IB · DP · Chemistry

2 hours 11 questions

Practice Paper 2

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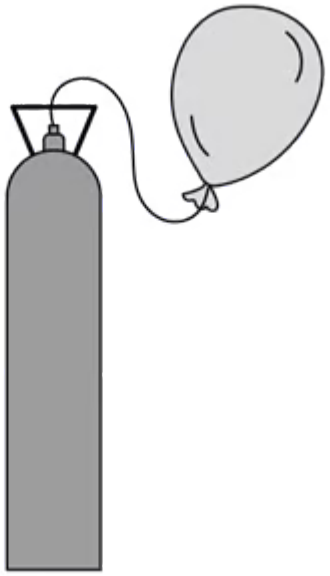
Total Marks **/90**

1 (a) Gas cylinders of helium, like the one shown below, are sometimes used to inflate party balloons.

Figure 1



A typical 11-inch party balloon has a fully inflated volume of 14.1 dm^3. The pressure in the gas cylinders is 20,000 kPa. If the gas cylinder can fill 160 balloons at 298 K and 108 kPa, what is the total volume of helium inside the gas cylinder in dm^3?

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(1 mark)

(b) Sketch a graph to show the relationship between the volume and temperature of an ideal gas at constant pressure. Describe the relationship between the two variables.

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(2 marks)

(c) Deep sea divers sometimes breathe mixtures of helium and oxygen in their scuba diving tanks when the conditions are very deep, so they can avoid nitrogen narcosis.

If a bubble of gas escapes from a scuba tank at 60 m depth where the pressure is 588 kPa and the temperature is 8 ^{o}C, determine the increase in the size of the bubble by the time it reaches the surface where the pressure is 100 kPa and the temperature is 20 ^{o}C.

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(2 marks)

(d) Commercial aircraft are fitted with oxygen cannisters that provide a supply of oxygen in case of the loss of cabin pressure. The cannisters contain sodium chlorate(V) which produces oxygen in the following decomposition reaction.

$$2NaClO_3\,(s)\ "\ 2NaCl\,(s) + 3O_2\,(g)$$

Determine the mass of sodium chlorate(V) needed to produce 10.0 dm^3 of oxygen at 298 K and 90 kPa.

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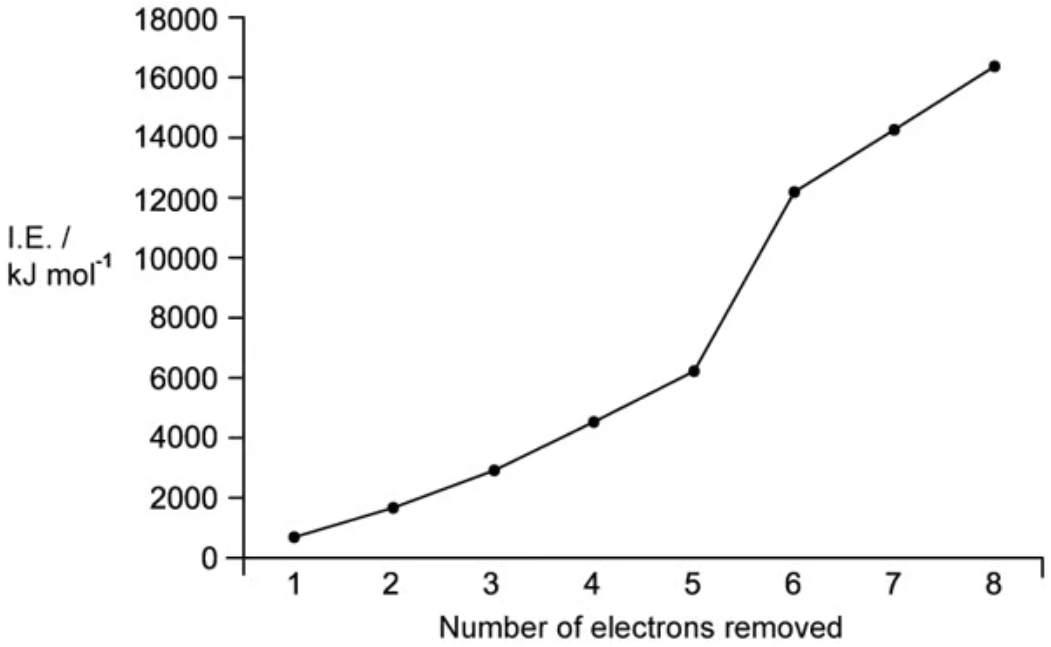
(4 marks)

2 (a) The successive ionisation energies of vanadium are shown.



