Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions

11 September 2024
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
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.

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

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

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

For Examiner's Use	
Section A	
1	**10**
2	**13**
3	**17**
4	**20**
Section B	
5 / 6	**20**
Total	**80**

This document consists of **24** printed pages.

[Turn over

Section A

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

1 (a) Petrol is a mixture of hydrocarbons that includes octane, C_8H_{18}. The density of petrol is typically 748.9 kg per litre and comprises 95% octane by mass.

(i) Write an equation for the complete combustion of octane.

…… [1]

(ii) Calculate the volume of carbon dioxide gas that will be emitted at r.t.p., if a full tank carrying 50 litres of petrol is completely combusted. You should assume that only octane undergoes combustion.

[3]

(iii) Ethanol is sometimes added to the petrol for internal combustion engine. The standard enthalpy change of combustion of ethanol, $\Delta H_c^{\ominus}$, can be determined by applying Hess' Law to the energy cycle in Fig. 1.1.

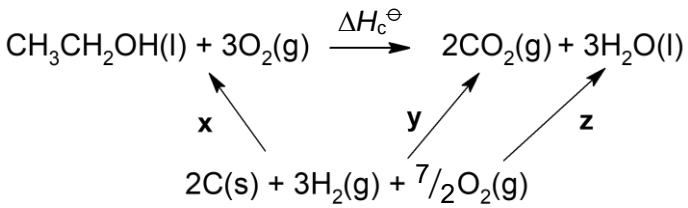

Fig. 1.1

Express the standard enthalpy change of combustion of ethanol, $\Delta H_c^{\ominus}$, in terms of **x**, **y** and **z**.

…… [1]

(iv) State the type of enthalpy change that **x** represents.

…… [1]

(b) Exhaust gases from internal combustion engine are harmful to the environment. These include oxides from carbon and nitrogen.

(i) Write an equation to show the removal of carbon monoxide **and** nitrogen monoxide from the exhaust gases.

…….. [1]

(ii) State one reason why carbon monoxide is harmful.

……

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……..……[1]

(iii) Butane is a fuel that is commonly used in gas canisters that light up stoves.

Suggest, with reference to structure and bonding, why butane is used as a fuel in gas canisters but not octane.

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……..……[2]

[Total: 10]

2 **(a)** Describe and explain the variation in ionic radius across Period 3 of the Periodic Table for the elements Na to C*l*.

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…… [4]

(b) **(i)** State what is meant by the term *electronegativity*.

……[1]

(ii) State how the bonding in the oxides of the elements sodium to sulfur changes across Period 3.

Explain this change in terms of the electronegativities of these elements.

……

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……

……

……

……[2]

(c) Ammonia, NH_3, forms ammonium cation, NH_4^+, when dissolved in water.

(i) Draw a 'dot-and-cross' diagram to show the bonding in NH_4^+.

[1]

(ii) State the shape and bond angle of NH_3 and NH_4^+.

Explain your answers using the Valence Shell Electron Pair Repulsion (VSEPR) theory.

shape of NH_3 …… bond angle of NH_3 ……

shape of NH_4^+ …… bond angle of NH_4^+ ……

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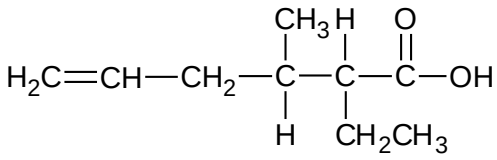
…… [5]

[Total: 13]

3 **(a)** The structure of compound **M**, $C_8H_{15}COOH$, is shown below.



M

(i) Draw the skeletal formula of **M**.

[1]

In the liquid state, **M** forms a dimer, $(C_8H_{15}COOH)_2$.

(ii) By representing the structure of **M** as RCOOH, draw a suitable diagram to illustrate the formation of the dimer.

Include lone pairs, dipoles and label the interactions formed.

[2]

(b) Dinitrogen tetroxide, N_2O_4, and nitrogen monoxide, NO, can exist in equilibrium with dinitrogen trioxide, N_2O_3.

$$N_2O_4(g) + 2NO(g) \rightleftharpoons 2N_2O_3(g) \qquad \Delta H^{\ominus} = -26 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_c, including its units.

