GCE A LEVEL

1410U30 – 1

MONDAY, 10 JUNE 2024 – 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 5.	10	
Section B	6.	9	
	7.	10	
	8.	18	
	9.	13	
	10.	20	
	Total	80	

ADDITIONAL MATERIALS

A calculator and ruler

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.

SECTION A Answer ALL questions.

SECTION B Answer ALL questions.

Write your answers in the spaces provided. If you run out of space, use the additional pages at the back of this 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 Question 10 (c) (ii).

SECTION A

Answer ALL questions.

1. (a) Write an equation, including state symbols, that represents the enthalpy change of lattice formation of solid magnesium chloride.

_____

[1 mark]

(b) Refer to the EQUATION for Question 1 (b) in the separate Diagram Booklet.
Complete the EQUATION.

[1 mark]

(Total for Question 1 = 2 marks)

2. Refer to the EQUATION for Question 2 (a) in the separate Diagram Booklet. When chlorine is bubbled into cold sodium hydroxide solution, the reaction shown occurs.

(a) Show that this is a disproportionation reaction.

[2 marks]

(b) Give ONE common use for sodium chlorate(I).

[1 mark]

(Total for Question 2 = 3 marks)

3. Calcium hydroxide, $Ca(OH)_2$, is a strong base that is sparingly soluble in water. A saturated solution of calcium hydroxide has a concentration of $2 \cdot 34 \times 10^{-2}$ mol dm^{-3} at 298 K

Find the pH of this solution.

Space for working

pH = _____

[2 marks]

(Total for Question 3 = 2 marks)

4. One proposal to reduce the carbon dioxide emissions from public transport is to replace diesel trains with trains powered by hydrogen fuel cells. Give ONE OTHER advantage of using hydrogen fuel cells.

_____

_____

_____

[1 mark]

(Total for Question 4 = 1 mark)

5. **Bismuth is the heaviest naturally occurring element in Group 5**

Suggest which oxidation state of bismuth would be most stable. Give a reason for your answer.

[2 marks]

(Total for Question 5 = 2 marks)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions.

6. Ammonia is a versatile compound produced on a large scale. It is used in fertilisers and cleaning products and to make a range of other nitrogen − containing compounds.

(a) Ammonia is an example of a weak base.

(i) State what is meant by a base and explain why the ammonia molecule is able to act as a base.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 6 (a) continued

6. (a) (ii) Ammonia can be used as part of a mixture that forms a buffer.

I. Suggest a compound that could be added to ammonia solution to form a buffer.

_____

_____

[1 mark]

II. Suggest a use for a buffer.

_____

_____

[1 mark]

continued on the next page . . .

Question 6 continued

6. (b) Ammonia can form a compound with borane (BH_3).

(i) Draw a dot and cross diagram of the compound formed in the space below.

[1 mark]

continued on the next page . . .

Question 6 (b) continued

6. (b) (ii) Boron − nitrogen bonds are also present in boron nitride. One form of boron nitride (hexagonal boron nitride) is sometimes called white graphite.

Complete the table for Question 6 (b) (ii) in the separate Diagram Booklet, giving similarities and differences in the structure and bonding of hexagonal boron nitride and graphite. One similarity has been included for you. A spare copy of the table has been provided.

[2 marks]

continued on the next page . . .

Question 6 continued

6. (c) Nitrogen forms a range of compounds such as NH_3 and NF_3 which have three covalent bonds. Phosphorus can form compounds such as PF_3 which has three covalent bonds and PF_5 which has five covalent bonds.

Explain this difference in the chemistry of nitrogen and phosphorus.

[2 marks]

(Total for Question 6 = 9 marks)

7. One method of studying the rates of chemical reactions is to use a clock reaction.

One clock reaction involves the reaction between iodate(V) ions, IO_3^-, and hydrogensulfate(IV) ions, HSO_3^-

A student is given the following three solutions:

- sodium hydrogensulfate(IV) solution containing $HSO_3^-(aq)$
- potassium iodate(V) solution containing $IO_3^-(aq)$
- starch solution

He is also provided with deionised water.

The student combines the volumes of solutions shown in the table for Question 7 in the separate Diagram Booklet and measures the time taken for the colour to change.

continued on the next page . . .