State the sub-levels from which each of the first four electrons are lost

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(2 marks)

(b) Outline why there is an increase in ionisation energy from electron 3 to electron 5.

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(2 marks)

(c) Explain why there is a large increase in the ionisation energy between electrons 5 and 6.

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(3 marks)

(d) The first six ionisation energies, in kJ mol^{-1}, of an element are shown below

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6
578	1816	2744	11576	14829	18375

Explain the large increase in ionisation energy from IE_3 to IE_4

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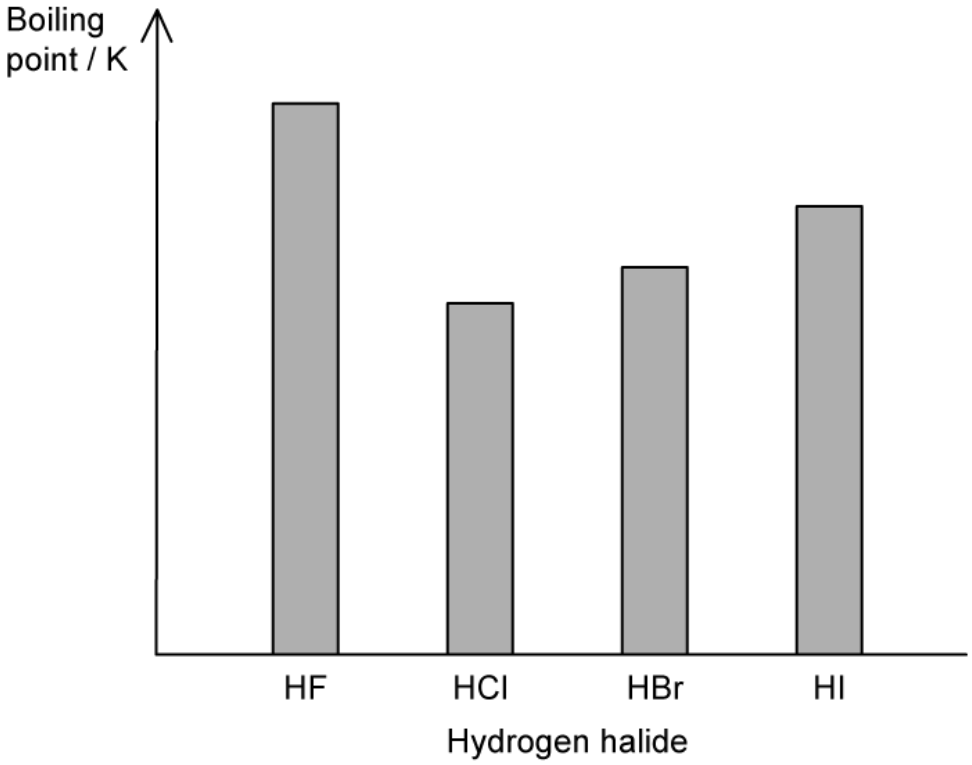
(2 marks)

3 (a) The hydrogen halides do not show perfect periodicity. A bar chart of boiling points, as seen in Figure 1, shows that the boiling point of hydrogen fluoride, HF, is much higher than periodic trends would indicate.

Figure 1



Explain why the boiling point of HF is much higher than the boiling point of the other hydrogen halides.

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(2 marks)

(b) There is an increase in boiling point moving from HCl to HI.

Explain this trend in boiling points of the hydrogen halides.

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(2 marks)

(c) A student adds a solution containing silver ions to two test tubes containing chloride and bromide ions. The student observes that both solutions turn cloudy.

Explain the observation the student made upon carrying out the experiment.

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(2 marks)

4 (a) When chromium(III) sulfate dissolves in water, a green solution containing the $[Cr(H_2O)_6]^{3+}$ ion forms.

i) State the bond angles found in this complex ion.

[1]

ii) Explain why the chromium(III) complex ion is coloured.

