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Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

12 May 2023

Zone A afternoon | **Zone B** morning | **Zone C** afternoon

Candidate session number

1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2223 – 6117

13 pages

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Answer **all** questions. Answers must be written within the answer boxes provided.

1. Analytical and spectroscopic techniques enable chemists to identify and determine structures of compounds.

(a) An unknown organic compound, **X**, comprising of only carbon, hydrogen and oxygen was found to contain 48.6 % of carbon and 43.2 % of oxygen.

Determine the empirical formula. [3]

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The mass spectrum of **X** is shown.

Removed for copyright reasons

(b) Identify fragments responsible for the peaks at *m/z* 74 and 45 using section 28 of the data booklet. [2]

m/z 74: . . . . . .

m/z 45: . . . . . .

(This question continues on the following page)

(Question 1 continued)

(c) Determine the molecular formula of **X**. [1]

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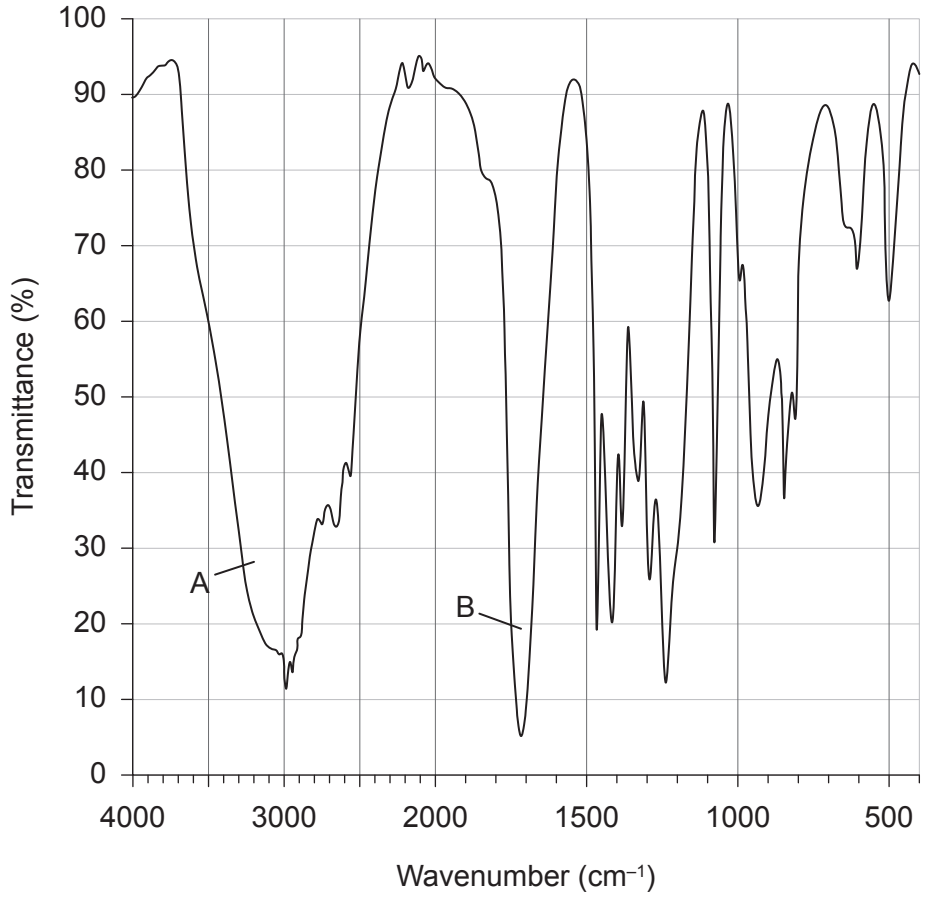
The infrared spectrum of **X** is shown.

Infrared spectrum of X



(d) Identify the bonds making the major contribution to peaks A and B using section 26 of the data booklet. [2]

A: . . . . . .

B: . . . . . .

2. Nitrogen (IV) oxide, NO_2, is a brown gas found in photochemical smog and has a pollutant causing acid deposition.

(a) Nitrogen (IV) oxide exists in equilibrium with dinitrogen tetroxide, $N_2O_4(g)$, which is colourless.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

(i) At 100 °C K_c for this reaction is 0.0665. Outline what this indicates about the extent of this reaction. [1]

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(ii) Calculate the value of K_c at 100 °C for the equilibrium: [1]

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

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(iii) Calculate the standard enthalpy change, in kJ mol^{-1}, for the reaction: [1]

$$N_2O_4(g) \rightarrow 2NO_2(g)$$

	$\Delta H^{\ominus}_f$ (kJ mol^{-1})
NO_2	33.18
N_2O_4	9.16

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(This question continues on the following page)

(Question 2 continued)

(b) Deduce the Lewis structure of N_2O_4. [1]

(c) The NO bond lengths in N_2O_4 are all 1.19×10^{-10} m.