Question 7 continued

7. (a) Complete the table to show the volume of deionised water that should be used in the final experiment. Give a reason for the value you have chosen.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 7 continued

7. (b) Find the order of reaction with respect to iodate(V) ions. Explain how you reached your conclusion.

Space for working

[2 marks]

continued on the next page . . .

Question 7 continued

7. (c) The reaction is fourth order overall. Suggest a rate equation for the reaction.

_____

[2 marks]

(d) Suggest a rate determining step for the reaction.

_____

[1 mark]

(e) Addition of lead(II) ions to the mixture after the reaction produces a mixture of products including lead(II) iodide and lead(II) iodate(V).

(i) Give the colour of lead(II) iodide.

_____

[1 mark]

continued on the next page . . .

Question 7 (e) continued

7. (e) (ii) A sample of lead(II) iodate(V) decomposes on heating to give a mixture of solids and a mixture of oxygen gas and iodine vapour.

At a temperature of $200\,^{\circ}C$, the volume of gas is $220\ cm^3$, but when cooled to $20\,^{\circ}C$ the iodine solidifies and the volume of gas is $110\ cm^3$

Calculate the number of moles of gas at these two temperatures and hence find the percentage of iodine molecules in the original gas mixture.

[All volumes are measured at a pressure of $1 \cdot 01 \times 10^5\ Pa$]

Space for working continues on the next page.

Question 7 (e) (ii) continued

Number of moles of gas at 200 °C = _____ mol

Number of moles of gas at 20 °C = _____ mol

Percentage of iodine molecules = _____ %

[3 marks]

(Total for Question 7 = 10 marks)

8. Vanadium is a transition element that forms compounds with a wide range of oxidation states. Its compounds are also used in a number of catalysts.

(a) State why transition elements can form a range of oxidation states in their compounds.

_____

_____

_____

[1 mark]

(b) Refer to the diagram for Question 8 (b) in the separate Diagram Booklet. The diagram shows the visible spectrum of an aqueous solution of a compound containing V^{3+} ions.

continued on the next page . . .

Question 8 (b) continued

8. (b) (i) Suggest the colour expected for aqueous solutions of V^{3+} compounds.

Give a reason for your answer.

[2 marks]

(ii) In aqueous solutions, most vanadium ions form complexes with water acting as a ligand.

I. Give the meaning of the term ligand.

[1 mark]

continued on the next page . . .

Question 8 (b) (ii) continued

8. (b) (ii) II. Describe the bonding that occurs between the ligand and the transition metal ion.

[2 marks]

continued on the next page . . .

Question 8 continued

8. (c) VO_2^+ **ions can be reduced to** VO^{2+} **ions by iodide ions as shown below.**

$$2VO_2^+ + 4H^+ + 2I^- \longrightarrow 2VO^{2+} + 2H_2O + I_2$$

(i) Write the half − equation for the oxidation of iodide ions.

[1 mark]

(ii) Write the half − equation for the reduction of VO_2^+ **ions in acid solution.**

[1 mark]

continued on the next page . . .

Question 8 continued

8. (d) Vanadium(V) oxide, V_2O_5, is used as a heterogeneous catalyst in the contact process.

(i) State what is meant by the term heterogeneous in this context.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 8 (d) continued

8. (d) (ii) This catalyst is used to catalyse the oxidation of sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

$\Delta H^{\theta} = -197 \text{ kJ mol}^{-1}$

$\Delta S^{\theta} = -187 \text{ J K}^{-1} \text{ mol}^{-1}$

I. The standard enthalpy change of formation of sulfur dioxide is -297 kJ mol^{-1}

Calculate the standard enthalpy change of formation of sulfur trioxide, SO_3

Space for working

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

[2 marks]

continued on the next page . . .

Question 8 (d) (ii) continued

8. (d) (ii) II. A student calculates the value at which $\Delta G = 0$ and states that this is the minimum temperature needed for the reaction to occur.

Find the temperature at which $\Delta G = 0$ and state, giving a reason, whether this is the MINIMUM temperature needed for the reaction to occur.