[2]

(ii) A mixture containing a 1:2 ratio of N_2O_4 and NO was allowed to reach equilibrium in a 5 dm^3 sealed vessel. At equilibrium, the amount of each compound was determined.

compound	amount / mol
N_2O_4	0.153
NO	0.307
N_2O_3	0.0511

Calculate the value for K_c.

[1]

(iii) State and explain how the position of equilibrium might change when

- temperature is increased,

……

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……

……

- the vessel is compressed.

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[2]

(iv) Predict how the value of K_c will change when

- temperature is increased,

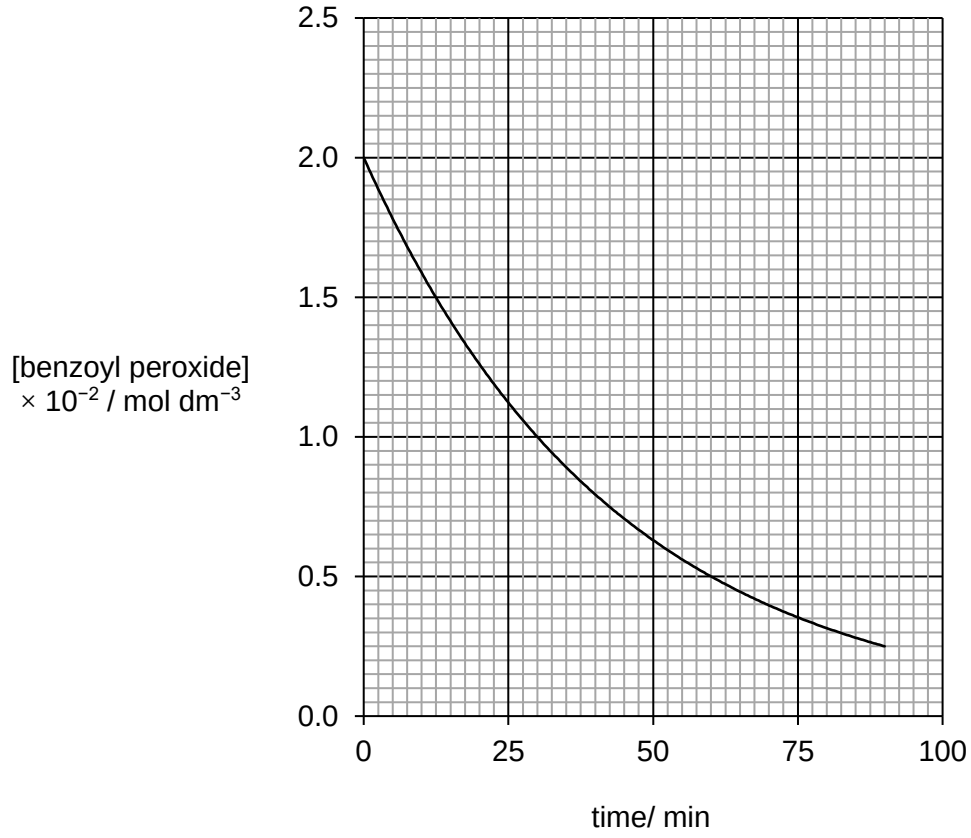
……

- the vessel is compressed.

……

[1]

(c) The graph shows the results obtained when the rate of thermal decomposition of benzoyl peroxide is investigated. The reaction is first order with respect to benzoyl peroxide.



(i) Explain in terms of particles why the rate of decomposition decreases with time.

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……

……[1]

(ii) Use the graph to show that the overall reaction is first order. [1]

(iii) The initial rate of the reaction is 4.62×10^{-4} mol dm^{-3} min^{-1}.

Write a rate equation for this reaction. Hence, calculate the value of the rate constant, *k*. Include its units.

[2]

(iv) Fig. 3.1 shows a Boltzmann distribution curve for the decomposition of benzoyl peroxide molecules at a fixed temperature, T_1.

