Candidate Full Name:	Candidate Number:

Anglo-Chinese School
(Independent)

THE BEST IS YET TO BE

YEAR 6 PRELIMINARY EXAMINATION 2021
INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME
CHEMISTRY HIGHER LEVEL

PAPER 2

Monday **13th September 2021** **2 hours 15 minutes**

INSTRUCTIONS TO CANDIDATES
- Do not open this examination paper until instructed to do so.
- Write your **candidate session number in the box above**.
- A calculator is required for this paper.
- A copy of the Chemistry Data Booklet is required for this paper.
- Write your answers in the boxes provided.
- If you use additional sheets of paper for your answer, attach them to the booklet. Indicate the question number clearly on these sheets.

For examiner's use	
Qn 1	/12
Qn 2	/8
Qn 3	/9
Qn 4	/11
Qn 5	/6
Qn 6	/11
Qn 7	/12
Qn 8	/7
Qn 9	/7
Qn 10	/7
Wrong s.f. /units	
Total	/90

This question paper consists of 20 printed pages including this cover page.

Answer **all** questions. Write your answers in the boxes provided.

1. (a) Sir James Jeans, who was a great populariser of science, once described an atom of carbon consisting of six bees buzzing around a space the size of a football stadium.

(i) Explain, in terms of an atom of carbon, what stopped the bees from flying away from the space of the football stadium. [1]

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(ii) State **one** inadequacy in Jeans' description when applied to an atom of carbon. [1]

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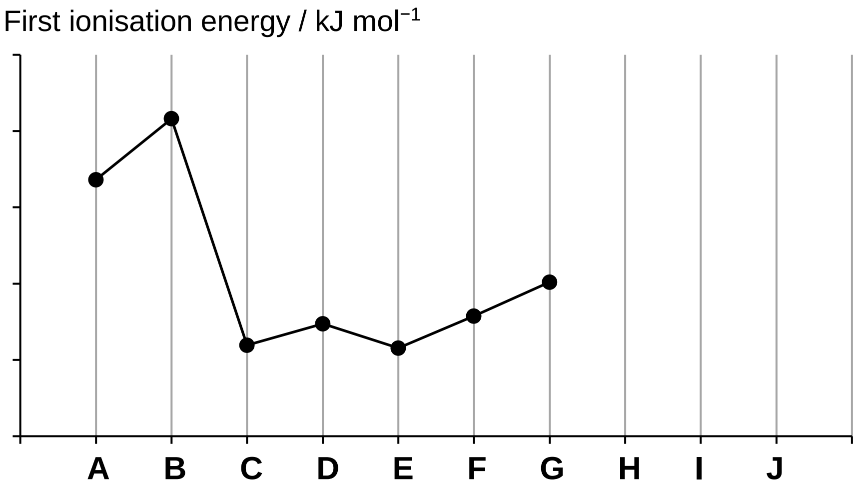
(b) The graph shows a sketch of the first ionisation energies of seven consecutive elements in Period 2 and 3 of the Periodic Table.



The letters are **not** the symbols of the elements.

(This question continues on the following page)

(Question 1 continued)

(i) Explain why the first ionisation energy of **C** is much lower than that of **B**. [2]

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(ii) Sketch on the same axes in (b) for the first ionisation energy trend of the elements **H**, **I** and **J**. [1]

(c) A 5.00 g mixture of sodium oxide and sulfur trioxide is dissolved in water to give a pH neutral solution.

(i) Write an equation for the reaction of each oxide with water. [2]

Sodium oxide: ....

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Sulfur trioxide: ....

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(ii) Determine the mass of sodium oxide in the mixture. [2]

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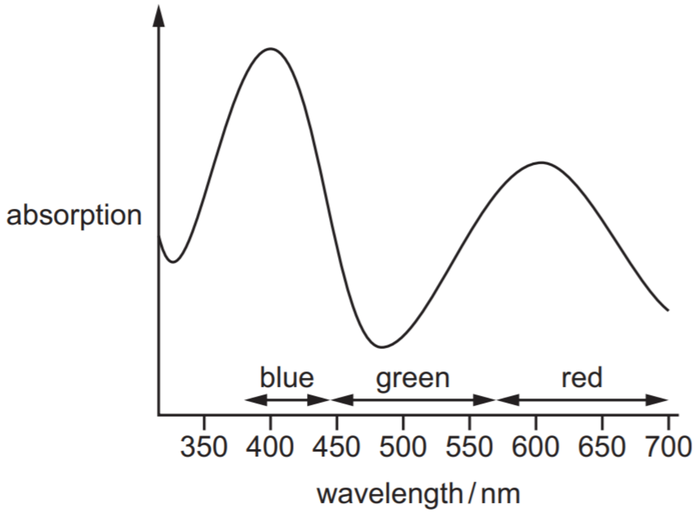
(Question 1 continued)

(d) (i) The diagram shows the visible spectrum of a solution of $[V(H_2O)_6]^{3+}$. [1]



State, giving a reason, the colour of the solution.

