

Chemistry Standard level Paper 2

12 May 2023

Zone A afternoon | Zone B morning | Zone C afternoon

Ca	ndida	ate s	essi	on n	umb	er	

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].



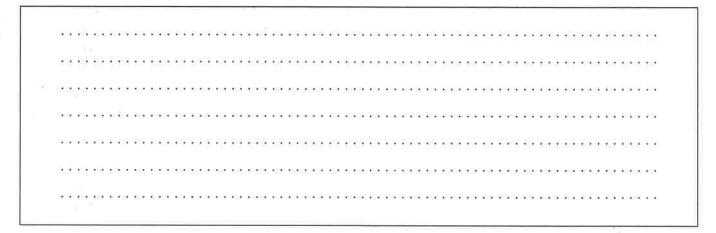


Answer all questions. Answers must be written within the answer boxes provided.

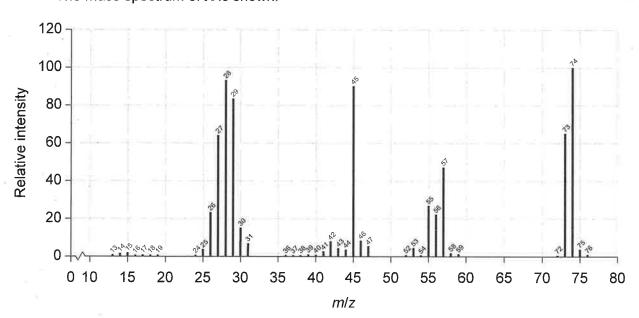
- 1. Analytical and spectroscopic techniques enable chemists to identify and determine structures of compounds.
 - (a) An unknown organic compound, **X**, comprising of only carbon, hydrogen and oxygen was found to contain 48.6% of carbon and 43.2% of oxygen.

Determine	the	empirical	formula
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[3]



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]

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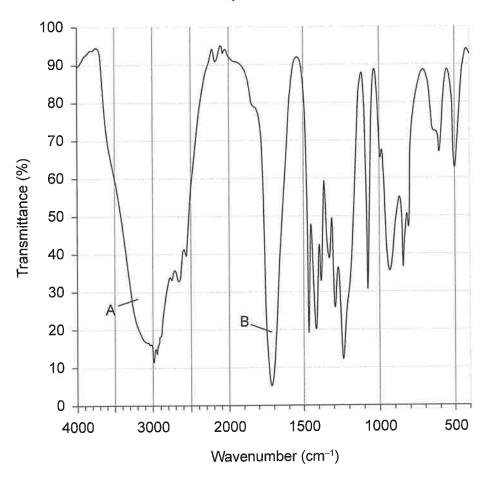


(Question 1 continued)

(c)	Determine the molecular formula of X .	[1]
* 6.7		

The infrared spectrum of \boldsymbol{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:		KA 634 K 614 40408 EU 809 819 11 1.7	





- 2. Nitrogen (IV) oxide, NO₂, 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 $100\,^{\circ}$ 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]

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

(iii) Calculate the standard enthalpy change, in kJ mol⁻¹, for the reaction:

[1]

$${\rm N_2O_4(g)} \rightarrow 2{\rm NO_2(g)}$$

	ΔH_{f}^{Θ} (kJ mol ⁻¹)
NO ₂	33.18
N ₂ O ₄	9.16



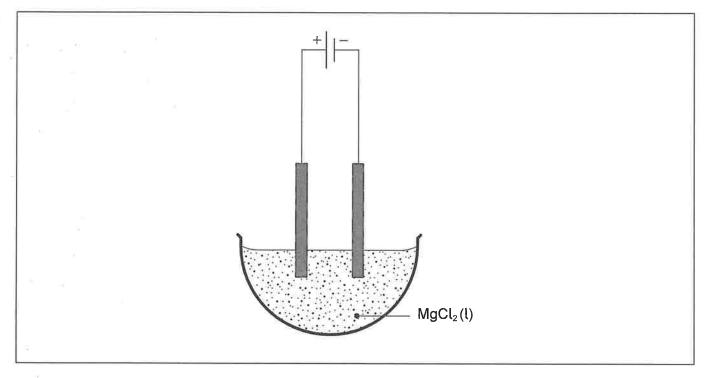


(b)	Deduce the Lewis structure of N ₂ O ₄ .	[1]
(c)	The NO bond lengths in N_2O_4 are all 1.19×10^{-10} m.	
	(i) Suggest what the bond lengths indicate about the structure of N ₂ O ₄ .	[1]
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107 E		
	(ii) Predict the ONN bond angle in N ₂ O ₄ .	[1]
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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, MgCl₂(l).



, (i)	Identify the product formed at the cathode.	[1]
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3 10 100 100 5 10		
(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:

$$\begin{split} 2\text{Mn}^{2^{+}}(\text{aq}) + \text{O}_{2}(\text{aq}) + 4\text{OH}^{-} &\to 2\text{MnO(OH)}_{2}(\text{s}) \\ \text{MnO(OH)}_{2}(\text{s}) + 2\text{I}^{-}(\text{aq}) + 4\text{H}^{+} &\to \text{Mn}^{2^{+}}(\text{aq}) + \text{I}_{2}(\text{aq}) + 3\text{H}_{2}\text{O} \\ & \text{I}^{-}(\text{aq}) + \text{I}_{2}(\text{aq}) \to \text{I}_{3}^{-}(\text{aq}) \\ 2\text{S}_{2}\text{O}_{3}^{2^{-}}(\text{aq}) + \text{I}_{3}^{-}(\text{aq}) \to \text{S}_{4}\text{O}_{6}^{2^{-}}(\text{aq}) + 3\text{I}^{-}(\text{aq}) \end{split}$$

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

	(i) Determine the concentration, in mol dm °, of oxygen dissolved in the water sample.	[၁]

	(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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2	(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 $^{\circ}$ C to 40.0 $^{\circ}$ C. The specific heat capacity of aluminium is 0.902 J g ⁻¹ K ⁻¹ .	[1]											
	1077 (AT)													
	20102													
	No.													





[2]

(Question 4 continued)

(d)	Argon has three naturally	occurring iso	topes, ³⁶ Ar	, ³⁸ Ar and ⁴⁰ A
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(i)	Identify the technique used to determine the relative proportions of the isotopes of argon.	[1]
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Tho	isotopic composition of a sample of argon is 0.34 % of ³⁶ Ar .0.06 % of ³⁸ Ar and	

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.

(e)	State the full electron configuration of the cobalt (II) ion, Co ²⁺ ,	[1]
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J.	Wethanoic 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 cm³ of NaOH (aq) neutralized 25.0 cm³ of methanoic acid. Determine the concentration of the methanoic acid.	[1]											
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6.	Bron	nine, $\mathrm{Br}_2(l)$, 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]
	(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]
	Stru	uctural formula:	





(Questior	6 con	tinued)
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(Question 6 continued)

(e)	Bromine also reacts with but-2-ene.													
	(i)	Identify the type of reaction.	[1]											
14: 40514														
<u> </u>														
	(ii)	Predict the structural formula of the reaction product.	[1]											

(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">https://webbook.nist.gov/cgi/cbook.cgi?ID=C79094&Mask=200#Mass-Spec">https://webbook.nist.gov/cgi/cbook.cgi?ID=C79094&Mask=200#Mass-Spec [Accessed 29 April 2021].
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