Space for working

Temperature = _____ K

_____

_____

[3 marks]

8. (d) (ii) III. Samples of $0 \cdot 040$ mol of SO_2 and $0 \cdot 040$ mol of O_2 are placed in a sealed vessel of volume $2 \cdot 00$ dm^3 The reaction is allowed to come to equilibrium, giving a concentration of $0 \cdot 014$ mol dm^{-3} of SO_3

Calculate the value of the equilibrium constant, K_c, under these conditions, giving its unit.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Space for working continues on the next page.

Question 8 (d) (ii) lll continued

K_c = _____

Unit _____

[4 marks]

(Total for Question 8 = 18 marks)

9. (a) Addition of a solution containing $Ag^+(aq)$ to solutions containing halide ions such as chloride, bromide or iodide causes precipitates to form.

(i) Give the colours of the precipitates formed with chloride, bromide and iodide ions.

chloride ions _____

bromide ions _____

iodide ions _____

[1 mark]

(ii) Refer to the table for Question 9 (a) (ii) in the separate Diagram Booklet. The standard enthalpy change of formation of $AgCl(s)$ is $-127 \cdot 1\ kJ\ mol^{-1}$

Use the data in the table to calculate the standard enthalpy change of formation of $AgBr(s)$ and hence show which of the two silver halides is more stable with respect to its elements. You MUST show your working.

continued on the next page . . .

Question 9 (a) (ii) continued

Space for working

[4 marks]

continued on the next page . . .

Question 9 continued

9. (b) The standard electrode potential for the half−equation below is +0•80 V

$$Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$$

(i) When a piece of copper metal is placed in a solution of silver nitrate, a displacement reaction occurs.

I. Write the IONIC equation for this displacement reaction.

[1 mark]

continued on the next page . . .

Question 9 (b) (i) continued

9. (b) (i) II. State what information this provides regarding the standard electrode potential for the $Cu(s)\,|\,Cu^{2+}(aq)$ half−cell. Give a reason for your answer.

_____

_____

_____

_____

_____

[2 marks]

(ii) Refer to the diagram for Question 9 (b) (ii) in the separate Diagram Booklet. The apparatus shown in the diagram was assembled with the $Pb(s)\,|\,Pb^{2+}(aq)$ half−cell under standard conditions connected to the $Ag(s)\,|\,Ag^{+}(aq)$ half−cell. The silver is the positive electrode.

continued on the next page . . .

Question 9 (b) (ii) continued

The value on the high−resistance voltmeter was recorded with different concentrations of silver ions used in the $Ag(s)\,|\,Ag^{+}(aq)$ half−cell. The results are shown in the table below.

Concentration of $Ag^{+}(aq)$ (mol dm^{-3})	Value recorded on high−resistance voltmeter (V)
1•0	0•93
0•1	0•87
0•01	0•81
0•001	0•75
0•0001	0•69

continued on the next page . . .

Question 9 (b) (ii) continued

9. (b) (ii) I. Calculate the value of the standard electrode potential for the $Pb(s) \mid Pb^{2+}(aq)$ half-cell.

Space for working.

E^{θ} = _____ V

[2 marks]

continued on the next page . . .

Question 9 (b) (ii) continued

9. (b) (ii) II. Explain why the value recorded on the voltmeter becomes less positive as the concentration of silver ions decreases.

[3 marks]

(Total for Question 9 = 13 marks)

10. Abandoned metal mines in Wales contribute to the pollution of some rivers and streams. The mines on Parys mountain on Anglesey have led the Afon Goch stream to become acidic and carry a range of metal ions.

(a) The pH of the initial stretch of Afon Goch was found to be $3 \cdot 24$

Calculate the concentration of H^+ ions in this water.

Space for working.

$[H^+]$ = _____ mol dm^{-3}

[2 marks]

continued on the next page . . .

Question 10 continued

10. (b) The three main metals contaminating the water of Afon Goch are iron, copper and zinc. A research group wishes to find the concentrations of all three metals in a water sample from the river.

An initial reduction step converts all the iron ions present to Fe^{2+} and all the copper ions present to copper metal. The AMPHOTERIC zinc ions are not affected. This produces test water A.

continued on the next page . . .

Question 10 (b) continued

Two students are asked to find the concentration of Fe^{2+} ions in test water A.

