NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY
8873/02
Paper 2 Structured Questions
17 September 2024
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, registration number and subject class on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **one** question.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

A1	**/7**
A2	**/12**
A3	**/20**
A4	**/11**
A5	**/10**
B6 / B7	**/20**
Paper 2	**/80**
Paper 1	**/30**

Weightage	
Paper 1 (33%)	**/33**
Paper 2 (67%)	**/67**
Overall	

This document consists of **23** printed pages and **1** blank page.

Section A

Answer **all** the questions in this section in the spaces provided.

1 The structure of the atom was the subject of much discussion by scientists in the 19th and 20th centuries. The model that is agreed upon today was largely developed by Bohr, Rutherford, Moseley and Chadwick and describes atoms as consisting of smaller particles called protons, neutrons and electrons.

(a) (i) Complete the Table 1.1 to show the relative charge, relative mass and behaviour in an electric field of each of these three sub-atomic particles.

Table 1.1

	proton	neutron	electron
relative charge			
relative mass			
Direction of deflection of particle in an electric field			

[2]

(ii) Which particle will be deflected the most in an electric field?

……

[1]

(b) An element has a proton number of 16 and a nucleon number of 33. Draw a detailed diagram to represent the arrangement of protons, neutrons and electrons in an atom of this element.

[2]

(c) The element sulfur has four naturally occurring isotopes as shown in Table 1.2.

Table 1.2

isotope	relative abundance / %
^{32}S	94.93
^{33}S	0.76
^{34}S	4.29
^{36}S	0.02

Use the relative abundance data to calculate the relative atomic mass of sulfur to 4 significant figures. Show your working.

[2]

[Total : 7]

2 (a) With reference to the *Data Booklet*, state and explain the trend in the thermal stability of hydrogen halides down the group.

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[2]

(b) Element **A** is from Period 4 of the Periodic Table. The first eight ionisation energies of element **A**, in kJ mol^{-1}, are

947 1798 2735 4837 6043 12310 14300 16800

(i) Identify element **A** and explain your answer.

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[2]

(ii) Explain the difference between the first ionisation energy of element **A** compared to the element to its right on the Periodic Table.

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[2]

(c) A student mixed up the labels of a few bottles in the laboratory. The following are the labels that were mixed up:

$AlCl_3$ Al_2O_3 SiO_2 PCl_5

The following tests were then conducted to identify the bottles and the observations are recorded:
X and **Y** are insoluble in water while **W** and **Z** dissolve readily in water. When tested, the pH of the solution of **W** is lower than that of **Z**.

Y can react with both HCl (aq) and NaOH (aq), but **X** can only react with concentrated NaOH.

Determine the identities and provide relevant equations to support the answer.

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[6]

[Total : 12]

3 (a) Sulfur dioxide SO_2 and sulfites, SO_3^{2-}, are used as a food preservative to prevent spoilage.

(i) Draw the dot and cross diagram of SO_2 and SO_3^{2-}.

[2]

(ii) Using the Valence Shell Electron Pair Repulsion theory, state and explain the O−S−O bond angle in SO_2 and SO_3^{2-}.

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[3]

(b) The maximum permissible level of sulfite in wine is 250 mg per dm^3 of wine.

The amount of sulfite can be determined via titration with an oxidising agent.

$$SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$$

A 25.0 cm^3 sample of a wine was acidified, warmed and titrated against $KMnO_4$ to determine its concentration. 19.00 cm^3 of 0.020 mol dm^{-3} $KMnO_4$ was needed to reach the end point.

(i) Write the overall equation for the reaction between SO_3^{2-} and MnO_4^-.

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[1]

(ii) Suggest why the wine sample need to be warmed before the titration?

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[1]

(iii) Determine the concentration in mol dm^{-3}, of SO_3^{2-} in the wine sample.

[2]

(iv) Hence, determine whether the wine is safe for consumption.

[2]

(c) Sulfur trioxide is formed from the reaction between SO_2 and O_2 as shown below:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

(i) With reference from the *Data Booklet*, determine the enthalpy change of the reaction.

[2]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction above, stating its units.

[1]

(iii) 3 mol dm^{-3} of SO_2 and 2.3 mol dm^{-3} of O_2 were mixed in a closed vessel and allowed to reach equilibrium. The equilibrium concentration of SO_2 is found to be 2.4 mol dm^{-3}.