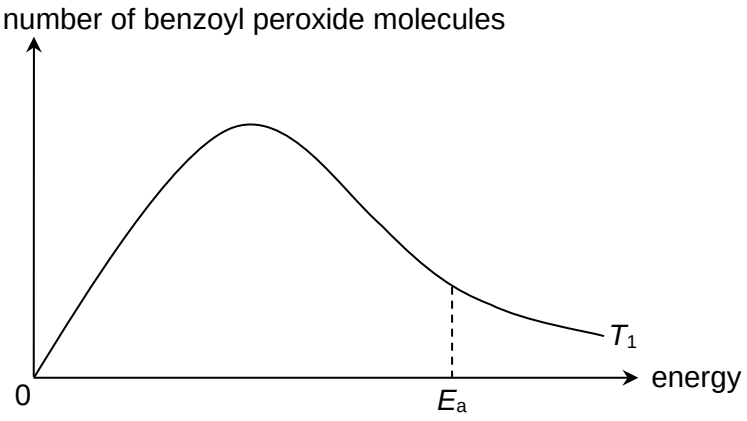

Fig. 3.1

Sketch, on Fig. 3.1, a Boltzmann distribution curve when the decomposition of benzoyl peroxide is carried out at a lower temperature, T_2. Shade the region that corresponds to the number of molecules having energy higher than the activation energy, E_a, at T_2.

[1]

(d) The decomposition of hydrogen peroxide, H_2O_2, can be accelerated by using an enzyme, catalase.

Fig. 3.2 shows how the rate of decomposition of hydrogen peroxide varies with its concentration in the presence of catalase.

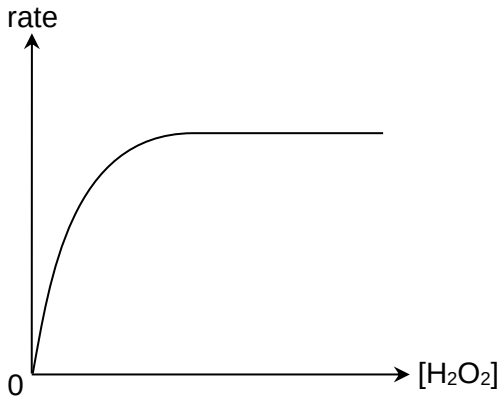

Fig. 3.2

(i) Define the term *catalyst*.

……

……

……[1]

(ii) Explain why the rate of decomposition remains constant at high concentrations of H_2O_2.

……

……

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……

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……[2]

[Total: 17]

4 (a) Two unknown polymers, polymer **A** and polymer **B**, have been provided for analysis. Table 4.1 shows the observed data from various tests performed on these polymers.

Table 4.1

property	polymer **A**	polymer **B**
glass transition temperature (T_g)/ °C	−125	100
melting temperature (T_m)/ °C	135	not applicable
flexibility	high	low
tensile strength/ MPa	20	140
electrical conductivity	no	no

T_g: the temperature at which a polymer changes from a hard, glassy material to a soft, rubbery material

T_m**:** the temperature at which a *crystalline polymer* transitions from a solid state to a liquid state

MPa: megapascal, a unit of pressure

(i) Explain what a *crystalline polymer* is.

……

……

……

…… [1]

(ii) Using relevant data from Table 4.1, classify polymer **A** and polymer **B** as either thermoplastic or thermoset polymer. Explain your answer with reference to structure and bonding.

polymer **A** …….. polymer **B** ……..

……

……

……

……

……

……

……[5]

(iii) With consideration of the data in Table 4.1, suggest one potential application each for polymer **A** and polymer **B** in everyday products.

……

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……

……

……[1]

(iv) With reference to the data in Table 4.1, discuss the environmental implications of using polymer **A** versus polymer **B**, particularly in terms of recycling and disposal.

……

……

……

……

……

……[2]

(b) **(i)** Ethene is the monomer of the polymer, polyethene.

Describe the bonding between the carbon atoms in ethene in relation to the σ and π bonds present.

Draw a diagram to show how the orbitals overlap to form the π bond. Label the π bond.

……

……

……

……

…… [3]

Fig. 4.1 shows a possible reaction pathway to produce ethene from ethane.

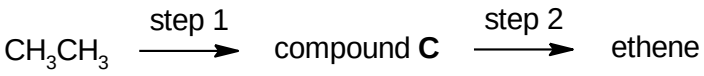


Fig. 4.1

(ii) State the reagents and conditions for steps 1 and 2.

step 1 ……..

step 2 ……..

[2]

(iii) Draw the structure of compound **C**.

[1]

Poly(ethylene-vinyl acetate), PEVA, is a copolymer of ethene and vinyl acetate.
Fig. 4.2 shows the structure of vinyl acetate.