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(ii) $[V(H_2O)_6]^{3+}$ reacted with Zn under suitable conditions to form a different colour solution containing $[V(H_2O)_6]^{2+}$ and Zn^{2+}. [2]

Explain why the solution changed colour.

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2. (a) The compounds shown below have similar relative molecular masses. Arrange the following compounds in order of **increasing** boiling point. [1]

CH_3CH_2CHO, $CH_3CH_2CH_2CH_3$, CH_3COOH, $CH_3CH_2CH_2NH_2$.

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(b) Explain the order of boiling points in the compounds you have listed in (a), in terms of intermolecular forces. [3]

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(c) Deduce the type of hybridization shown by the nitrogen atoms in NF_4^+ and N_2H_2. [2]

NF_4^+: ....

N_2H_2: ....

(d) Describe how sigma (σ) and pi (π) bonds are formed. [2]

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3. Consider the following reaction:

$$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$$

(a) Using the average bond enthalpy values in section 11 of the Data Booklet, calculate the standard enthalpy change for this reaction. [2]

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(b) If ammonia was produced as a liquid and not as a gas, state and explain the effect this would have on the value of $\Delta H^{\ominus}$ for the reaction. [2]

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(c) The absolute entropy values, S, at 300 K for N_2 (g), H_2 (g) and NH_3 (g) are 193, 131 and 192 J $K^{-1}mol^{-1}$ respectively. Calculate $\Delta S^{\ominus}$ for the reaction and explain the sign of $\Delta S^{\ominus}$. [3]

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(Question 3 continued)

(d) Determine the temperature, in K, at which this reaction becomes spontaneous, using (a) and (c). [2]

(If you do not have answers for (a) and (c), use $\Delta H^{\ominus} = -100$ kJ and $\Delta S^{\ominus} = -300$ J K^{-1}, but these are not the correct answers.)

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4. 1,2-dibromoethane, $C_2H_4Br_2$, reacts with potassium iodide as shown in the equation.

$$C_2H_4Br_2 + 2KI \rightarrow C_2H_4 + 2KBr + I_2$$

10.0 cm^3 of potassium iodide solution was added to a 10.0 cm^3 of 1,2-dibromoethane solution in the presence of a known fixed amount of sodium thiosulfate and a little starch.

The iodine formed will first react with sodium thiosulfate and the excess iodine will react with starch to give a dark blue complex.

The time taken for an intense blue colour to appear is measured and the experiment was repeated using different volumes of 1,2-dibromoethane and potassium iodide.

Experiment	**Volume of $C_2H_4Br_2$ /cm^3**	**Volume of KI /cm^3**	**Volume of deionised water /cm^3**	**Time, t, for intense blue colour to appear /s**	**$\frac{1}{t}$* / $\times 10^{-2}$ s^{-1}**
1	10.0	10.0	0.0	35	2.86
2	7.5	10.0	2.5	47	2.13
3	12.5	5.0	2.5	56	1.79
4	5.0	7.5	7.5	**y**	**–**

**The reciprocal of the time in seconds can be used as a measure of the rate of reaction.*

(a) Write an equation for the reaction between iodine and sodium thiosulfate. [1]

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(Question 4 continued)

(b) Explain why the addition of sodium thiosulfate is necessary in this kinetic study. [1]

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(c) Deduce, giving your reason, the order of reaction with respect to 1,2-dibromoethane and potassium iodide. [2]

1,2-dibromoethane: ……..

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Potassium iodide: ……..