(i) Suggest what the bond lengths indicate about the structure of N_2O_4. [1]

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(ii) Predict the ONN bond angle in N_2O_4. [1]

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(d) Acid deposition is formed when nitrogen oxides dissolve in water. Write an equation for nitrogen (IV) oxide reacting with water to produce two acids. [1]

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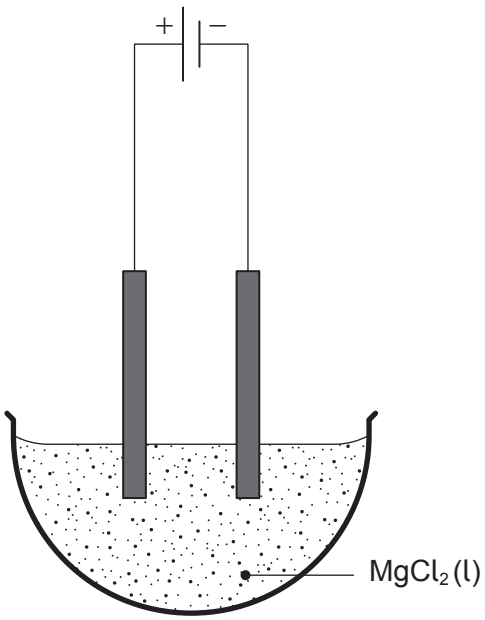
3. Electrolysis and Winkler titrations are both applications of redox reactions.

(a) An electrolytic cell was set up using inert electrodes and molten magnesium chloride, $MgCl_2(l)$.



(i) Identify the product formed at the cathode. [1]

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(ii) Annotate the diagram to show the movement of electrons. [1]

(iii) Graphite rods are sometimes used as inert electrodes. Describe the structure of graphite and explain why graphite conducts electricity. [2]

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(This question continues on the following page)

(Question 3 continued)

(b) Winkler titrations can be used to determine the biochemical oxygen demand, BOD, of a water sample. One set of equations for the reactions occurring is:

$$2Mn^{2+}(aq) + O_2(aq) + 4OH^- \rightarrow 2MnO(OH)_2(s)$$

$$MnO(OH)_2(s) + 2I^-(aq) + 4H^+ \rightarrow Mn^{2+}(aq) + I_2(aq) + 3H_2O$$

$$I^-(aq) + I_2(aq) \rightarrow I_3^-(aq)$$

$$2S_2O_3^{2-}(aq) + I_3^-(aq) \rightarrow S_4O_6^{2-}(aq) + 3I^-(aq)$$

150 cm^3 of a water sample was tested using a Winkler titration. 36.0 cm^3 of 0.00500 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3(aq)$, was required to reach the end point.

(i) Determine the concentration, in mol dm^{-3}, of oxygen dissolved in the water sample. [3]

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(ii) Outline how the BOD of the water sample could be determined. [2]

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(iii) Suggest what a low BOD value indicates about a water sample. [1]

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4. The periodic table provides information about electron configuration, and physical and chemical properties of elements.

(a) Bismuth has atomic number 83. Deduce **two** pieces of information about the electron configuration of bismuth from its position on the periodic table. [2]

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(b) Outline why aluminium is malleable. [1]

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(c) An 11.98 g block of pure aluminium was heated. Calculate the heat energy absorbed, in J, to increase its temperature from 18.0 °C to 40.0 °C. The specific heat capacity of aluminium is 0.902 J g^{-1} K^{-1}. [1]

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(This question continues on the following page)

(Question 4 continued)

(d) Argon has three naturally occurring isotopes, ^{36}Ar, ^{38}Ar and ^{40}Ar.

(i) Identify the technique used to determine the relative proportions of the isotopes of argon. [1]

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The isotopic composition of a sample of argon is 0.34 % of ^{36}Ar, 0.06 % of ^{38}Ar and 99.6 % of ^{40}Ar.

(ii) Calculate the relative atomic mass of this sample, giving your answer to two decimal places. [2]

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(e) State the full electron configuration of the cobalt(II) ion, Co^{2+}. [1]

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5. Methanoic acid is a monoprotic weak acid.

(a) The concentration of methanoic acid was found by titration with a 0.200 mol dm^{-3} standard solution of sodium hydroxide, NaOH(aq), using an indicator to determine the end point.

Calculate the pH of the sodium hydroxide solution. [2]

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(b) Write an equation for the reaction of methanoic acid with sodium hydroxide. [1]

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(c) 22.5 cm^3 of NaOH(aq) neutralized 25.0 cm^3 of methanoic acid. Determine the concentration of the methanoic acid. [1]

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6. Bromine, $Br_2(l)$, and methanoic acid, $HCOOH(aq)$, react in the presence of sulfuric acid.

$$Br_2(l) + HCOOH(aq) \rightarrow 2HBr(aq) + CO_2(g)$$

(a) Suggest an experimental method that could be used to determine the rate of reaction. [2]

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(b) The sulfuric acid is a catalyst in this reaction. Explain how a catalyst increases the reaction rate. [2]

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(c) Methanoic acid can react with ethanol to produce an ester. Draw the full structural formula of the organic product and state its name. [2]

Structural formula:

Name: . . . . . .

(This question continues on the following page)

(Question 6 continued)

(d) (i) Write the equation for the complete combustion of ethanol. [1]

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(ii) Determine the enthalpy change for the combustion of ethanol, in kJ mol^{-1}, using section 11 of the data booklet. [3]

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(Question 6 continued)

(e) Bromine also reacts with but-2-ene.

(i) Identify the type of reaction. [1]

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(ii) Predict the structural formula of the reaction product. [1]

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(iii) Draw the structure of a section of a polymer formed from **three** monomers of but-2-ene. [1]

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References:

1.(d) SDBS, National Institute of Advanced Industrial Science and Technology.

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