ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2 0 S**

CHEMISTRY 9729/02

Paper 2 Structured Questions **1 September 2021**

2 hours

Candidate 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 a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the **spaces provided** on the Question Paper.

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

A Data Booklet is provided.

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.

For Examiner's Use		
Q1		9
Q2		9
Q3		24
Q4		20
Q5		13
Total		75

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

1 (a) Fig. **1.1** shows a sketch of the logarithm of the first ten ionisation energies, log (IE), of element **A** against the number of electrons removed.

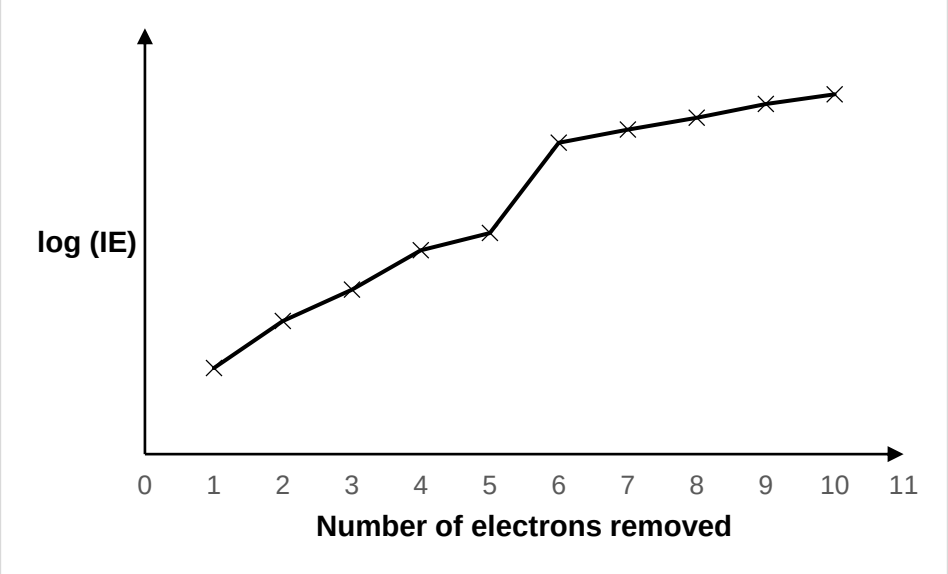


Fig. 1.1

(i) Write an equation for the *second ionisation energy* of element **A**. **[1]**

(a) (ii) Explain the following features of Fig. **1.1**.

- the general trend in ionisation energy shown in the graph
- the significant jump in values from the 5th to the 6th ionisation energy **[4]**

(iii) Element **A** is in Period 3.

Identify element **A** using information from Fig. **1.1** and complete its electronic configuration. **[1]**

Element **A** is _____

Electronic Configuration: $1s^2\ 2s^2$ _____

(b) Sulfur is another element in Period 3. It forms covalent bonds with other elements in covalent compounds such as SO_2, SO_3, SCl_2.

(i) Describe a covalent bond. **[1]**

(ii) Predict the intermolecular force which exists between SO_3 molecules. Explain how this force arises. You may use diagrams where appropriate to illustrate your answer. **[2]**

[Total: 9 marks]

2 Esters are commonly used as artificial flavourings in food products such as cakes and sweets. However, the shelf life of acidic foods containing esters are relatively short as esters are prone to acid-catalysed hydrolysis.