[3]

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(4 marks)

(b) Vanadium(V) oxide is the catalyst used in the Contact process as shown by the reactions:

$$SO_2\,(g) + V_2O_5\,(s) \rightarrow SO_3\,(g) + V_2O_4\,(s)$$

$$V_2O_4\,(s) + \tfrac{1}{2}O_2\,(g) \rightarrow V_2O_5\,(s)$$

i) Explain, using the equations, why V_2O_5 is a catalyst.

[1]

ii) Explain why V_2O_5 can act as a catalyst in this reaction.

[1]

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(2 marks)

(c) Excess ammonia is added to a solution of Cu^{2+} ions resulting in the substitution of 4 ligands.

Using section 15 of the data booklet, explain why this reaction results in a shift in the wavelength of light absorbed by the Cu^{2+} complex.

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(1 mark)

5 (a) Draw the structure of silicon dioxide and state the type of bonding present.

(2 marks)

(b) Describe the similarities and differences you would expect in the properties of silicon and diamond.

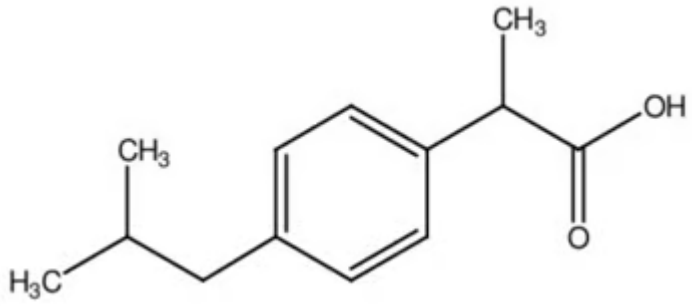
(3 marks)

(c) The boiling point of diamond is 3550 °C, but for carbon dioxide it is -78.5 °C. Both are covalent substances.

Explain this difference with reference to structure and bonding.

(4 marks)

6 (a) Ibuprofen is a common non-steroidal anti-inflammatory drug (NSAID). It contains a benzene ring and a carboxylic acid at the end of one of the branches.



Deduce the number of resonance structures possible in the deprotonated form of ibuprofen.

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(1 mark)

(b) Deduce the number of:

i) Sigma (σ) bonds in ibuprofen

[1]

ii) Pi (π) electrons in ibuprofen

[1]

.....

.....

(2 marks)

(c) The ibuprofen molecule contains both sp^3 and sp^2 hybridised orbitals.

i) Identify how many sp^3 hybrid orbitals are present.

[1]

ii) Identify how many sp^2 hybrid orbitals are present.

[1]

(2 marks)

(d) Explain why the benzene ring is a regular, planar hexagon.

(3 marks)

7 (a) State the formula for calculating the standard enthalpy change of reaction, ΔH_r, using bond energies.

(1 mark)

(b) Use section 11 of the data booklet to calculate the enthalpy change, in kJ mol^{-1}, for the following reaction.

$$Cl_2 + H_2 \rightarrow 2HCl$$

(4 marks)

(c) State whether the energy change for the reaction in part (b) is endothermic or exothermic.

