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (d) (ii) A student studies the equilibrium at a higher temperature. She adds samples of **0.40 mol** of **H₂O** and **0.14 mol** of **Cl₂O** to the non-aqueous solvent giving a total volume of **1000 cm³**
- At equilibrium the concentration of **HOCl** is **0.22 mol dm⁻³**
- I. Find the value of the equilibrium constant ***K_c*** at this temperature.

Space for working:

K_c = _____

[3 marks]

continued on the next page . . .

(Turn over)

Question 10 (d) (ii) continued

10. (d) (ii) II. State, giving a reason, whether this reaction is endothermic or exothermic.

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (d) (ii) continued

10. (d) (ii) III. Look at the equation for Question 10 (d) (ii) III. In the separate Diagram Booklet. HOCl can act as an oxidising agent.

Look at the table for Question 10 (b) (ii) III. In the separate Diagram Booklet. Give the formulae of all the metal ions in the table that can be oxidised by HOCl (aq). Explain why you have chosen these ions.

[2 marks]

(Total for Question 10 = 18 marks)

(Turn over)

11. Carboxylic acids are classed as weak acids.

(a) State what is meant by the term weak acid.

[1 mark]

**(b) Substituted propanoic acids,
 $\text{CH}_3\text{CHXCOOH}$, have different acid
strengths.**

**Look at the table for Question 11 (b)
in the separate Diagram Booklet.**

**The table gives some information about
three substituted propanoic acids.**

continued on the next page . . .

(Turn over)

Question 11 (b) continued

Place these acids in order of increasing acid strength. YOU MUST SHOW YOUR WORKING.

Space for working:

Weakest _____ **Strongest**

[3 marks]

continued on the next page . . .

(Turn over)

Question 11 continued

11. (c) A buffer is produced by mixing 100 cm^3 of ethanoic acid ($K_a = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$) of concentration 0.80 mol dm^{-3} with 50 cm^3 of aqueous sodium hydroxide of concentration 0.80 mol dm^{-3} at a temperature of 298 K .

(i) Calculate the initial pH of the aqueous sodium hydroxide.

Space for working:

pH = _____

[2 marks]

continued on the next page . . .

(Turn over)

Question 11 (c) continued

11. (c) (ii) Calculate the pH of the buffer solution.

Space for working:

pH = _____

[2 marks]

continued on the next page . . .

(Turn over)

12. The formula of an unknown mineral is $\text{Mg}_a\text{X}_b(\text{CO}_3)_c(\text{OH})_d \cdot e\text{H}_2\text{O}$.

Look at the table for Question 12 in the separate Diagram Booklet.

A student performs a series of experiments to calculate the values **a**, **b**, **c**, **d** and **e** and name element **X**.

- (a) Find the value of **e**, the number of water molecules in each formula unit.

Space for working:

e = _____

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

- 12. (b) Find the value of C, the number of carbonate ions in each formula unit.**

Space for working:

C = _____

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

12. (c) Explain the observations seen in experiment 3. Use these to name element X.

[3 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

12. (d) In experiment 4 the acid reacts with all the hydroxide and carbonate ions.



Calculate the value of d , the number of hydroxide ions present in each formula unit.

Space for working:

$d =$ _____

[4 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

12. (e) The compound has 56 atoms in each formula unit.

Use your answers to (a), (b), (c) and (d), and the total number of atoms to find the formula of the mineral.

Space for working:

Formula _____

[3 marks]

(Total for Question 12 = 14 marks)

END OF PAPER

TOTAL 80 MARKS

(Turn over)



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CHEMISTRY – A2 UNIT 3

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Diagram Booklet

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

Question 2

Table

	Enthalpy / kJ mol^{-1}
Standard enthalpy of hydration for Ag^+	-464
Standard enthalpy of hydration for Cl^-	-364
Enthalpy of lattice formation of AgCl	-905

Question 8 (d)

