



Chemistry

Standard level

Paper 2

12 May 2023

Zone A afternoon | Zone B morning | Zone C afternoon

Candidate session number

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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]**.

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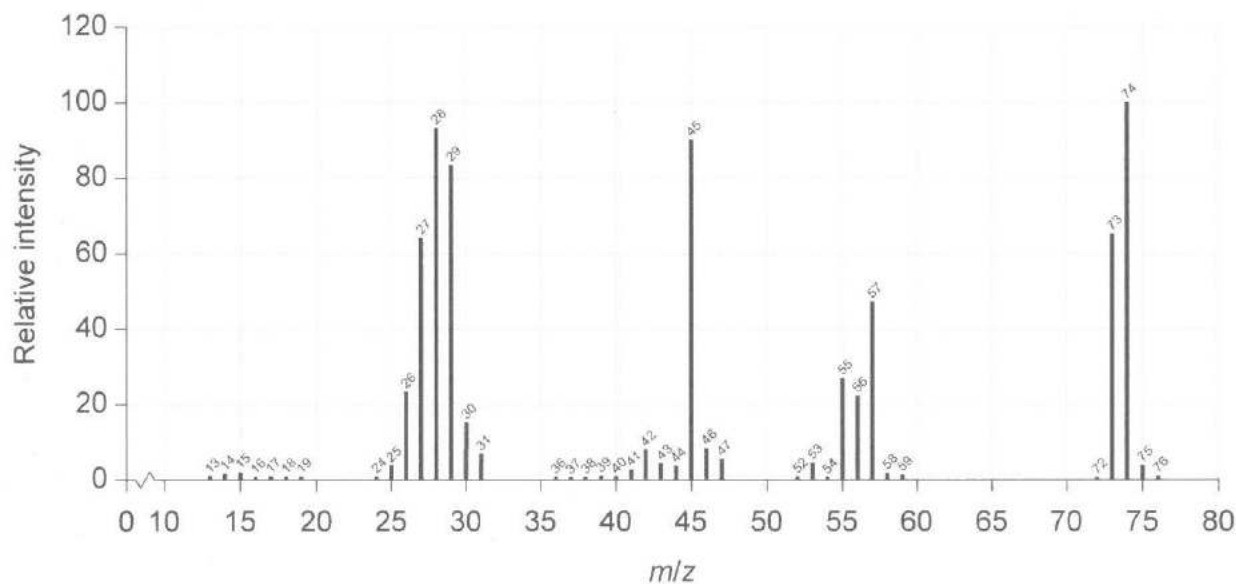
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The mass spectrum of **X** is shown.



(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:

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(Question 1 continued)

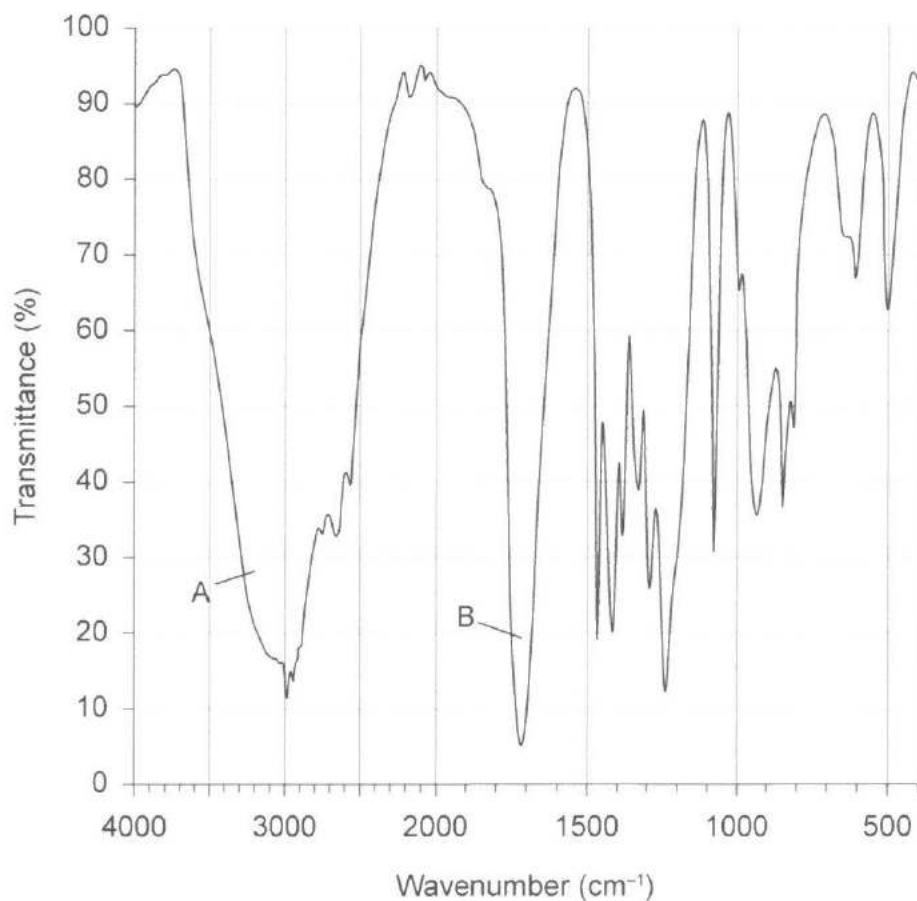
(c) Determine the molecular formula of X.

[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, $\text{N}_2\text{O}_4(\text{g})$, which is colourless.



(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]



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

[1]



	$\Delta H_f^\ominus (\text{kJ mol}^{-1})$
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.