10. (b) (i) The reduction step produced $4 \cdot 55$ mg of copper metal from a 250 cm^3 sample of river water.

Suggest how this could be separated from test water A.

[1 mark]

(ii) One student attempts to find the iron content in $25 \cdot 0$ cm^3 of test water A by gravimetric analysis. He adds excess aqueous sodium hydroxide, filters and then heats the precipitate in an oxygen − rich atmosphere.

continued on the next page . . .

Question 10 (b) (ii) continued

10. (b) (ii) I. Give TWO reasons why the aqueous sodium hydroxide that is added must be in excess.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 10 (b) (ii) continued

10. (b) (ii) II. The experiment produced 14•5 mg of Fe_2O_3

Use this value to show that the concentration of Fe^{2+} ions in test water A is $7•27 \times 10^{-3}$ mol dm^{-3}

$M_r(Fe_2O_3) = 159•6$

Space for working

[2 marks]

continued on the next page . . .

Question 10 (b) (ii) continued

10. (b) (ii) III. The total error when measuring the mass of Fe_2O_3 by difference was $0 \cdot 2$ mg

Find the percentage error in this measurement.

Space for working

Percentage error = _____ %

[1 mark]

continued on the next page . . .

Question 10 (b) continued

10. (b) (iii) The second student titrated $25 \cdot 0\ cm^3$ samples of test water **A** against a solution of acidified potassium manganate(VII) of concentration $2 \cdot 10 \times 10^{-3}\ mol\ dm^{-3}$

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

The mean volume of acidified potassium manganate(VII) solution required for reaction was $18 \cdot 10\ cm^3$ and the percentage error in the titration was $0 \cdot 8\%$

I. State what observation would be made at the end-point of the titration.

_____

_____

[1 mark]

continued on the next page . . .

Question 10 (b) (iii) continued

10. (b) (iii) II. Calculate the concentration of Fe^{2+} ions in the sample of test water A.

Space for working

Concentration = _____ mol dm^{-3}

[2 marks]

continued on the next page . . .

Question 10 (b) continued

10. (b) (iv) The two students compared their results and decided that they are in agreement.

Calculate the percentage difference between the concentrations of Fe^{2+} ions found by the two students in parts (ii) and (iii) and hence show whether the students' decision is valid.

Space for working

Percentage difference = _____ %

[2 marks]

continued on the next page . . .

Question 10 continued

10. (c) Refer to DIAGRAM 1 for Question 10 (c) in the separate Diagram Booklet. One method of determining the concentration of copper ions present in a solution is to form a complex ion with a characteristic colour and measure the concentration of this using colorimetry.
Two such copper complexes are

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ **and**

$[Cu(cyclen)(H_2O)_2]^{2+}$

The structural formulae of these two complexes are shown in DIAGRAM 1.

Cyclen is a cyclic tetradentate ligand with four nitrogen atoms that can bond to a transition metal ion. The structure of the cyclen ligand is shown in DIAGRAM 2 for Question 10 (c) in the separate Diagram Booklet.

continued on the next page . . .

Question 10 (c) continued

10. (c) (i) Give the colour of the

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex.

_____

[1 mark]

(ii) An equilibrium exists between

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ and

$[Cu(cyclen)(H_2O)_2]^{2+}$ in aqueous solution.

Refer to the EQUATION for Question 10 (c) (ii) in the separate Diagram Booklet.

Measurements show that the strengths of the Cu—N bonds in

$[Cu(NH_3)_4(H_2O)_2]^{2+}$

and $[Cu(cyclen)(H_2O)_2]^{2+}$ are similar and that the Gibbs free energy change for the equilibrium is negative.

continued on the next page . . .

Question 10 (c) (ii) continued

Discuss the information given.

Your answer should:

- **explain why the enthalpy change for the reaction is very small**
- **suggest why the Gibbs free energy change for this equilibrium would be negative**
- **state and explain the effect of a negative Gibbs free energy change on the value of K_c for an equilibrium**

[6 QER marks]

(Total for Question 10 = 20 marks)

TOTAL FOR SECTION B = 70 MARKS

END OF PAPER

TOTAL FOR PAPER = 80 MARKS

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

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GCE A LEVEL

1410U30–1

MONDAY, 10 JUNE 2024 – MORNING

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 1 (b)

EQUATION

$$\text{standard enthalpy change of solution} = \frac{\quad}{\quad} - \text{standard enthalpy change of lattice formation}$$

Question 2 (a)

EQUATION

Question 6 (b) (ii)

TABLE

	Similarity between hexagonal boron nitride and graphite	Difference between hexagonal boron nitride and graphite
Structure		

continued on the next page . . .