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(d) State the rate expression for the reaction. [1]

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(e) With reference to experiment 1 and 4, determine the time taken, **y**, in seconds in experiment 4 for the intense blue colour to appear. [1]

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(Question 4 continued)

(f) This method does not allow the initial rate to be determined. Outline a method that would allow the initial rate to be determined and how it can be obtained from the data collected. [2]

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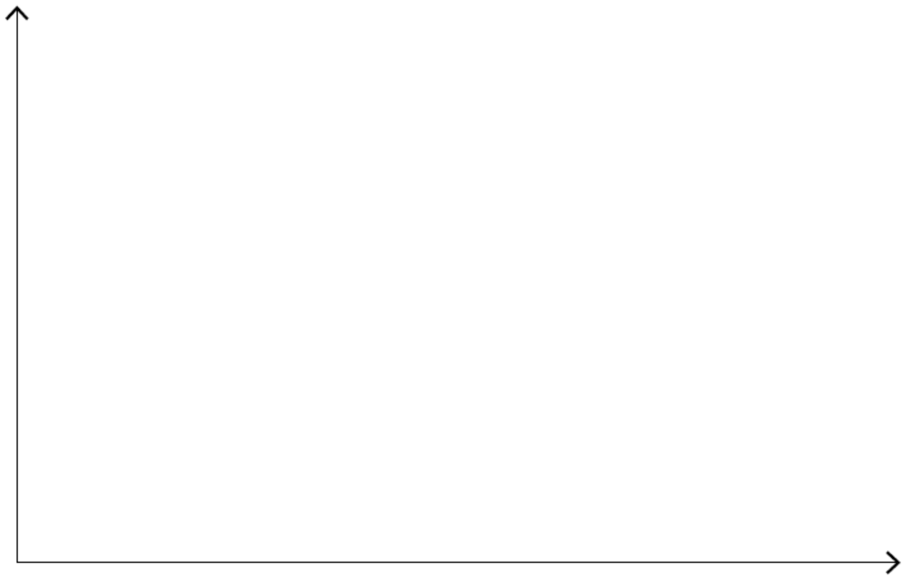
(g) (i) Additional experiments were carried out at an elevated temperature. On the axes below, label the axes and sketch the Maxwell–Boltzmann energy distribution curves at two temperatures T_1 and T_2, where $T_2 > T_1$. [2]



(ii) Suggest **one** reason why the values of rate of reaction obtained at higher temperatures may be less accurate. [1]

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5. About 75 % of the hydrogen produced for industrial use is from the steam-reforming process. This process is carried out in two stages.

The primary stage involves the reaction of methane with steam in the presence of nickel catalyst and high temperature to form a mixture of carbon monoxide and hydrogen, as shown in the following equation.

$$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO\,(g) + 3H_2\,(g)$$

(a) State the equilibrium constant expression, K_c, for the reversible reaction. [1]

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(b) In a particular set-up, 1.5 mol of methane was mixed with 2.8 mol of steam and passed into a 1 dm^3 reactor. When equilibrium was established, it was found that there was only 0.6 mol of methane remaining in the reacting vessel. [3]

Calculate the value of K_c for the reaction, leaving your answer to 2 significant figures.

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(This question continues on the following page)

(Question 5 continued)

(c) Predict the effect on the position of equilibrium when the following conditions are applied. [2]

The volume of the reactor is doubled:

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Powdered form of nickel catalyst is used instead of granules:

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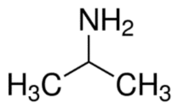
6. Isopropylamine, $(CH_3)_2CHNH_2$, is a common compound used as a starting material for the preparation of insecticides and pharmaceuticals. It behaves as a weak base in a similar manner to ammonia.



Isopropylamine

(a) Write an equation to show isopropylamine, $(CH_3)_2CHNH_2$, acting as a Brønsted–Lowry base and a different equation to show it acting as a Lewis base. [2]

Brønsted–Lowry base:

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Lewis base:

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(This question continues on the following page)

(Question 6 continued)

(b) Describe **two** tests that can be carried out in the laboratory, and the expected results to distinguish between 0.10 mol dm^{-3} aqueous isopropylamine and 0.10 mol dm^{-3} aqueous sodium hydroxide. [2]

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(c) 20.00 cm^3 of 0.10 mol dm^{-3} aqueous isopropylamine was reacted with 0.20 mol dm^{-3} aqueous hydrochloric acid to form isopropylammonium chloride, $(CH_3)_2CHNH_3Cl$.