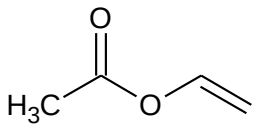


Fig. 4.2

(iv) Identify the functional groups present in Fig. 4.2.

……..……...…. [1]

(v) State the type of polymerisation that produces PEVA.

……..……...…. [1]

(vi) Draw one possible repeat unit of PEVA.

[1]

(c) Platinum nanoparticles are often integrated into a polymer matrix in catalytic converters. Catalytic converters are designed to reduce harmful emissions from vehicle exhaust systems by converting toxic gases into less harmful substances.

(i) Define what is meant by the term *nanoparticles*.

……

…… [1]

(ii) Explain how the unique properties of nanoparticles enhance the performance of the catalyst.

……

……

……

……

…… [1]

[Total: 20]

Section B

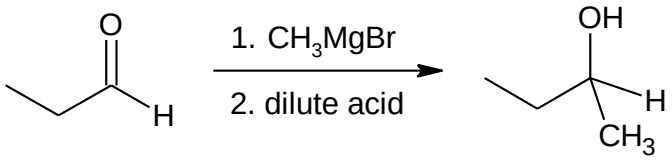
Answer **one** question from this section in the spaces provided.

5 Carbon, nitrogen and oxygen are pivotal elements that form a vast array of organic compounds.

(a) Alcohols and aldehydes are functional groups containing carbon and oxygen atoms.

Alcohols can be synthesised from aldehydes using a Grignard reagent. A Grignard reagent is an organometallic reagent containing magnesium attached to an alkyl group and a halogen.

CH_3MgBr is an example of a Grignard reagent. When reacted with propanal, followed by the addition of a dilute acid, butan–2–ol can be obtained.



propanal butan-2-ol

(i) State the IUPAC name of the reactant that can be converted to butan-2-ol using lithium aluminium hydride in dry ether.

……..……...…. [1]

(ii) Compound **V** can react with CH_3MgBr, followed by the addition of a dilute acid, to form ethanol. Draw the structure of **V**.

[1]

(b) Nickel also features in many organometallic compounds containing carbon and oxygen atoms.

(i) Table 5.1 shows the percentage composition of each of the element in an organometallic compound containing nickel. This organometallic compound has a formula mass of 170.7.

Table 5.1

element	% composition
Ni	34.4
C	28.1
O	37.5

Determine the molecular formula of this organometallic compound.

[2]

(ii) A sample of nickel contains 3 isotopes of nickel. Table 5.2 shows the identity of these isotopes and their relative abundance in the sample.

Table 5.2

isotope	relative abundance / %
^{58}Ni	75.4
^{60}Ni	22.5
^{78}Ni	2.1

Calculate the relative atomic mass of nickel in the sample. Leave your answer to 2 decimal places.

[1]

(c) Elemental nickel can be oxidised by nitric acid, HNO_3, to form Ni^{n+} ions. Nitrous oxide, NO, is produced as one of the products of this reaction.

In an experiment, 5 g of nickel was reacted with an excess of nitric acid. At the end of the reaction, 1.36 dm^3 of NO gas was collected at room temperature and pressure.

(i) Write the half-equation for the reduction of HNO_3 to NO.

……..……...…. [1]

(ii) Calculate the amount of electrons transferred in this reaction.

[1]

(iii) Using appropriate calculations, determine the value of *n* in Ni^{n+}.

Hence, write the equation for the reaction that has occurred.

value of *n* ……..

equation ……...

[2]

(d) Carboxylic acids also contain carbon and oxygen atoms. Carboxylic acids are considered both Arrhenius acids and Brønsted-Lowry acids.

(i) Define the term *Arrhenius acid*.

……

…….…….…. [1]

(ii) Propanoic acid is a weak acid. Propanoic acid acts as a Brønsted-Lowry acid when added to water.

Write an equation to show the Brønsted-Lowry acid behaviour of propanoic acid when it is added to water. Your equation should include the **displayed formula** of the conjugate base of propanoic acid.

[2]

(iii) Suggest a suitable indicator for a titration involving propanoic acid and potassium hydroxide.

……..…….…. [1]

(iv) Group 1 elements react with propanoic acid to produce hydrogen gas.
State the role of the Group 1 elements in this reaction and describe how their reactivity will vary down the group.

role ……..

reactivity ……..……...