Question 6 (b) (ii) continued

TABLE

	Similarity between hexagonal boron nitride and graphite	Difference between hexagonal boron nitride and graphite
Bonding	each atom is bonded by covalent bonds to three others in both graphite and BN	

Spare copy

Question 6 (b) (ii)

TABLE

	Similarity between hexagonal boron nitride and graphite	Difference between hexagonal boron nitride and graphite
Structure		

continued on the next page . . .

TABLE

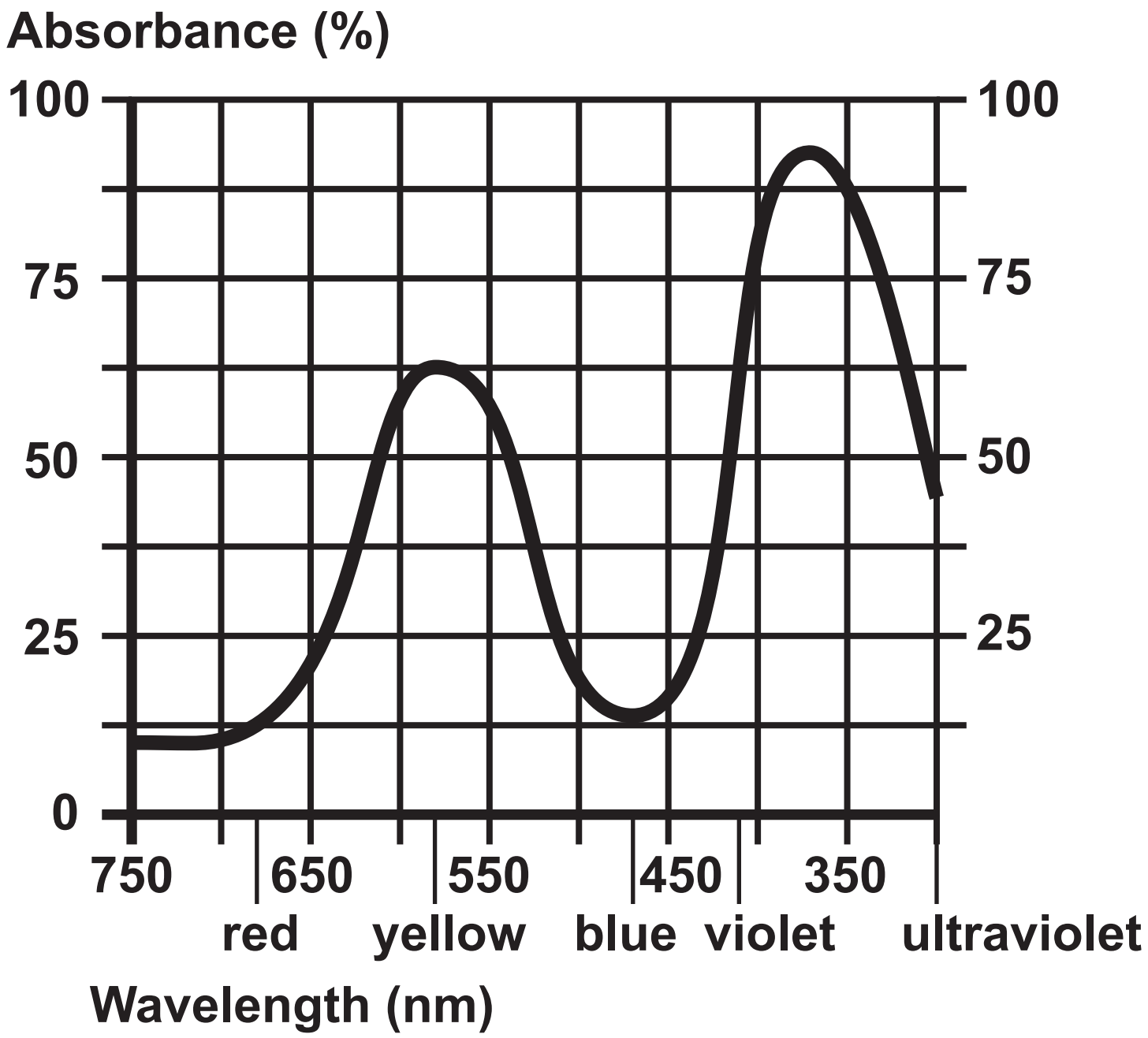
	Similarity between hexagonal boron nitride and graphite	Difference between hexagonal boron nitride and graphite
Bonding	each atom is bonded by covalent bonds to three others in both graphite and BN	