(i) The initial pH of the isopropylamine solution was found to be 11.81. Determine the base dissociation constant, K_b, for isopropylamine. [2]

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(ii) Outline, using an equation, why isopropylammonium chloride is acidic. [1]

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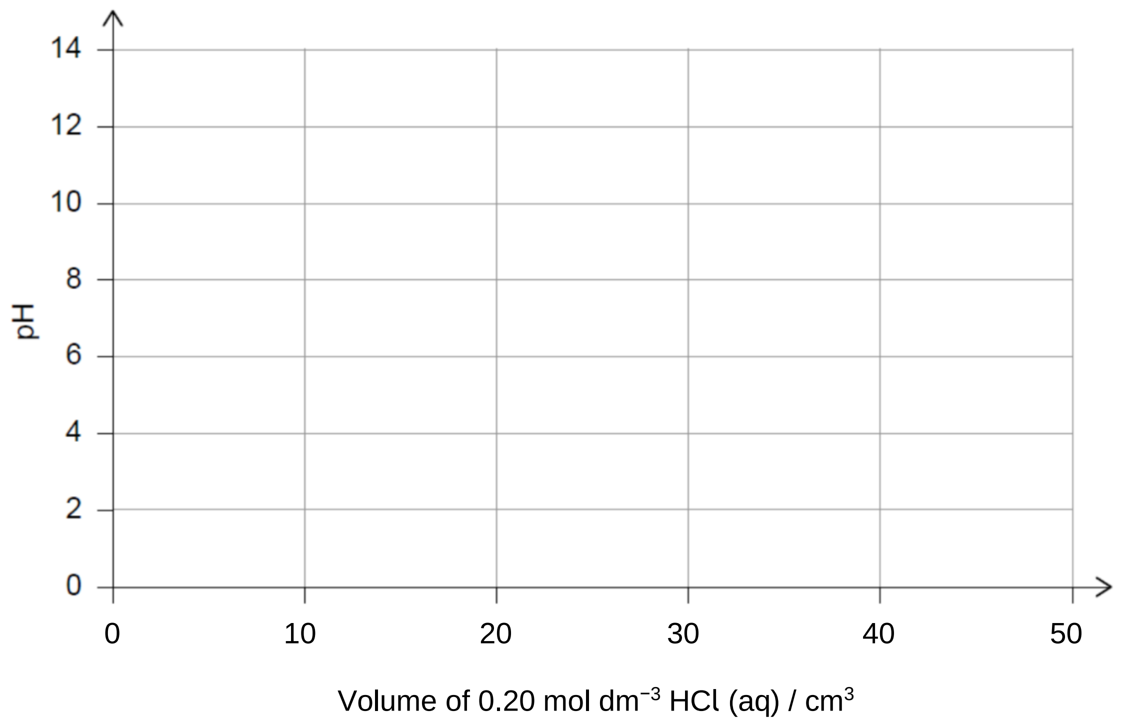
(Question 6 continued)

(iii) Sketch a graph of pH against volume when 50.00 cm^3 of 0.20 mol dm^{-3} HCl (aq) is gradually added to 20.0 cm^3 of 0.10 mol dm^{-3} $(CH_3)_2CHNH_2$ (aq). [2]



(iv) Suggest a suitable indicator for this titration, using section 22 of the data booklet. [1]

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(v) During the reaction, the partial neutralisation of isopropylamine with hydrochloric acid allows the mixture to act as a buffer solution. State the volume of 0.20 mol dm^{-3} HCl (aq) required to reach the maximum buffering capacity. [1]

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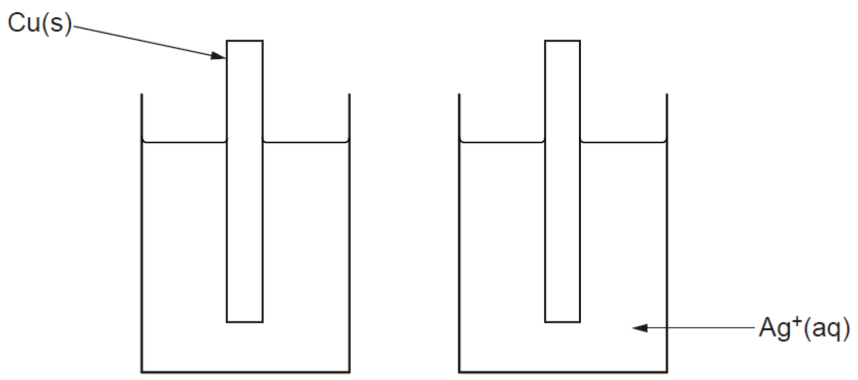
7. The diagram below shows an incomplete cell consisting of Cu^{2+}/Cu and Ag^{+}/Ag half-cells.



