Catholic Junior College

JC2 Preliminary Examinations

Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

Paper 2 Structured Questions

8873/02
26 August 2024
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions**.**

Section B
Answer **one** question.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part of the question.

Section A	**Q1**	**10**
	Q2	**9**
	Q3	**10**
	Q4	**21**
	Q5	**10**
Section B	**Q6**	**20**
	Q7	**20**
Paper 2 (67%)		**80**
Paper 1 (33%)		**30**
Percentage		
Grade		

1 Dioxygen, O_2 and ozone, O_3 are two allotropes of oxygen found in the atmosphere. The thermochemical equation for the reversible conversion between ozone and dioxygen is shown below.

$$2O_3(g) \rightleftharpoons 3O_2(g) \qquad \Delta H = -286.0 \text{ kJ mol}^{-1}$$

(a) Draw the structure and suggest the shape of ozone, O_3.

Structure of O_3

Shape of ozone:

[2]

(b) Using *Le Chatelier's Principle*, explain why an increase in temperature causes the ozone concentration to increase.

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..... [2]

(c) Sketch, on the same axis below, two graphs that show how the rate of forward and reverse reactions vary over time. Label your graphs clearly and indicate *t*, the time when equilibrium was established.

[1]

(d) The diagram below shows that the concentration of ozone in the atmosphere varies with altitude above sea level.

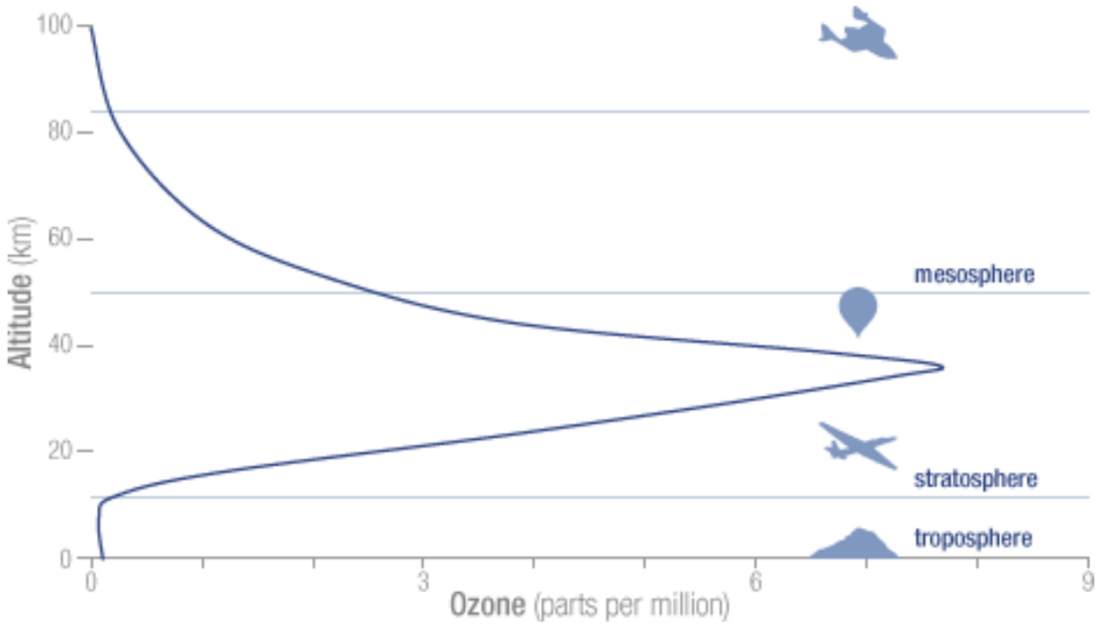

Diagram taken from https://ozonewatch.gsfc.nasa.gov/facts/SH.html

Between about 20 to 50 km above sea level, at the stratosphere, the ozone layer consists of a mixture of dioxygen and ozone molecules. Different types of Ultraviolet (UV) radiation from the Sun is absorbed by the ozone layer during the dioxygen-ozone reversible reaction.

The table below shows information on the different types of ultraviolet radiation.

Type of ultraviolet rays	Relative activation energy	Absorption by ozone layer
UV-A	Low	No
UV-B	Moderate	Yes
UV-C	High	Yes

Table 1.1

(i) Give a reason why the reversible conversion between dioxygen and ozone in the atmosphere is unlikely to reach a state of dynamic equilibrium.