Calculate the K_c value.

[2]

The concentrations of the species were monitored over a period in the Fig 3.1:

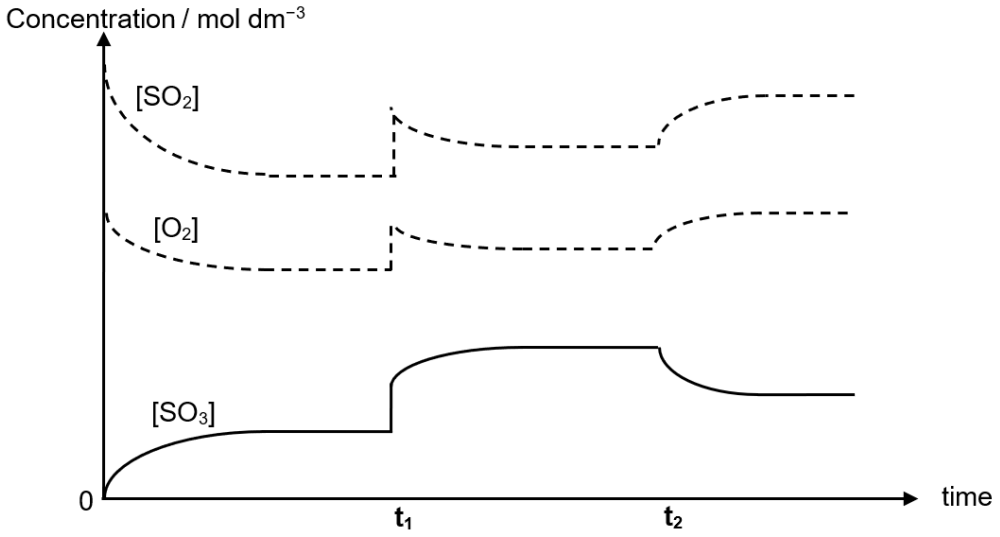

Fig 3.1

(iv) At t_1, the vessel was compressed and the total pressure increases.

Using Le Chatelier's Principle, explain the change in concentration of SO_3 between t_1 and t_2.

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[2]

(v) Considering your answer in **(c)(i)**, deduce the change in condition at t_2.

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[2]

[Total: 20]

4 (a) Poly(methyl methacrylate) (PMMA) is the synthetic polymer derived from methyl methacrylate (MMA) with the structural formula $CH_2C(CH_3)COOCH_3$. It is used as an engineering plastic, and it is a transparent thermoplastic.

(i) Draw the MMA monomer and one repeating unit of the PMMA polymer.

[2]

(ii) State the type of polymerisation that MMA undergoes.

……..……

[1]

(iii) When PMMA is exposed to environments with high humidity, it absorbs water and reduces its tensile strength. With the aid of a diagram, show interaction formed between the water molecule and PMMA.

[2]

(iv) With reference to the structure, suggest why PMMA cannot be used to hold alkaline based cleaners.

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[1]

(v) Explain why thermoplastics can be recycled.

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[1]

(vi) Methacrylic acid, $CH_2=C(CH_3)COOH$, can be used to synthesize methyl methacrylate (MMA), $CH_2C(CH_3)COOCH_3$.

Suggest the reagent and condition required for this synthesis.

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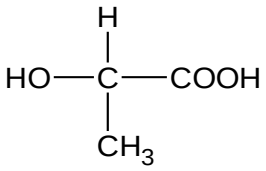
[1]

(b) Unlike PMMA, the polymer, polylactide (PLA) is biodegradable. The monomer required to produce PLA is lactic acid.

The structure of lactic acid is as shown.



(i) Give the IUPAC name for lactic acid.

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[1]

(ii) Draw the structure of the polymer PLA, showing two repeat units.

[1]

(iii) Explain why PLA is biodegradable.

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[1]

[Total : 11]

5 (a) Butan-2-ol can undergo reaction to produce a mixture of 3 isomers, **X**, **Y** and **Z** with the molecular formula C_4H_8.

(i) State the type of reaction.

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[1]

(ii) Suggest the reagent and condition required for the above conversion.

……..……

[1]

(iii) Suggest the structure of the 3 isomers and state the isomeric relationship between **X** and **Y**, and between **X** and **Z**.

[4]

(b) A possible source of energy for road vehicles of the future is hydrogen. One of the problems still to be solved is the storage of hydrogen in the vehicle.