……..…….....…
[2]

(e) Amides and esters are carboxylic acid derivatives.

(i) DCC is used in the formation of amides when carboxylic acids react with amines.

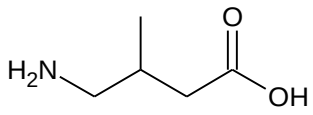
State the type of reaction and the role of DCC in this reaction

type of reaction …….

role of DCC ……..

[2]

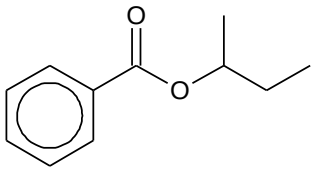
(ii) Compound **W** reacts with DCC. Draw the structure of the product, C_5H_9NO.



W

[1]

(iii) Compound **X** contains an ester functional group.



X

Draw the structures of the two organic products formed when **X** was heated in acidified $KMnO_4$.

[2]

[Total: 20]

6 Lactic acid is a monoprotic organic acid and has the molecular formula, $C_3H_6O_3$. Lactic acid is an α-hydroxy acid because the hydroxyl (−OH) group and the carboxyl (−COOH) group are bonded to the same carbon.

(a) Draw the displayed formula of lactic acid.

[1]

(b) State the IUPAC name for lactic acid.

……..……..[1]

(c) A student added 0.180 mol dm^{-3} sodium hydroxide gradually to 25.0 cm^3 of 0.180 mol dm^{-3} lactic acid to produce an acidic buffer solution. This solution of lactic acid used in the titration has a pH of 2.30.

(i) Calculate the concentration of H^+ ions in the lactic acid solution.

[1]

(ii) Hence, explain whether lactic acid is a strong or weak acid.

……

……

…… [1]

(iii) Write the K_a expression for lactic acid. You may use HA and A^- to represent lactic acid and its conjugate base respectively.

[1]

(iv) Hence, calculate the value of K_a for lactic acid.

[1]

(v) Define *buffer solution*.

……

……

…….. [1]

(vi) A buffer solution is said to be at its **maximum buffering capacity** when it is most effective in resisting pH change. For an acidic buffer solution, this occurs when the concentration of weak acid is equal to the concentration of the salt containing its conjugate base.

Suggest the volume of NaOH to be added to the lactic acid for the acidic buffer solution to be at its **maximum buffering capacity**.

volume of NaOH to be added = …… cm^3

[1]

(vii) A mixture of lactic acid and sodium lactate can be used as an acidity regulator. An acidity regulator ensures that there is little variation in the pH of food products.

With the aid of an equation, explain how the mixture of lactic acid and sodium lactate can maintain the pH when a small amount of an acid is added to a food product.

You may use HA and A^- to represent lactic acid and lactate ion respectively.

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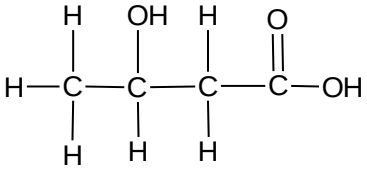
…….. [2]

(d) Another type of hydroxy acid **W** is shown. Compound **W** reacts with alumina, Al_2O_3, to form 3 isomers, **X**, **Y** and **Z**.



W

(i) Name the type of reaction occurring when **W** reacts to form **X**, **Y** and **Z**.

…… [1]

(ii) The structural formula of isomer **X** is CH_2CHCH_2COOH. When it is heated with hydrogen gas in the presence of a nickel catalyst, compound **V** is formed.

Draw the structure of **V**.

[1]

(iii) Name the type of isomerism in **Y** and **Z**.

…… [1]

(iv) Draw the structures of **Y** and **Z**.

[1]

(v) Suggest a simple chemical test to distinguish **X** from **W**. State the expected observations for each compound.

……

……

……

……

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……

……

…….. [2]

(e) **(i)** Suggest the pH of the resulting solution when Al_2O_3 is mixed with water. State the final colour of the solution when a few drops of Universal Indicator are added.

pH of resulting solution ……

final colour of solution ……..……

[1]

(ii) Explain why Al_2O_3 does not react with water.

……

……

……

…….. [1]

(iii) Al_2O_3 is amphoteric in nature.

Write equations for its separate reactions with aqueous HC*l* and NaOH.

with HC*l* ……..……..…

with NaOH ……

[2]

[Total: 20]