Equation

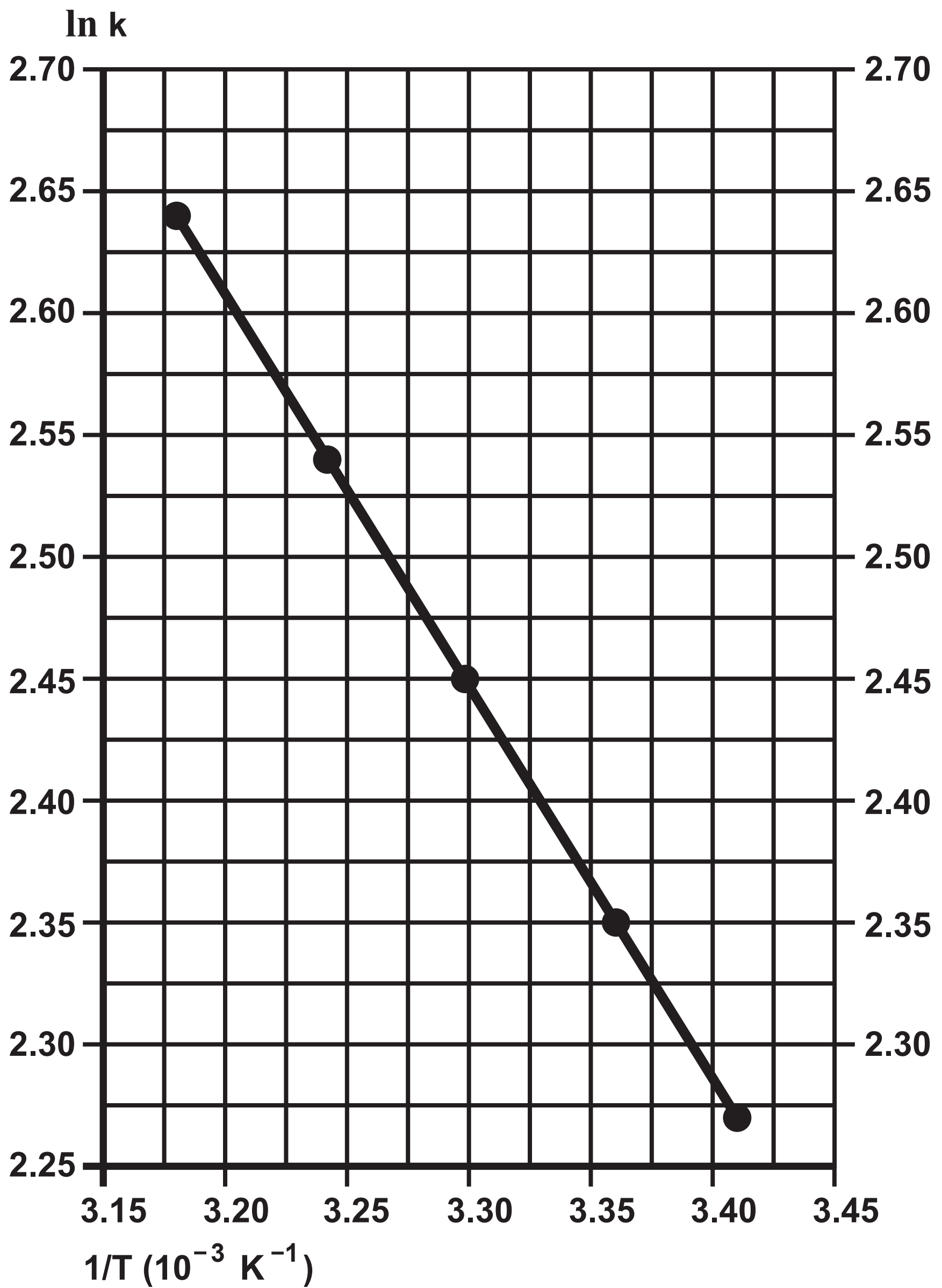


$$\Delta H^\theta = 348 \text{ kJ mol}^{-1} \quad \Delta S^\theta = 385 \text{ J K}^{-1} \text{ mol}^{-1}$$

Table

Substance	Standard enthalpy change of formation, $\Delta_f H^\theta / \text{kJ mol}^{-1}$
K_2CrO_4	- 1382
Cr_2O_3	- 1128

Question 9 (c) (ii)



Question 10 (a)

Table

Substance	Standard enthalpy change of formation, $\Delta_f H^\theta / \text{kJ mol}^{-1}$	Standard molar entropy, $S^\theta / \text{J K}^{-1} \text{mol}^{-1}$
F₂O	24.5	247
Cl₂O	80.3	266
O₂		205
F₂		203
Cl₂	0	

Question 10 (d) (ii) III.

Equation



Question 10 (d) (ii) III.

Table

	Standard electrode potential, E^θ / V
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77
$\text{Tl}^{3+} + 2\text{e}^- \rightleftharpoons \text{Tl}^+$	+1.25
$\text{Pb}^{4+} + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+}$	+1.69
$\text{Co}^{3+} + \text{e}^- \rightleftharpoons \text{Co}^{2+}$	+1.82

Question 11 (b)

Table

Substituted propanoic acid, CH₃CHXCOOH	
X = H	The pH of a 0.50 mol dm⁻³ aqueous solution is 2.59
X = Cl	$K_a = 1.48 \times 10^{-3}$ mol dm⁻³
X = OH	p<i>K</i>_a = 3.86

Question 12
Information

Experiment Number	Experiment	Result
1	Heating a sample of 0.0200 mol of the mineral to dryness.	The sample loses 1.44 g of mass.
2	Addition of 0.0200 mol of the mineral to excess hydrochloric acid.	A volume of 490 cm³ of carbon dioxide gas is released at 298 K and 1 atm pressure. The remaining solution has a green colour.
3	Addition of excess aqueous sodium hydroxide gradually to the solution produced in experiment 2 .	A precipitate forms that shows a mixture of white and grey–green colours. Addition of excess sodium hydroxide leaves a white precipitate in a green solution.
4	Addition of a sample of 1.00 × 10⁻³ mol of the mineral to 25.0 cm³ of HCl of concentration 1.00 mol dm⁻³ . Titration of the remaining acid against standard aqueous sodium hydroxide of concentration 0.500 mol dm⁻³	A volume of 14.00 cm³ of the aqueous sodium hydroxide is required for complete reaction.