Question 7

TABLE

Volume of HSO_3^- (cm^3)	Volume of IO_3^- (cm^3)	Volume of starch (cm^3)	Volume of deionised water (cm^3)	Time (s)
10	10	5	25	164
10	20	5	15	82
10	30	5	_____	55

Question 8 (b)

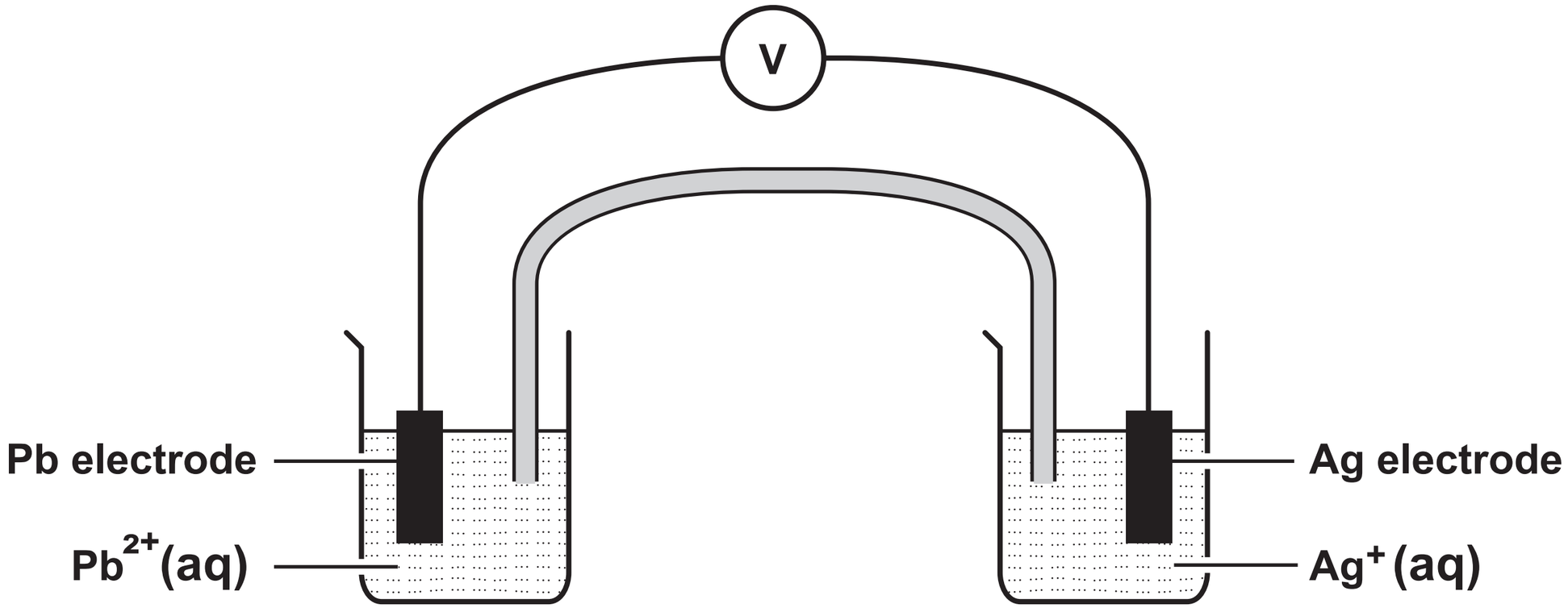

Absorbance (%)
100
75
50
25
0
100
75
50
25
750
650
550
450
350
red
yellow
blue
violet
ultraviolet
Wavelength (nm)