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..... [1]

(d) (ii) Complete the energy profile diagram of the dioxygen-ozone reversible reaction using the axes below.

The sketch should include labels for

- The formula, stoichiometric coefficient, and state symbols of both reactants and products;
- The enthalpy change of reaction, ΔH;
- Based on Table 1.1, indicate the type of ultraviolet rays, UV–A, UV–B or UV–C, absorbed to the relative activation energies of both the forward and backward reactions respectively. Each type of UV rays should be used only once or not at all.

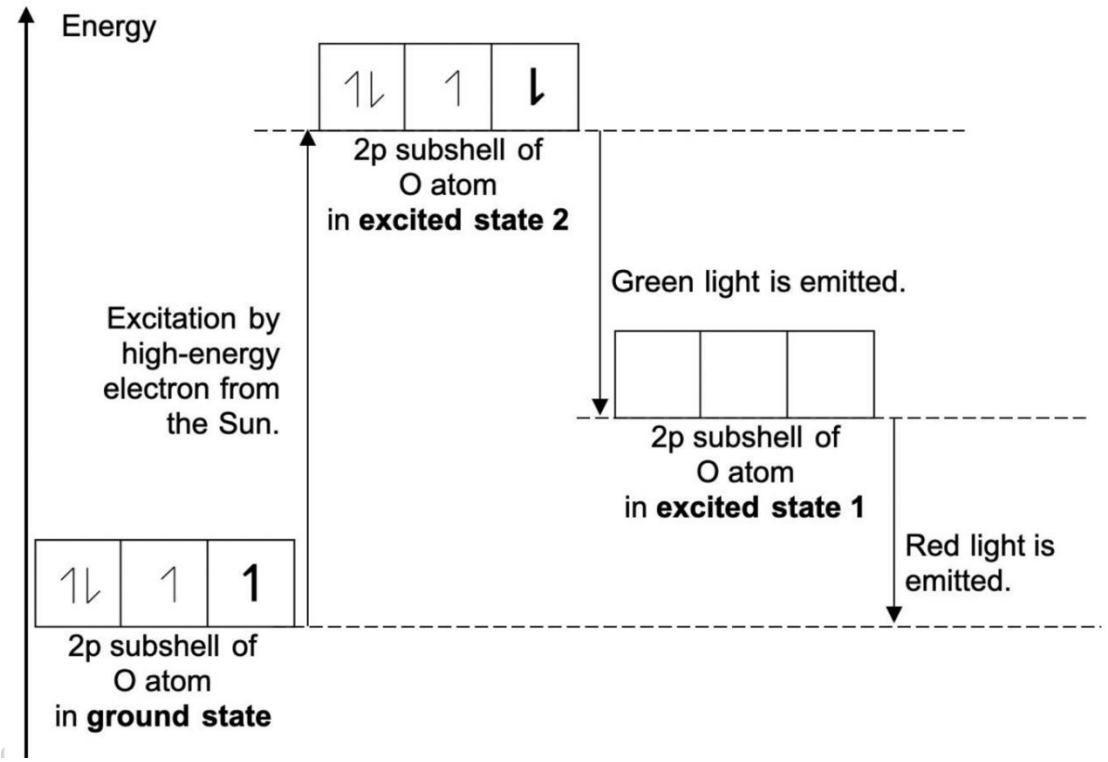
[3]

(e) The Northern Lights or *Aurora Borealis* occurs near the North Pole about 100 to 300 km above sea level. Absorption of UV rays by an oxygen molecule causes the O=O bond to break and two oxygen atoms are formed as shown in the equation below.

$$O_2(g) \rightarrow 2O(g)$$

When an oxygen atom in its **ground state** collides with a high energy electron from the Sun, one of its valence electrons (**bolded** in the energy level diagram below) is excited to a higher energy arrangement as seen in **excited state 2**. As energy is released, green light is emitted with an electron arrangement in **excited state 1** that violates Hund's rule.

When the electron transits to a lower energy level, coloured light is emitted as shown in the energy level diagram below.



In the diagram above, draw the electron arrangement in the 2p subshell of an oxygen atom in excited state 1 by changing the arrangement of the **bold electron only**. [1]

[Total: 10]

2 25.0 cm^3 of H_2O_2 solution reacted with 23.40 cm^3 of 0.0250 mol dm^{-3} $KMnO_4$ in a titration in the presence of excess dilute sulfuric acid according to the following equation:

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

(a) Explain in terms of change in oxidation number why the above reaction is considered a redox reaction. Identify all the relevant species in your explanation.