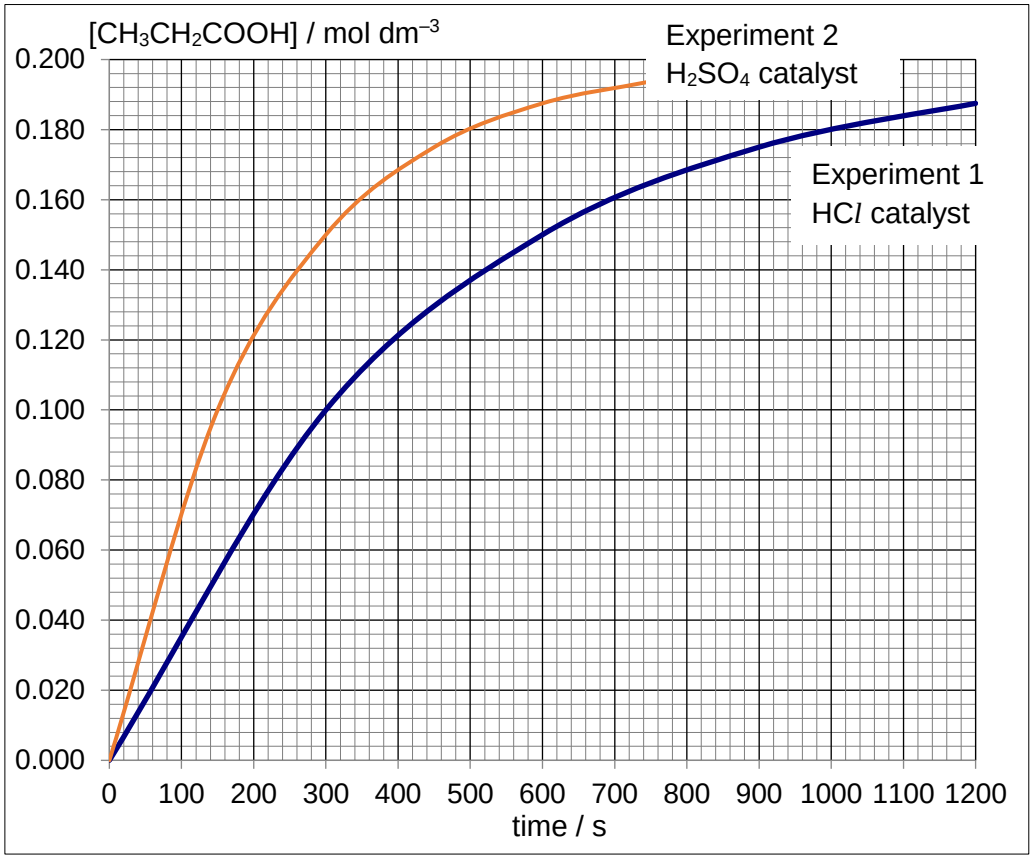
The kinetics of the acid-catalysed hydrolysis of the ester, methyl propanoate, $CH_3CH_2CO_2CH_3$, was investigated in an experiment.

(a) Write a balanced equation for the hydrolysis of methyl propanoate. **[1]**

_____

(b) 0.200 mol of ester was hydrolysed by heating with water and hydrochloric acid catalyst in a 1 dm^3 mixture. In a second experiment, hydrochloric acid was replaced with sulfuric acid of the same concentration. When the reaction is complete, 0.200 mol of propanoic acid is obtained.

The following results were obtained.



(b) (i) Based on the results obtained, show that the reaction is first order with respect to the ester and first order with respect to H^+ ions. **[4]**

(ii) State the units of the rate constant, *k*. **[1]**

(c) With the aid of a sketch of the Boltzmann distribution, explain how an increase in temperature changes the rate of ester hydrolysis. **[3]**

[Total: 9 marks]

3 Scuba diving is an extreme sport where divers carry their own source of breathing gas to explore the open sea.

Table **3.1** lists the compositions by volume of two breathing gases used by scuba divers.

Table 3.1

Mixture	Composition by volume
Nitrox	32% oxygen, 68% nitrogen
Heliox	21% oxygen, 79% helium

(a) (i) State one assumption of the kinetic theory as applied to an ideal gas. Hence, deduce, with reasons, whether Nitrox or Heliox shows greater deviation from ideal gas behaviour. **[2]**

(ii) Use of the *Data Booklet* is relevant to this question.

A canister of breathing gas has a density of 435 g m^{-3} at standard temperature and pressure (s.t.p). Calculate the average molar mass of the mixture.

Hence, with reference to Table 3.1, deduce the identity of the breathing gas. **[3]**

(b) At sea level, the atmospheric pressure is 1 atm. In the sea, there is an increase in pressure of 1 atm for every 10 m of depth below the surface. For example, at 10 m, the pressure on the diver's body is 2 atm and at 20 m, the corresponding pressure is 3 atm.

When a diver inhales from the gas canister, the air that enters the diver's lungs is at the surrounding pressure.

For safety reasons, divers should not inhale oxygen at partial pressures greater than 1.3 atm, as this may lead to oxygen toxicity, causing seizures and death.

(i) A scuba diver takes a deep breath from his oxygen gas canister to fill up his lungs to 6 dm^3 at a depth of 15 m. Calculate the volume that will be occupied in his lungs by this amount of air at the surface. **[2]**

(ii) "Never hold your breath when surfacing" is a fundamental rule of scuba diving. With reference to your answer in **(b)(i)**, explain why. **[1]**

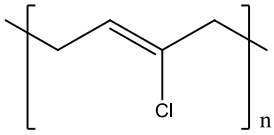
_____

_____

(b) (iii) A scuba diver uses Nitrox for a dive. Calculate the total pressure of the Nitrox mixture that corresponds to oxygen at a partial pressure of 1.3 atm. Hence, determine the maximum depth the diver can descend to safely. **[2]**

(iv) State an assumption that you have made in your calculations for **(b)(i)** and **(b)(iii)**. **[1]**

(c) Diving suits are commonly made of neoprene, a synthetic polymer that is waterproof and a good insulator.



neoprene

Neoprene can be synthesised from 1,3-butadiene by the following route shown in Fig. **3.2**.