Question 9 (a) (ii)

TABLE

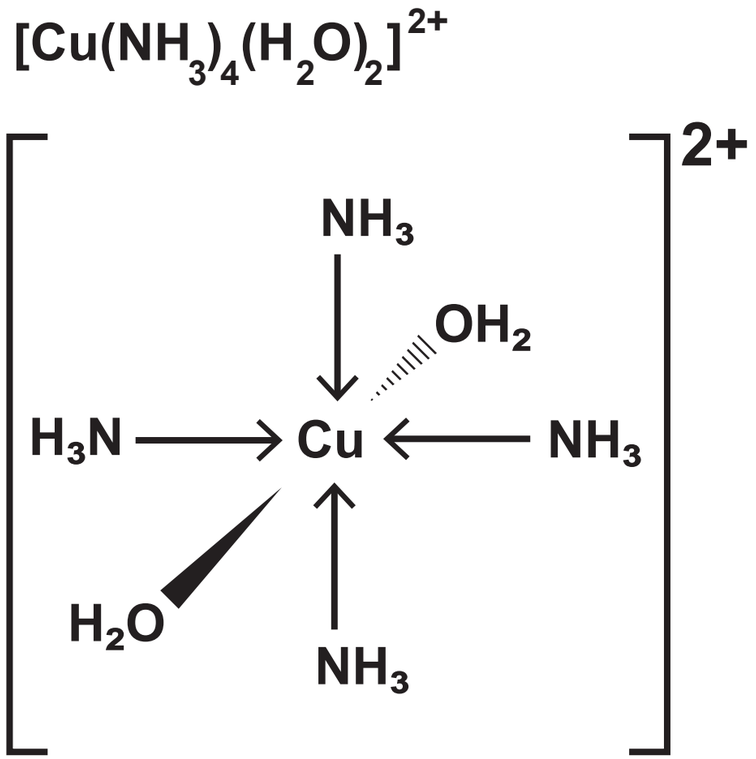
Reaction	Standard enthalpy change, ΔH^{θ} (kJ mol^{-1})
$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$	+105•6
$Br_2(l) + 2e^{-} \longrightarrow 2Br^{-}(aq)$	–243•1
$AgBr(s) \longrightarrow Ag^{+}(aq) + Br^{-}(aq)$	+84•4

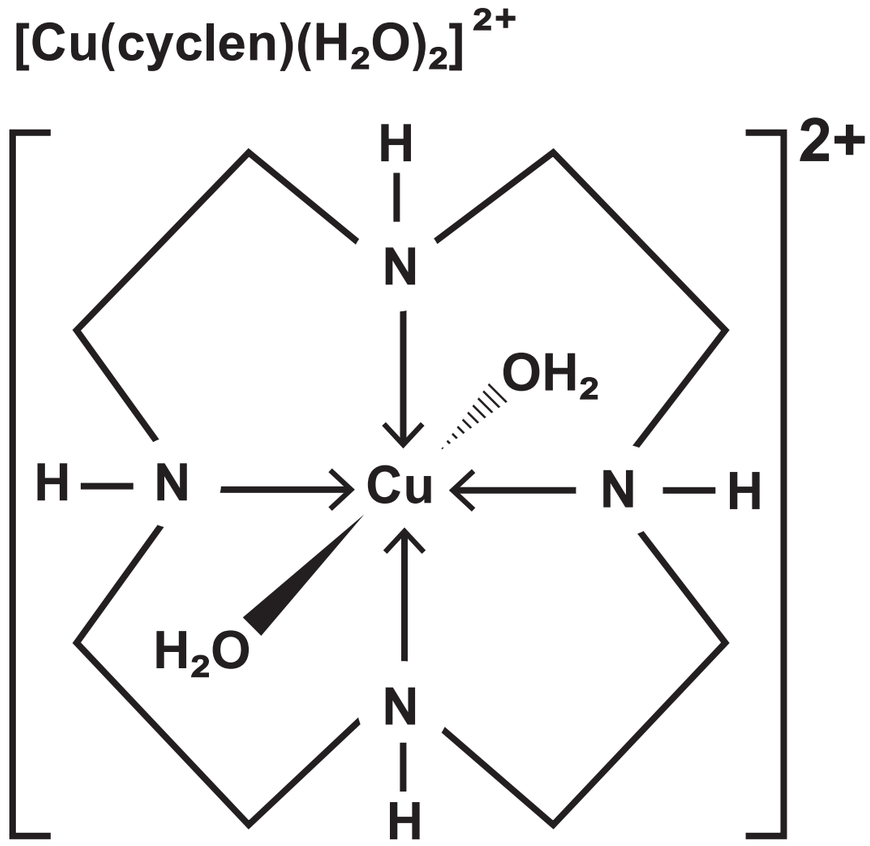
Question 9 (b) (ii)