(i) Suggest 2 potential issues with the storage of hydrogen in vehicle.

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[2]

One alternative is to use a fuel tank packed with carbon nanotubes. The hydrogen in the tank would be adsorbed onto the surface of the nanotubes at a pressure no more than a few atmospheres.

(ii) Suggest an approximate width of a carbon nanotube.

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[1]

(iii) State the forces that are responsible for holding the hydrogen on the surface of the nanotubes.

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[1]

[Total : 10]

Section B

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

6 (a) The condensation of ethanoic acid and ethanol to form ethyl ethanoate is catalysed by acid as shown by the equation

$$CH_3CO_2H + C_2H_5OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

To determine the orders of reaction with respect to ethanol and ethyl ethanoate, various volumes of the these were reacted and the results for the rates of the reactions are given in the Table 6.1.

Table 6.1

Expt	Vol of C_2H_5OH/cm^3	Vol of CH_3CO_2H/cm^3	Vol of H^+/cm^3	Vol of H_2O/cm^3	Rate of reaction/ mol dm^{-3} s^{-1}
1	20	10	5	35	2.5×10^{-4}
2	40	10	5	15	5.1×10^{-4}
3	40	20	5	5	1.0×10^{-3}

(i) Define the term rate of reaction.

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[1]

(ii) Explain why varying volumes of water were used.

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[1]

(iii) The order of reaction with respect to H^+ is found to be zero. Sketch the graph of rate against concentration of H^+.

[1]

(iv) Deduce the order of reaction with respect to C_2H_5OH and CH_3CO_2H.

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[2]

(v) Hence, state the rate equation for the condensation reaction. Deduce the units of the rate constant.

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[2]

(vi) With the aid of a Boltzmann distribution curve, explain the effect on the rate of reaction when temperature is increased.

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[3]

(b) H_2SO_4 is a strong acid while CH_3COOH is a weak acid.

(i) Calculate the pH of a 0.200 mol dm^{-3} H_2SO_4 solution.

[2]

(ii) Explain how a solution of CH_3COOH and CH_3COO^- can act as a buffer upon addition of small amounts of HC*l* and NaOH.

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[2]

(c) Ethanol has a boiling point of 76 °C while water has a boiling point of 100 °C.

In terms of structure and bonding, explain the difference in the boiling point of the two compounds.

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[2]

(d) Fig 6.1 shows an energy cycle involving the fuel ethanol.

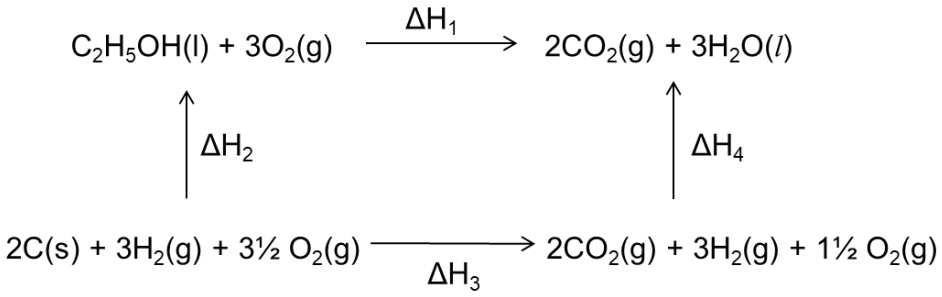

Fig 6.1

(i) In the energy cycle above, what enthalpy change is represented by ΔH_2?

……...
[1]

(ii) Write an equation that links ΔH_1, ΔH_2, ΔH_3 and ΔH_4.

……...
[1]

(iii) Use the following data to calculate the standard enthalpy change of combustion of ethanol.

$\Delta H_c^{\ominus}$ carbon = –393 kJ mol^{-1}

$\Delta H_c^{\ominus}$ hydrogen = –286 kJ mol^{-1}

$\Delta H_f^{\ominus}$ ethanol = –277 kJ mol^{-1}

[2]

[Total : 20]

7 (a) A sample of pure N_2O_5 (g) is placed in an evacuated container and allowed to decompose at a constant temperature of 300K.

$$2N_2O_5\,(g) \rightarrow 4NO_2(g) + O_2(g)$$

The concentration of N_2O_5 in the container is measured over a period of time, and the measurement are recorded in Table 7.1.