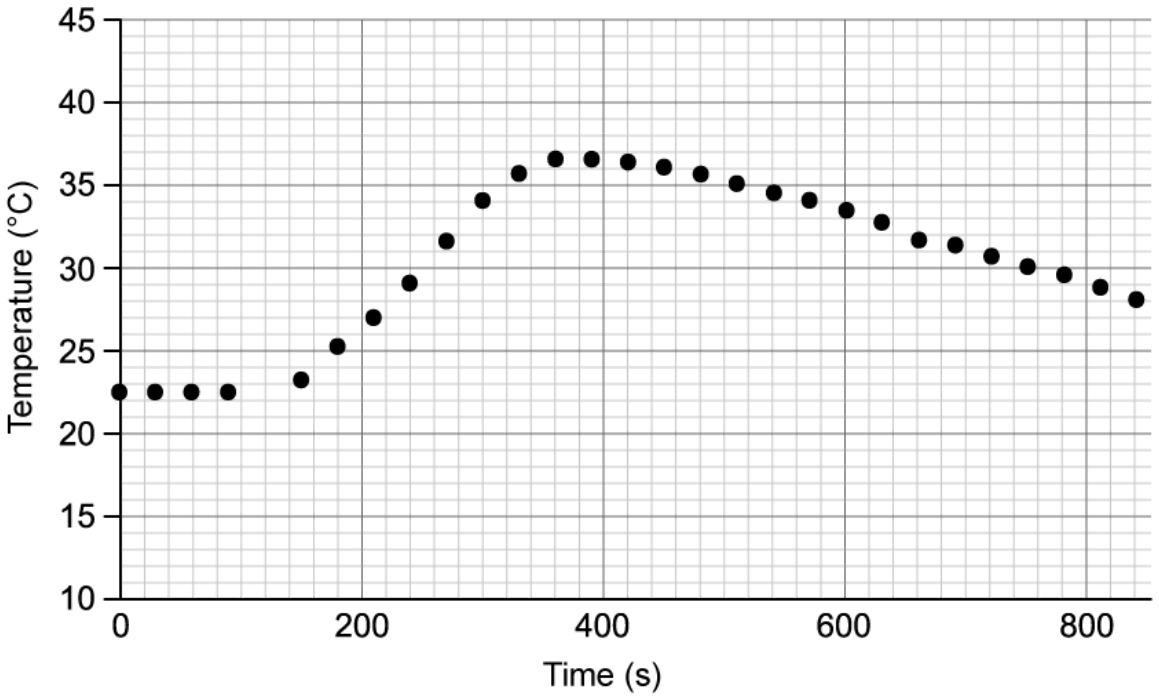
(1 mark)

(d) Using section 11 of the data booklet, calculate the enthalpy change of reaction, ΔH_r, in kJ mol^{-1} for the following reaction.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(4 marks)

8 (a) A student measured the energy change when 1.35 g of zinc was added to 50 cm^3 of 0.5 mol dm^{-3} copper sulfate, $CuSO_4$ (aq), solution. The initial temperature of 21 ^oC was recorded before the addition of the zinc and a temperature reading was taken every 30 seconds.



Use the graph to determine the overall temperature change for the reaction

(1 mark)

(b) Calculate the enthalpy change for the reaction in kJ mol^{-1}.

(4 marks)

(c) Calculate the percentage error between your value for the enthalpy change of reaction and the literature value of -217 kJ mol^{-1}. Give your answer to two significant figures.

(1 mark)

(d) Explain why your calculated value for the enthalpy change of reaction is different from the literature value of -271 kJ mol^{-1}.

(3 marks)

9 (a) Define the term *nucleophile*.

(2 marks)

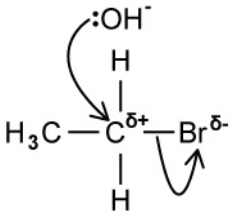
(b) Explain why the hydroxide ion, OH^-, is a stronger nucleophile than water.

(2 marks)

(c) State the two ways a nucleophilic substitution reaction can occur.

(1 mark)

(d) State the the name of the mechanism occurring in the image below which will form ethanol in one step.



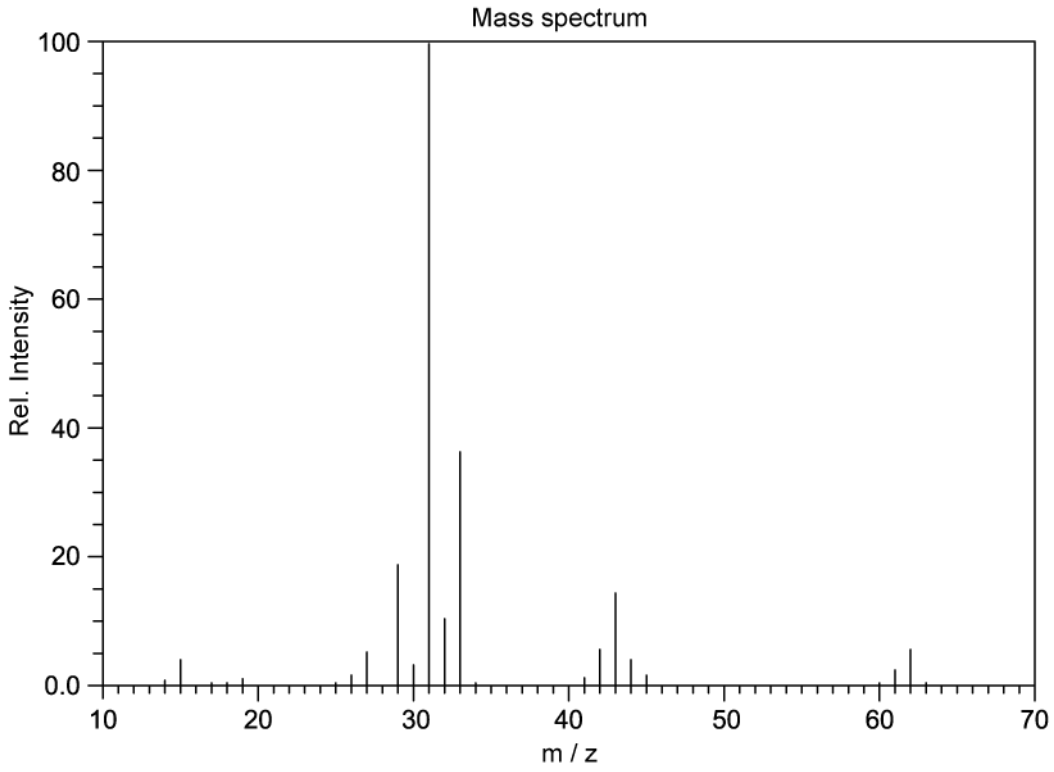
(1 mark)