Question 10 (c)

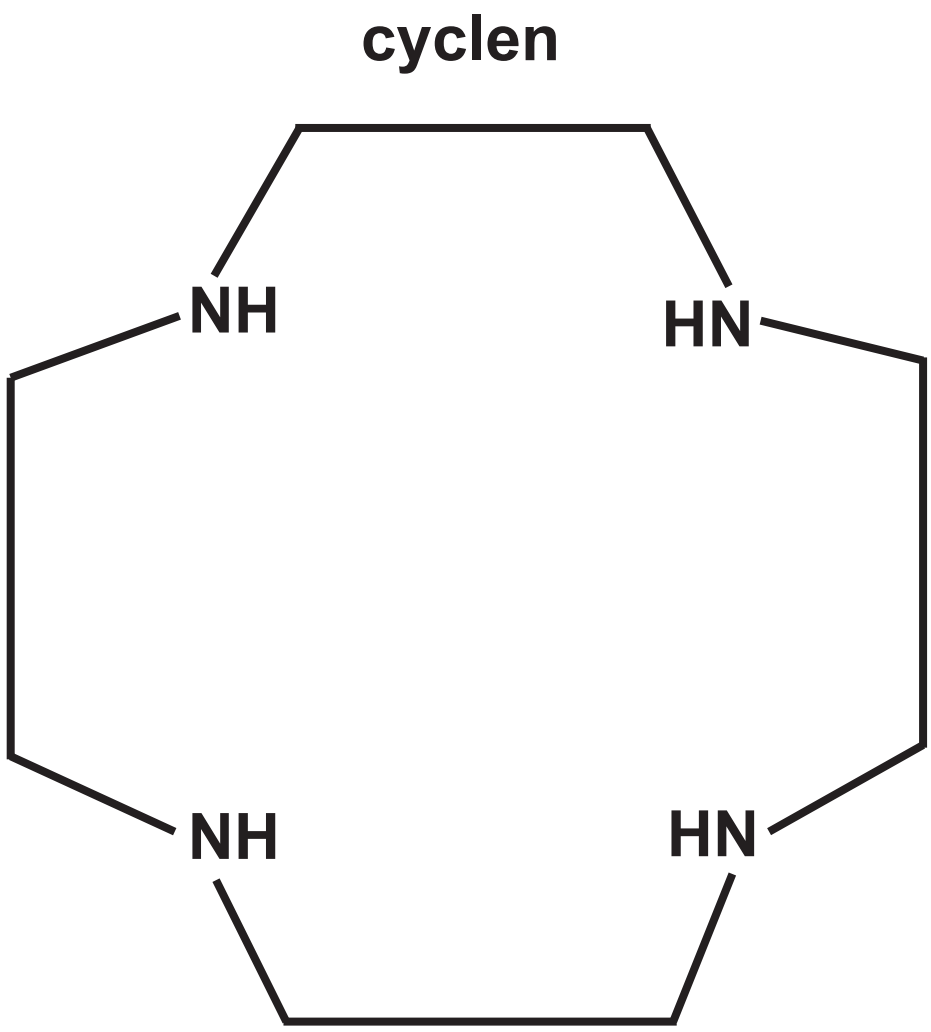
DIAGRAM 1





Question 10 (c)

DIAGRAM 2



Question 10 (c) (ii)

EQUATION

$\Delta H^{\theta} = +1 \cdot 2 \text{ kJ mol}^{-1}$