Table 7.1

Time (min)	$[N_2O_5]$/ moldm^{-3}
0	0.480
10	0.381
20	0.302
30	0.240
40	0.190
50	0.150

(i) With the use of the data in Table 3.3, show that the order of reaction with respect to N_2O_5 is one.

[1]

(ii) State the rate equation for the reaction. Deduce the units of the rate constant.

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[2]

(iii) With the aid of a Boltzmann distribution curve, explain the effect on the rate of reaction when a catalyst is added.

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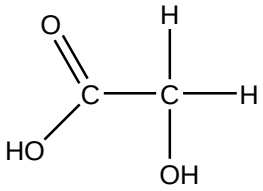
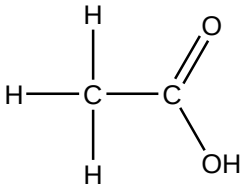
[3]

(b) Table 7.2 shows the K_a values of glycolic acid and ethanedioic acid.

Table 7.2

Acid	 glycolic acid	 ethanoic acid
K_a	1.48×10^{-4}	1.8×10^{-5}

(i) With reference to the table above, explain which acid is the stronger acid.

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[1]

(ii) Write the K_a expression for the dissociation of glycolic acid. You may represent glycolic acid using RCOOH.

[1]

(iii) The pH of the equivalence point of the titration between glycolic acid and NaOH is 7.6.

The working range pH of two indicators are shown in Table 7.3.

Table 7.3

Indicator	working range pH
Methyl Orange	3 – 5
Thymolphthalein	8 – 10

Explain which indicator is suitable for this titration.

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[1]

(iv) 50.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) are added to 25.0 cm^3 of 0.100 mol dm^{-3} of glycolic acid.

Calculate the pH of the resulting solution.

[2]

(c) A reaction scheme involving glycolic acid is shown in Fig 7.1

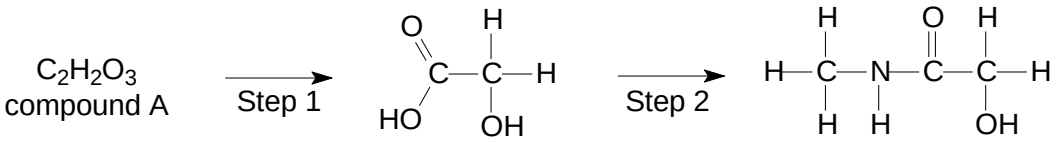

Fig 7.1

(i) State the type of reaction for Step 1 and Step 2

Step 1 : ……

Step 2 : ……

[2]

(ii) Draw the structure of compound **A**.

[1]

(iii) Suggest the reagents and conditions for the reaction in Fig 7.1.

Step 1	
Step 2	

[2]

(d) The enthalpy change of neutralisation between 1.00 mol dm^{-3} glycolic acid and 1.00 mol dm^{-3} sodium hydroxide can be determined experimentally by measuring the change in temperature when the two solutions are mixed together. Table 7.4 shows the data obtained:

Table 7.4

volume of glycolic acid used / cm^3	25.0
volume of sodium hydroxide used / cm^3	30.0
initial temperature of glycolic acid solution / ºC	31.3
initial temperature of sodium hydroxide solution / ºC	30.8
highest temperature rise after mixing / ºC	38.7

(i) Define the term *standard enthalpy change of neutralisation*.

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[1]

(ii) When the initial temperatures of two solutions are different and mixed, the initial temperature of the mixed solution will not be an average.

The weighted average initial temperature is given below:

Weighted average initial temperature = $(\frac{\boldsymbol{V_1}}{\boldsymbol{V_1 + V_2}} \times \boldsymbol{T_1}) + (\frac{\boldsymbol{V_2}}{\boldsymbol{V_1 + V_2}} \times \boldsymbol{T_2})$

where $\boldsymbol{V_1}$ and $\boldsymbol{V_2}$ are the volumes of solutions 1 and 2 respectively,
$\boldsymbol{T_1}$ and $\boldsymbol{T_2}$ are the initial temperatures of solutions 1 and 2 respectively.

Calculate the weighted average initial temperature of the reaction.

[1]

(iii) Calculate the enthalpy change of neutralisation between glycolic acid and sodium hydroxide.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and the density of each solution is 1.00 g cm^{-3}.

[2]

[Total : 20]