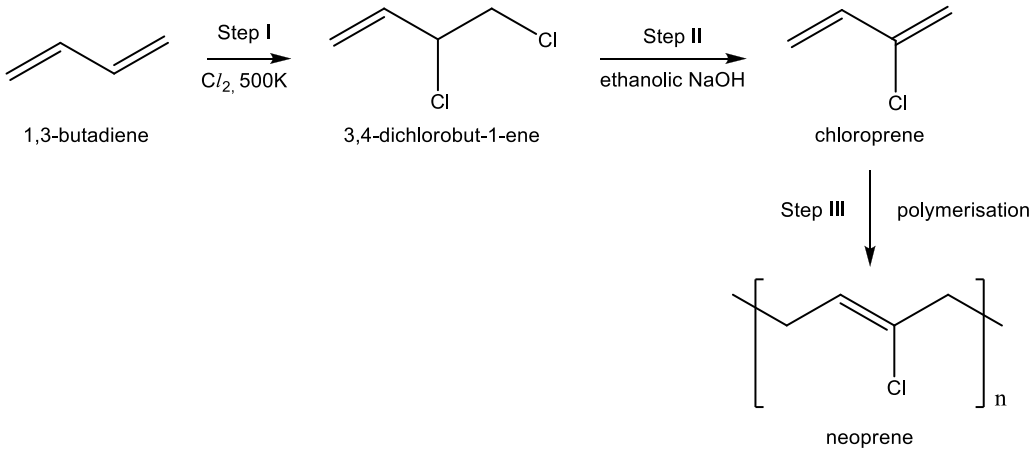


Fig. 3.2

(c) **(i)** Draw the structure of a possible side product formed in Step **I**. **[1]**

(ii) Suggest how to minimise formation of this side product in **(c)(i)**. **[1]**

_____

(iii) Name the type of reaction occurring in Step **II**. **[1]**

_____

(d) The polymerisation of chloroprene proceeds via a free radical mechanism. A common class of free radical polymerisation initiators are peroxide compounds, ROOR.

Explain what is meant by the term *free radical* and explain how the bond in ROOR breaks to form RO• free radicals. You may use a diagram in your answer. **[2]**

(i)

_____

_____

_____

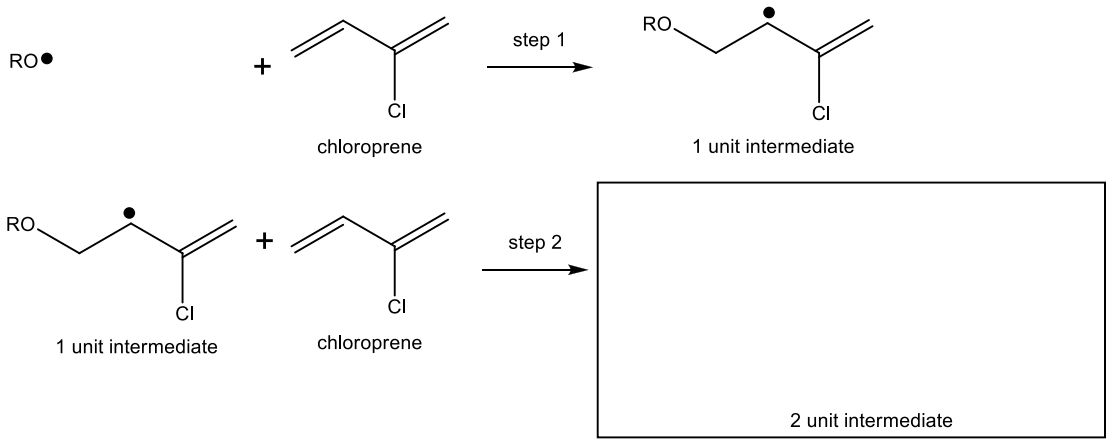
_____

(d) (ii) Suggest why only a trace amount of ROOR is required in the polymerisation of chloroprene. **[1]**

_____

_____

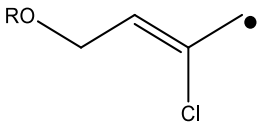
(e) (i) Complete Fig. **3.3** to suggest the mechanism for the chain growth. Show the structure of the 2 unit intermediate and the movement of electrons in steps 1 and 2 by using curly arrows.



n unit intermediate + chloroprene → (n+1) unit intermediate

Fig. 3.3 **[3]**

(ii) Explain the preferential production of the 1 unit intermediate over isomer **E** in step 1.