10 (a) Ethane-1,2-diol, $C_2H_6O_2$, can be distinguished from ethanedioic acid,$C_2H_2O_4$, by a number of analytic techniques including MS, IR and NMR

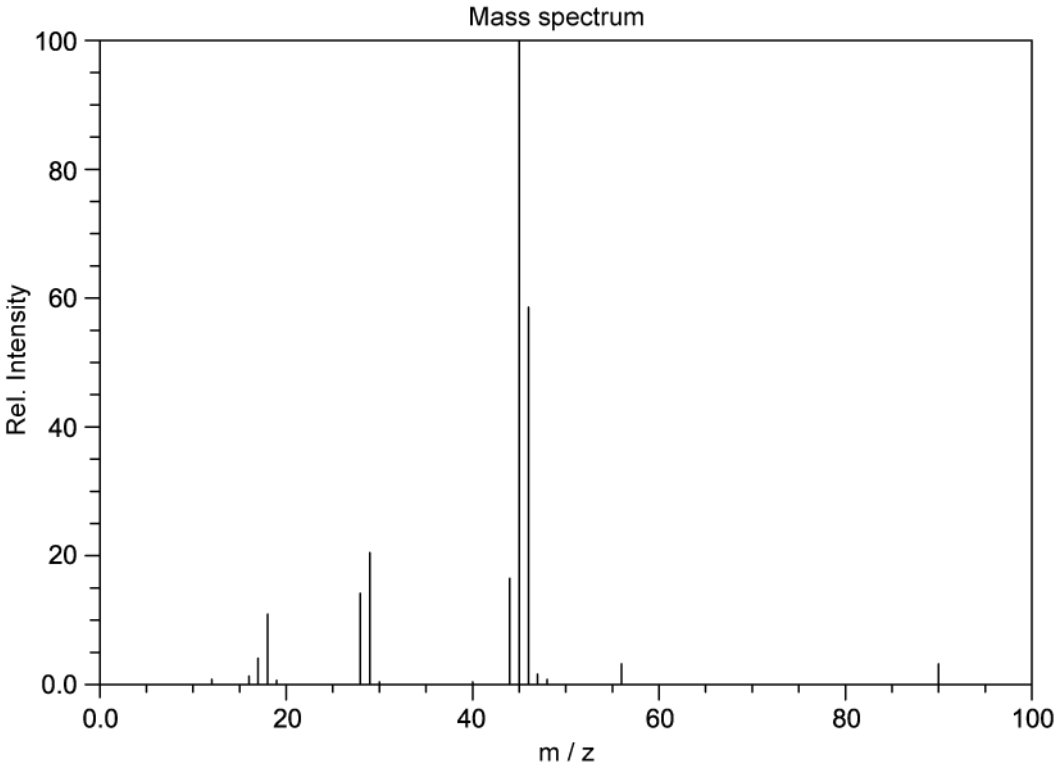
The MS of these molecules is shown below.

Which spectrum belongs to each molecule? Justify your answer.