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..... [2]

(b) Calculate the concentration, in mol dm^{-3}, of the H_2O_2 solution.

[2]

(c) With reference to structure and bonding, explain why the melting point of H_2O_2 is higher than O_2.

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..... [2]

(d) The Winkler Test is used to determine the amount of dissolved oxygen in a water sample. In the test, oxygen reacts with excess Mn^{2+} under alkaline conditions to produce a precipitate of $MnO(OH)_2$.

equation 1 $2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$

The precipitate, $MnO(OH)_2$ is then dissolved in acid and reacted with iodide ions, I^-, forming iodine, I_2, and Mn^{2+}.

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

Finally, the amount of iodine, I_2, produced is determined by titration with thiosulfate, $S_2O_3^{2-}$.

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

When a sample was analysed using the Winkler Test, 25.0 cm^3 of 0.10 mol dm^{-3} of thiosulfate was used in the reaction.

(i) From the three equations given above, deduce the stoichiometric relationship between thiosulfate ions and oxygen gas.

[1]

(ii) Hence, calculate the volume of oxygen gas present in the original sample at r.t.p.

[2]

[Total: 9]

3 Period 3 solid oxides, **X** and **Y** react with water as follows:

- **X** reacts with water to form a triprotic acid.
- **Y** reacts with water to form a strongly alkaline solution.

(a) **(i)** State the identities of **X** and **Y**.

..... [1]

(ii) Write the equations for the reactions of the oxides of **X** and **Y** with water, and state the pH of the resulting solution.

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..... [2]

(b) 1.00 g of a supplement tablet containing MgO was dissolved in 100 cm^3 of 1.00 mol dm^{-3} of dilute sulfuric acid which was in excess to form solution **A**.

25.0 cm^3 of solution **A** containing excess H_2SO_4 required 22.00 cm^3 of 2.00 mol dm^{-3} aqueous NaOH for complete reaction.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

(i) Write an equation between MgO and dilute sulfuric acid.

..... [1]

(ii) Calculate the percentage of MgO in the supplement tablet.

[4]

(iii) With the knowledge of the acid-base behaviour of Period 3 oxides, suggest how SiO_2 can be obtained from a mixture of MgO and SiO_2 via filtration. Identify the species present in the residue and filtrate.

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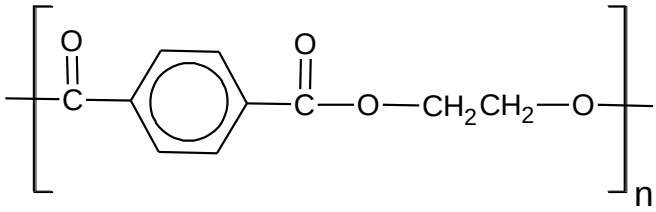
..... [2]

[Total: 10]

4 Polyethylene terephthalate, PET, is a thermoplastic polymer.



PET

(a) **(i)** Define the term *polymer*.

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..... [1]

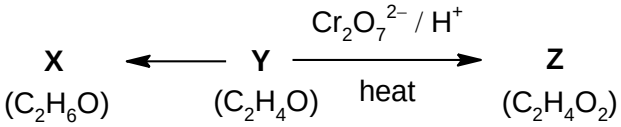
(ii) Name the type of reaction PET undergoes as it is heated with sodium hydroxide.

..... [1]

(iii) Draw the structure of the products formed from the reaction in **(a)(ii)**.

[2]

(b) Another type of PET degradation results in the formation of compound **Y** with an infra-red absorption frequency of 1670−1740 cm^{-1}.
Some reactions of compound **Y** are given below.



Compound **Z** gives an effervescence when reacted with sodium carbonate solution.

(i) Name the functional groups present in compounds **Y** and **Z**.

..... [2]

(ii) Suggest the structures of compounds **X**, **Y** and **Z**.

Compound X	**Compound Y**	**Compound Z**

[3]

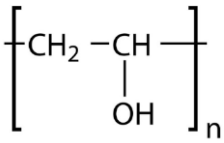
(iii) State the reagent and conditions needed to convert compound **Y** to **X**.

..... [1]

(iv) Name the type of reaction observed in the conversion of compound **Y** to **Z**.

..... [1]

(c) In contrast to PET, poly vinyl alcohol (PVA) is water soluble.



poly vinyl alcohol (PVA)

(i) State the type of polymerisation that occurs during the production of PVA.