[1]

Isomer **E**

_____

_____

(f) (i) Besides diving suits, neoprene can be used to make alkali resistant rubber gloves. Suggest a reason why neoprene is not susceptible to reaction with alkali such as aqueous NaOH. **[1]**

_____

(ii) Under suitable conditions, NaOH can be used to distinguish between 3,4-dichlorobut-1-ene and chloroprene.

Describe the simple chemical test involving NaOH to distinguish between the two compounds. Write relevant balanced equations for the reactions that occurred. **[2]**

_____

_____

_____

_____

_____

_____

[Total: 24 marks]

4 (a) Gallium is an element in Group 13.

A sample of gallium contains two isotopes, ^{69}Ga and ^{71}Ga. The relative atomic mass of the gallium in this sample is 69.8.

(i) Explain what is meant by the term *relative atomic mass*. **[1]**

_____

_____

(ii) Calculate the percentage abundance of each of these isotopes. Show your working. **[2]**

(iii) Complete the table which describes a gaseous atom of gallium.

Isotope	Number of neutrons	Type of orbital contains electron in **highest** energy level	Total number of electrons in this **highest** occupied orbital
^{69}Ga			

[2]

(b) Gallium and its compounds show similar properties to aluminium and its compounds. Gallium reacts with excess chlorine to form gallium trichloride.

In their gaseous form, equimolar amounts of PH_3 and $GaCl_3$ combine to form a solid product PH_3GaCl_3 at 120 ^oC in a closed reaction vessel.

$$PH_3(g) + GaCl_3(g) \rightleftharpoons PH_3GaCl_3(s) \text{ ---------- Equilibrium 1}$$

The equilibrium constant was determined to be 550 mol^{-2} dm^6.

(b) (i) The reaction between PH_3 and $GaCl_3$ is similar to that between NH_3 and $AlCl_3$. Suggest the role of $GaCl_3$ in this reaction. Explain your answer. **[2]**

(ii) Write the expression for the equilibrium constant, K_c, for equilibrium 1. Hence, show that the concentration of PH_3 in the closed vessel was 0.0426 mol dm^{-3} after some solid PH_3GaCl_3 was formed at equilibrium. **[2]**

(iii) Suggest what happens to the concentration of PH_3 when some of the solid PH_3GaCl_3 is removed. **[1]**

(iv) Predict the effect on the equilibrium constant, K_c, when the reaction vessel is heated. Explain your answer. **[2]**

(b) **(v)** The value of K_c does not change when a catalyst is added. Explain why this is the case. **[2]**

_____

_____

_____

(c) Gallium is a silver-grey solid. Aluminium and gallium share many similar chemical properties.

Write the equation for the reaction between Ga_2O_3 and dilute hydrochloric acid. **[1]**

_____

(d) Gallium objects have a thin insoluble oxide layer on their surfaces. This oxide layer can be removed by adding aqueous sodium hydroxide to the gallium object.

An initial reaction occurs during which no observations are made. After a short time, bubbles of hydrogen gas are produced. When these bubbles appear, the object is removed from the aqueous sodium hydroxide and rinsed.

(i) Explain why Ga_2O_3 is insoluble in water. **[1]**

_____

(ii) Write an equation, with state symbols, which describes the initial reaction occurring when NaOH(aq) is first added to the object, before the bubbles are seen. **[2]**

_____

(iii) Explain, with the aid of a relevant equation, the reaction that resulted in the formation of H_2 gas. **[2]**

_____

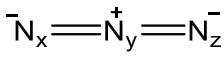
_____

_____

[Total: 20 marks]

5 One important class of chemicals in everyday life are the azides, compounds which contain the azide anion N_3^-.

(a) Given the structure of the azide ion, deduce the hybridisation of the nitrogen atom labelled N_y, and state the number of σ and π bonds present in the ion.



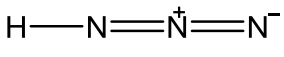
Azide ion **[2]**

Hybridisation: _____

Number of σ bonds: _____

Number of π bonds: _____

(b) The azide ion can be obtained from gaseous hydrazoic acid, HN_3, which has the following structure.