Spectrum **A**



Spectrum **B**



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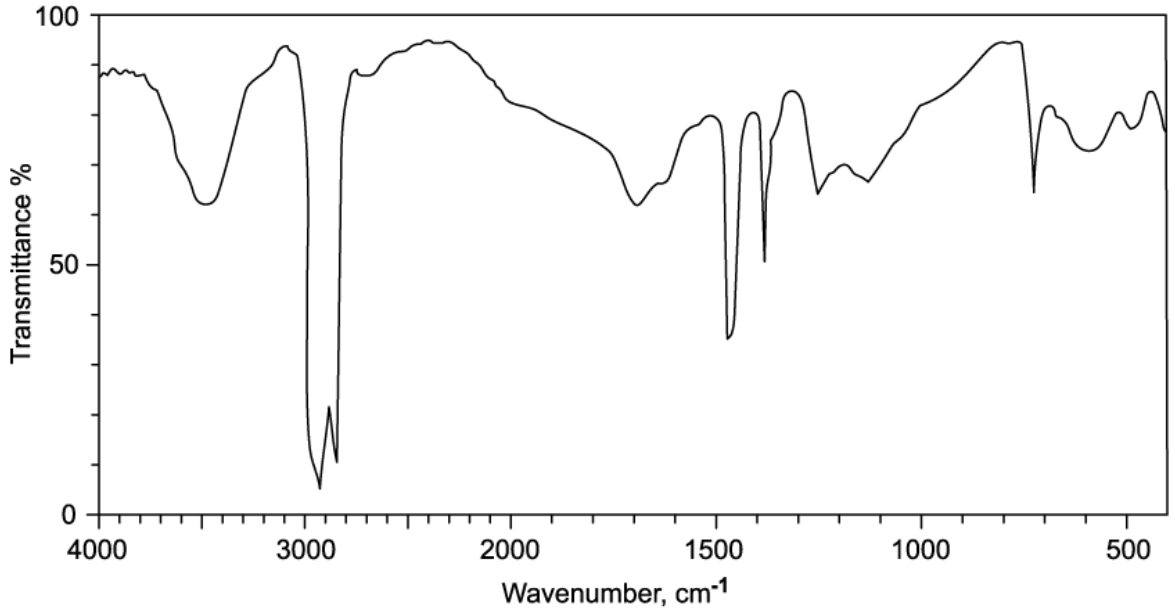
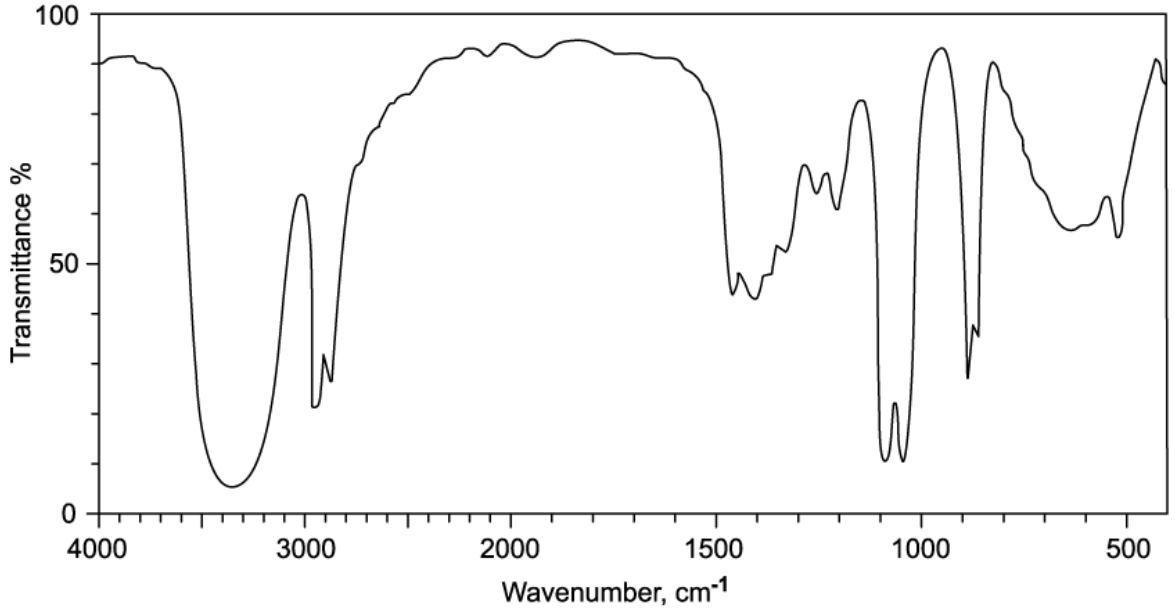
(2 marks)

(b) The IR spectra of ethane-1,2-diol, $C_2H_6O_2$, and ethanedioic acid dihydrate,$C_2H_2O_4.2H_2O$, are shown in spectrum **C** and **D**. Use Section 26 of the Data Booklet to answer this question.