(a) (i) Deduce the equation for the cell reaction. [1]

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(ii) Draw and label the connections needed to show the direction of electron movement and ion flow between the two half-cells in the diagram above. [2]

(b) (i) Calculate the standard cell potential, $E^{\ominus}_{cell}$, using section 24 of the data booklet. [1]

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(ii) Using your answer to (b)(i) and section 1 of the data booklet, calculate the Gibbs free energy, $\Delta G^{\ominus}$, in kJ. [2]

(If you do not have answer for (b)(i), use $E^{\ominus}_{cell}$ = +0.50 V, but this is not the correct answer.)

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(This question continues on the following page)

(Question 7 continued)

(c) (i) The copper electrode in the earlier set up was obtained by purification of copper via an electrolytic cell. In the electrolytic cell, impure copper is the anode, pure copper is the cathode and the electrolyte is copper(II) sulfate solution. [2]

Formulate the half-equations at each electrode.

Positive Electrode:

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Negative Electrode:

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(ii) A current of 0.480 A is passed through the electrolytic cell for 50.0 minutes. Calculate the Faraday's constant for this experiment If the mass of copper deposited at the pure copper cathode is 0.500 g. [2]

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(iii) Using section 2 of the data booklet and your answer to (c)(ii), calculate the percentage error for the calculated Faraday's constant. [1]

(If you do not have answer for (c)(ii), use F = 92000 C mol^{-1}, but this is not the correct answer.)

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(iv) Suggest a possible reason for the deviation from the theoretical Faraday's constant. [1]

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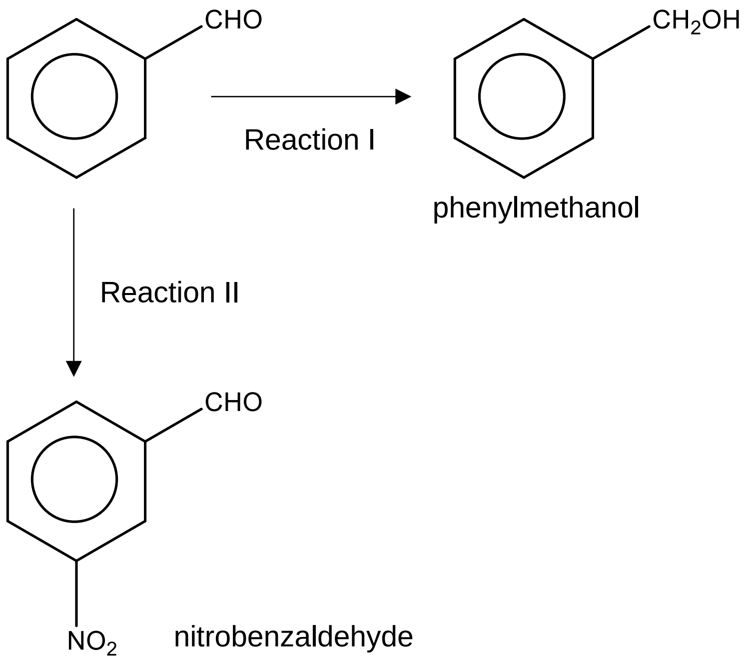
8. Benzaldehyde, C_6H_5CHO, is an organic compound that has the characteristic almond-like odour.

(a) Benzaldehyde undergoes reaction forming different compounds shown below.



(i) Name the type of reaction that occurs in each step. [2]

Reaction I: ....

Reaction II: ……..

(ii) State the reagents and conditions required for Reaction II to take place. [2]

Reagents: …..

Conditions: ....

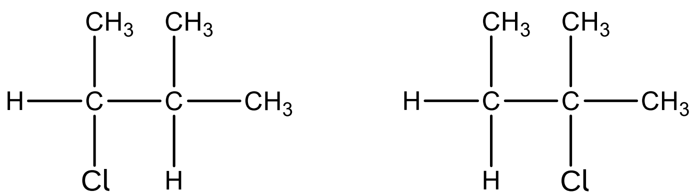
(This question continues on the following page)

(Question 8 continued)

(b) Phenylmethanol can also be synthesised in two steps using methylbenzene. [3]

Suggest the synthesis route including all the necessary reactants and conditions.

9. 2-methylbut-2-ene reacts with hydrogen chloride at room conditions to produce two products. The structural formulas of two organic compounds are shown below.