..... [1]

(c) **(ii)** Draw the skeletal formula of the monomer used in PVA.

[1]

(iii) With reference to structure and bonding, explain why PVA is soluble in water.

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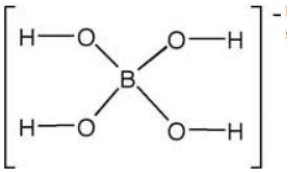
..... [2]

(iv) Upon the addition of borate ion, PVA can be cross-linked forming a thermoset polymer. The reaction produces water as a by-product.



Borate ion

With the aid of a diagram, illustrate how PVA is cross-linked with a borate ion, showing clearly how the covalent bonds are formed.

[2]

(d) Poly(tetrafluoroethene) is used as non-stick coating for pans and textile finishes that repels water and oil stains. It is also used in containers for reactive and corrosive chemicals due to its non-reactive properties.

(i) With reference to the structure and bonding in PTFE, suggest a reason to explain the property of PTFE in its uses as non-reactive containers.

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..... [1]

(ii) Geckos may not be able to stick on non-stick pans, but geckos can climb walls.
Explain why geckos have the ability to climb walls.

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..... [3]

[Total: 21]

5 Oleic acid is one of three fatty acids formed from the degradation of olive oil with a melting point of 13.0 °C and a condensed structural formula of $CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$. It can exist as a pair of isomers.

(a) (i) State the type of isomerism exhibited in oleic acid.

..... [1]

(ii) Explain how the type of isomerism in **(a)(i)** occurs.

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..... [2]

(iii) Draw and label the structural formulae of the pair of isomers in oleic acid.

[2]

(iv) With the use of a labelled diagram, describe the bonding in C=C in terms of orbital overlap.

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..... [3]

(v) Describe a simple chemical test to distinguish between oleic acid and ethane, stating clearly the observations for both compounds.

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..... [2]

[Total: 10]

Section B

Answer **one** question from this section in the spaces provided.

6 **(a)** Carbonic acid, H_2CO_3, is a *weak Bronsted acid*.

(i) Explain the term *weak Bronsted acid*.

..... [1]

(ii) The equation for the reaction between carbonic acid and water is as shown:

$$H_2CO_3(aq) + H_2O \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

Write an expression for the acid dissociation constant, K_a, for the above, stating its units clearly.

[2]

Carbonic acid can be mixed with sodium hydrogen carbonate to make a buffer solution.

(iii) Explain what is meant by the term buffer solution.

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..... [1]

(iv) Explain, by reference to the equilibrium in **(a)(ii)**, how this mixture behaves as a buffer. Write relevant equations in your answers.

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..... [2]

A number of equilibria exist when carbon dioxide is dissolved in water.

Equilibrium 1	$CO_2(g) \rightleftharpoons CO_2(aq)$	
Equilibrium 2	$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$	$K_c = 1.20 \times 10^{-3}$ at 25 °C
Equilibrium 3	$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$	

(b) A bottle of Coca-Cola drink contains carbon dioxide dissolved in water. The equilibrium concentration of aqueous carbon dioxide in an unopened bottle of Coca-Cola is 0.082 mol dm^{-3}.

(i) Write the equilibrium constant, K_c, of equilibrium 2, showing its units clearly.

[1]

(ii) Calculate the equilibrium concentration of carbonic acid, H_2CO_3 in an unopened bottle of Coca-Cola drink at 25 °C.

[1]

(iii) Suggest the effect on the pH of the drink when the Coca-Cola bottle is opened. Explain your reasoning in terms of the effect on the equilibrium concentrations and relative positions based on the reactions above.

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..... [3]

(c) The reaction of carbon dioxide with water to reach equilibrium with carbonic acid, H_2CO_3, was found to exhibit first order kinetics with a half life of 0.028s.

(i) Sketch the graphs of

- $[CO_2(aq)]$ in mol dm^{-3} against time in seconds.
- Rate of forward reaction in mol dm^{-3} s^{-1} against $[CO_2(aq)]$ in mol dm^{-3}

[2]

(ii) Determine the rate constant for this reaction, stating its units clearly.

[1]

(iii) Using, $\frac{c_t}{c_0} = (\frac{1}{2})^n$, calculate the time taken for carbonic acid to reach 98% of its equilibrium concentration.

[2]

(d) The enzyme, carbonic anhydrase, speeds up the reaction of carbon dioxide in water in living cells.