Hydrazoic acid

(i) The enthalpy change of formation of gaseous hydrazoic acid is +264 kJ mol^{-1}. Using the relevant bond energy values from Table **5.1**, calculate the average bond energy of the N=N double bond in hydrazoic acid.

You can assume that the bond energy in hydrazoic acid is not affected by the charges on the N atoms.

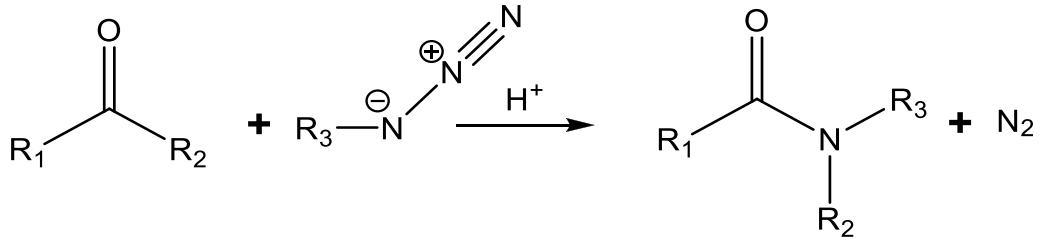
Bond	**Bond energy / kJ mol^{-1}**
H-H	436
N≡N	944
N-H	390

Table 5.1 **[3]**

(b) (ii) Suggest why the value calculated in **(b)(i)** is different from the value stated in the *Data Booklet*. **[1]**

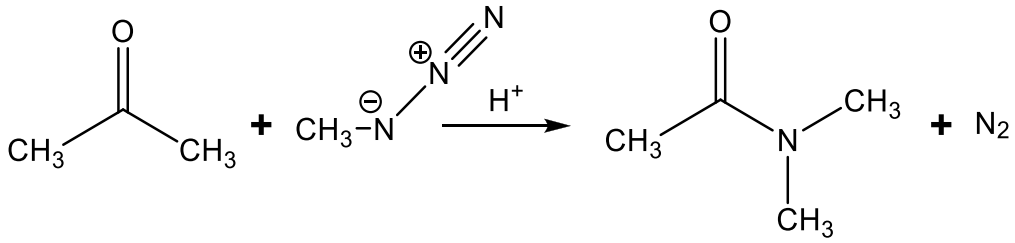
(c) Azides are also a functional group in organic chemistry with the structure $R–N_3$, where R is an alkyl group. These are known as alkyl azides.

In the Schmidt/Boyer reaction, alkyl azides react with carbonyl compounds under acidic conditions to form amides.



Where R_1/R_2 are H or alkyl groups.

For example, propanone reacts with methyl azide to form an amide.



(i) When butanone reacts with methyl azide, two products are formed. Draw the structure of both organic products. **[2]**

(c) (ii) The Schmidt/Boyer reaction is very useful in synthesising β-lactams, four-member cyclic amides, a structure found in many antibiotics.

Compound **R** is an example of a simple β-lactam. Compound **R** can be prepared by a sequence of reactions, starting from 3-chloro-2-methylpropanal as shown in Fig. **5.1**.

Suggest the type of reaction for Reaction **1**, and suggest the structure of compound **Q**, which has an aldehyde and an azide group.

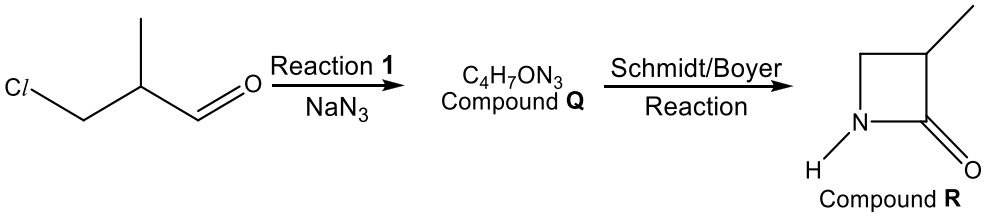


Fig 5.1 **[2]**

Reaction **1**: _____

Compound **Q**

(iii) Compound **R** is not basic. Explain. **[1]**

_____

_____

(iv) Using VSEPR theory **only**, state the *expected* bond angle of the C-N-C bond in compound **R**. **[1]**

Expected bond angle: _____

(v) The C-N-C bond in compound **R** has been experimentally found to be 90°. Using this information and your answer in **(c)(iv)**, suggest why compound **R** undergoes hydrolysis more readily than ethanamide. **[1]**

_____

_____

[Total: 13 marks]

~End of Paper~