A **B**

(a) State the name of the major product formed from the reaction, applying IUPAC rules. [1]

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(Question 9 continued)

(b) Sketch the mechanism for the reaction of 2-methylbut-2-ene with hydrogen chloride using curly arrows to obtain the major product in (a). [4]

(c) Deduce, giving a reason, which compound, **A** or **B**, can exhibit optical activity. [1]

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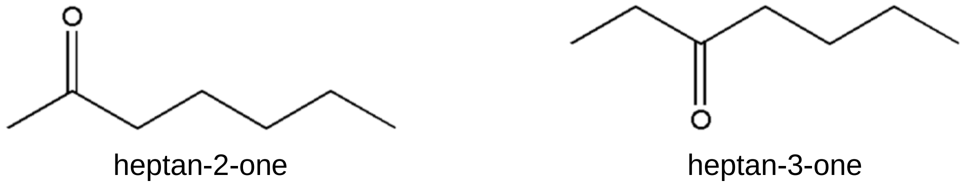
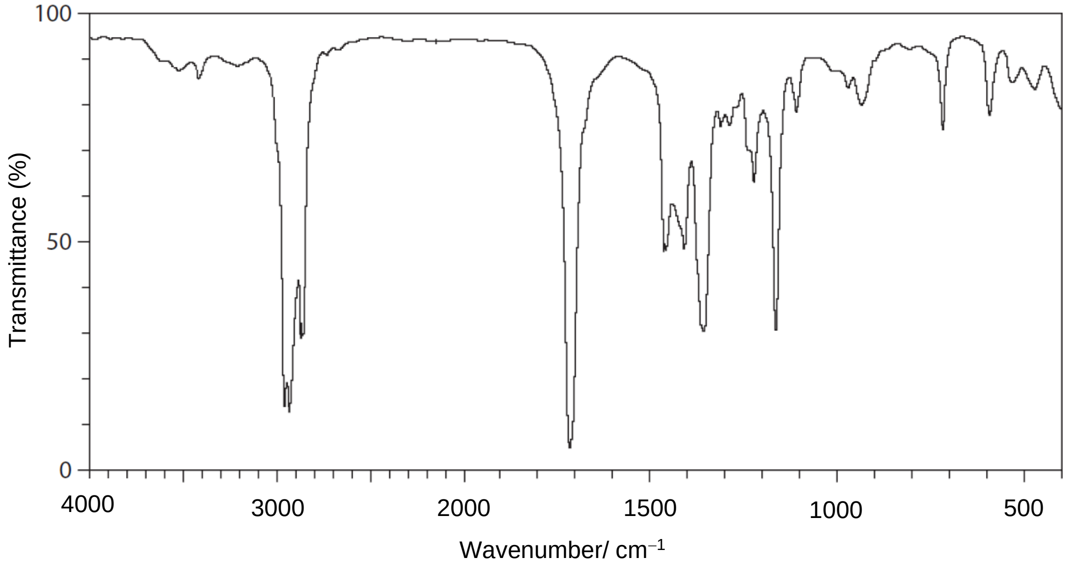
(d) Draw the three-dimensional representation of the **two** enantiomers. [1]

10. Heptan-2-one and heptan-3-one are isomers and their structures are given below.



The infrared spectrum of heptan-2-one is shown below.



(a) (i) Using section 26 of the data booklet, circle the peak in the spectrum that you would expect to find in the infrared spectrum of any ketone but not in an alkane. [2]

Identify the bond responsible for the stretching vibration giving this peak.

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(ii) State and explain whether their infrared spectra could be used to distinguish between samples of heptan-2-one and heptan-3-one. [1]

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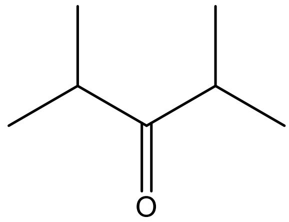
(Question 10 continued)

(b) 2,4-dimethylpentan-3-one is an isomer of heptan-2-one and has the following structure.



(i) Predict the number of signals in the ^{1}H NMR spectrum of 2,4-dimethylpentan-3-one. [1]

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(ii) State the ratio of the peak areas. [1]

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(iii) Deduce the splitting pattern and the chemical shift you would expect for the signals in a high resolution ^{1}H NMR spectrum of 2,4-dimethylpentan-3-one, using section 27 of the data booklet. [2]

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End of Paper