Spectrum **C**



Spectrum **D**



Which spectrum belongs to each molecule? Justify your answer.

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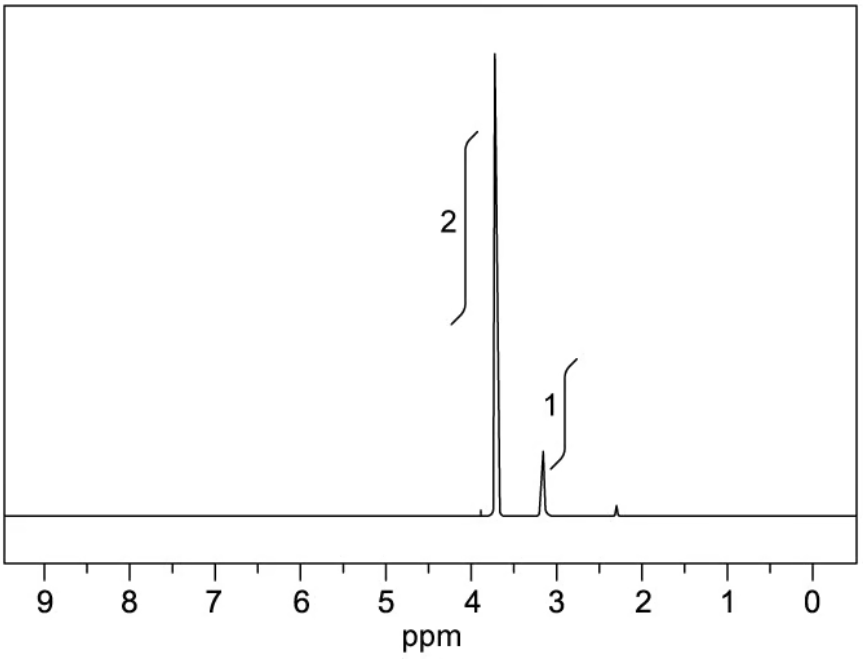
(2 marks)

(c) The ^{1}H NMR spectrum of ethane-1,2-diol is shown in spectrum **E**. Explain the significance of the spectrum.

Spectrum **E**



(3 marks)

11 (a) The Winkler method is a chemical technique used to measure the concentration of dissolved oxygen in water samples. The method involves treating the samples to convert the dissolved oxygen into iodine which is then titrated against standard sodium thiosulfate solution as shown below:

Step 1: $2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)$

Step 2: $MnO_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$

Step 3: $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

A student wanted to check if the water in a fish tank was sufficiently oxygenated and analysed two 500 cm^3 samples, five days apart.

The following results in **Table 1** were obtained when the resulting iodine was titrated against 0.0120 $moldm^{-3}$ $Na_2S_2O_3$ (aq).

Table 1

Oxygen analysis in fish tank water on day 0

Initial burette reading / $cm^3 \pm 0.1cm^3$	0.20
Final burette reading / $cm^3 \pm 0.1cm^3$	26.0
Titre / cm^3	

i) Determine the reacting ratio by moles of $S_2O_3^{2-}$ to O_2, using the balanced equations in steps 1-3.

ii) Calculate the titre and determine the percentage uncertainty in the reading.

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(3 marks)

(b) Determine the number of moles of oxygen in the 500 cm^3 sample and hence the concentration in ppm.

(3 marks)

(c) It is generally considered that dissolved oxygen levels of at least 4-5 ppm are sufficient for most aquatic life. The day 5 sample contained 5.03×10^{-5} moles of oxygen.

Discuss whether the student should be concerned about the oxygen levels in the fish tank over the 5-day period.

(2 marks)

(d) Suggest two modifications to the procedure which would make the result more reliable.

(2 marks)