Fig. 6.1 shows how the rate of reaction is affected by the presence of the small amount of carbonic anhydrase

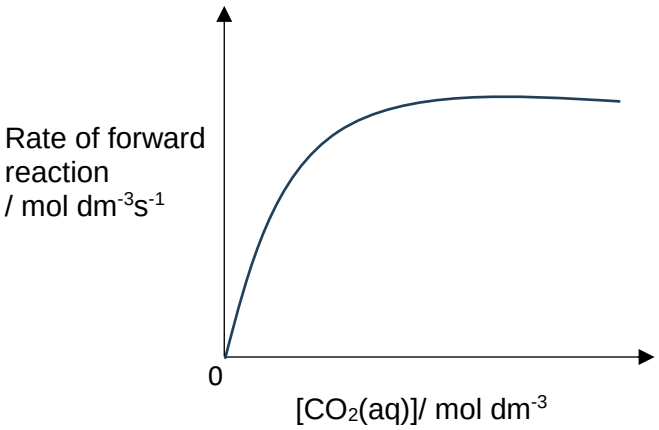

Fig. 6.1

Explain fully the shape of the graph.

When $[CO_2(aq)]$ is low, ...

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When $[CO_2(aq)]$ is high, ...

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..... [2]

(e) Solutions of carbonates react with acids according to the following equation.

$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g) \quad \text{---- reaction 4}$$

The table below shows the enthalpy change of formations for the following species.

Species	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$H_2O(l)$	–286
$CO_2(g)$	–394
$CO_3^{2-}(aq)$	–677
$H^+(aq)$	0.0

Calculate the enthalpy change of reaction of carbonate with acid, ΔH_r, in reaction 4.

[2]

[Total: 20]

7 This question is about oxides of nitrogen.

(a) Dinitrogen tetroxide, N_2O_4, decomposes into NO_2 as shown in the equation below.

$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

An experiment was conducted at 25 ^oC by varying initial concentrations of N_2O_4 and NO_2 contained in a closed reaction vessel. The initial and equilibrium concentrations of the two gases are shown in Table 7.1.

Expt	Initial concentration /mol dm^{-3}		Equilibrium concentration /mol dm^{-3}	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
1	0.000	0.200	0.0898	0.0204
2	0.600	0.040	0.594	0.0523
3	0.500	0.030	0.491	0.0475

Table 7.1

(i) State *Le Chatelier's Principle*.

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..... [1]

(ii) State and explain what will be observed when the pressure in the reaction vessel is decreased.

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..... [2]

(iii) Using experiment 2, calculate the equilibrium constant, K_c, of the reaction, stating its units.

[1]

(b) Catalytic converters are fitted in cars to remove oxides of nitrogen, which has significant environmental consequences if emitted into the atmosphere.
Platinum can be used as a catalyst in the catalytic converter.

(i) State the type of catalysis and outline the sequence and mode of action of the catalyst in the catalytic converter.

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..... [4]

(ii) Draw a Boltzmann distribution curve for the catalysed reaction and explain the effect on how the addition of catalyst would have on the rate of reaction

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..... [3]

(c) Nitric acid, HNO_3, is formed by the reaction of NO_2 with water. This is an example of an inorganic *strong acid*. Ethanoic acid, CH_3COOH, on the other hand, is an example of an organic acid, and is considered a *weak acid*.

(i) Explain what is meant by the terms in italics and illustrate your answers with the use of relevant equations.

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..... [2]

(ii) In an experiment, 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is added to 30 cm^3 of 1.00 mol dm^{-3} aqueous nitric acid. The temperature of the mixture increases by 5.6 ^oC

Calculate the enthalpy change of the neutralisation between sodium hydroxide and nitric acid.

The specific heat capacity of water is 4.18 J cm^{-3} K^{-1}.

[3]

(iii) A student repeated the experiment using 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide and 30 cm^3 of 1.00 mol dm^{-3} aqueous ethanoic acid. All other conditions were kept constant.

Suggest whether the temperature increase will be more or less than 5.6 ^oC and give an explanation for your answer.

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..... [2]

(iv) Suggest a suitable indicator for the titration of ethanoic acid with aqueous sodium hydroxide. Explain your choice.

Indicators	Working range
Screened methyl orange	2.2 to 4.4
Congo red	3.0 to 5.0
Phenolphthalein	8.0 to 9.6

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..... [2]

[Total: 20]