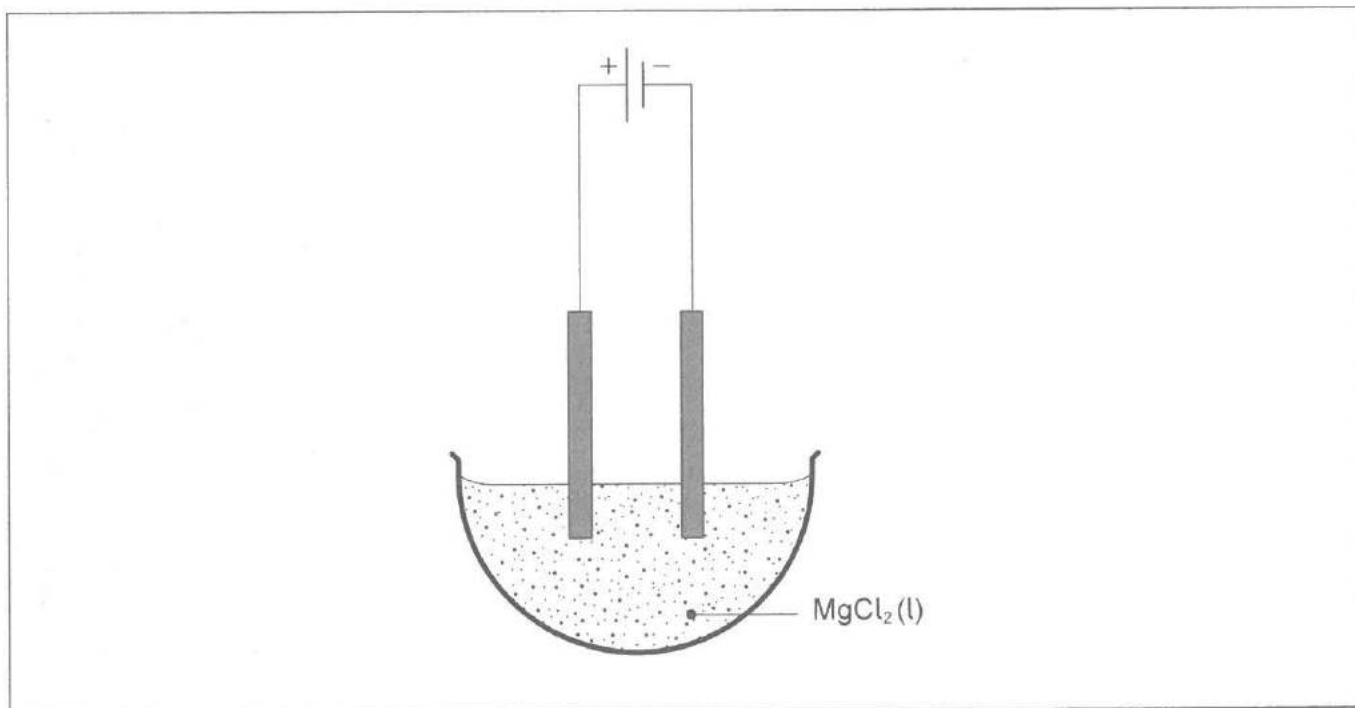
[1]

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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, $\text{MgCl}_2(\text{l})$.



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

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

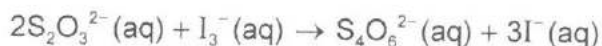
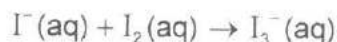
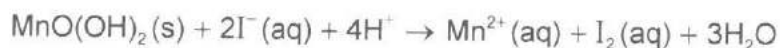
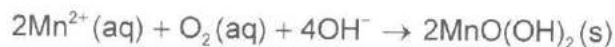
(iii) Graphite rods are sometimes used as inert electrodes. Describe the structure of graphite and explain why graphite conducts electricity. [2]

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(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:



150 cm³ of a water sample was tested using a Winkler titration. 36.0 cm³ of 0.00500 mol dm⁻³ sodium thiosulfate solution, Na₂S₂O₃(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 11.98g 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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(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 $0.200 \text{ mol dm}^{-3}$ standard solution of sodium hydroxide, $\text{NaOH}(\text{aq})$, 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]

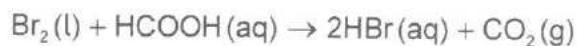
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- (c) 22.5 cm^3 of $\text{NaOH}(\text{aq})$ neutralized 25.0 cm^3 of methanoic acid. Determine the concentration of the methanoic acid.

[1]

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6. Bromine, Br₂(l), and methanoic acid, HCOOH(aq), react in the presence of sulfuric acid.



- (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:

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(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.(a)(ii) National Institute of Standards and Technology, US Department of Commerce, 2014. *NIST Chemistry WebBook, SRD 69*. [online] Available at: <<https://webbook.nist.gov/cgi/cbook.cgi?ID=C79094&Mask=200#Mass-Spec>> [Accessed 29 April 2021].
- 1.(a)(iv) Chemical Book, 2017. *Propionic acid(79-09-4) IR1*. [online] Available at: <https://www.chemicalbook.com/SpectrumEN_79-09-4_IR1.htm> [Accessed 30 April 2021].
- 2.(a)(i) NC State University, Department of Chemistry, Lecture Demonstrations, n.d. Equilibrium. [pdf] Available at: <<https://projects.ncsu.edu/project/chemistrydemos/Equilibrium/NO2.pdf>> [Accessed 30 April 2021].