**Suggested Solutions**

# DUNMAN HIGH SCHOOL
# Preliminary Examination
# Year 6

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## H1 CHEMISTRY

## 8873/02

Paper 2 Structured Questions

**11 September 2024**
**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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**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 **20** printed pages.

## 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]

$C_8H_{18}(l) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$

**(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]

Mass of octane combusted = $50 \times 0.95 \times 748.9 = 35572.75$ kg
No. of mol of octane combusted = $\frac{35572.75 \times 1000}{114} = 3.12 \times 10^5$ mol

Since $C_8H_{18} \equiv 8CO_2$, no of mol of $CO_2$ emitted = $3.12 \times 10^5 \times 8$
$= 2.50 \times 10^6$ mol

Volume of $CO_2$ emitted at r.t.p. = $2.50 \times 10^6 \times 24$
$= 5.99 \times 10^7$ $dm^3$

**(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.

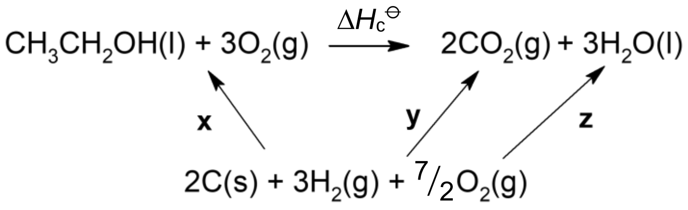


**Fig. 1.1**

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

[1]

$\Delta H_c^{\ominus} = -\mathbf{x} + \mathbf{y} + \mathbf{z}$

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

[1]

standard enthalpy change of formation of ethanol

**(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]

$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g)$

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

[1]

Carbon monoxide is harmful because it can cause suffocation/ death if inhaled in high concentration.

**(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.

[2]

Butane has a smaller and less polarisable electron cloud resulting in weaker instantaneous dipole–induced dipole interactions between molecules compared to octane. Hence, less energy is required to overcome these weaker intermolecular forces of attraction and butane has a lower boiling point/more volatile than octane. Therefore, butane exists as a gas that can be stored in a canister but not octane.

[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*.

[4]

Across the period from $Na^+$ to $Si^{4+}$ and from $P^{3-}$ to $Cl^-$, **number of protons and hence** nuclear charge increases. However, screening effect is the same as the isoelectronic ions have the same number of electrons. Therefore effective nuclear charge increases.

This results in a progressively stronger electrostatic forces of attraction between nucleus and valence electrons/ valence electrons are progressively pulled closer to the nucleus.

Thus, the ionic radius decreases as the atomic number increases.

Anions have an additional electron shell as compared to the cations.

Despite the larger nuclear charge of anions, valence electrons of anions are more shielded and further away from the nucleus than the valence electrons of cations.

Thus, ionic radii of anions are larger than cations in the same period.

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

[1]

Electronegativity refers to the ability of an atom to attract a shared pair of electrons in a covalent bond.

**(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.

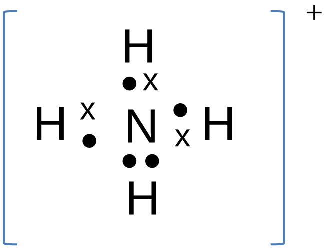
[2]

Bonding in the oxides of the elements changes from ionic to covalent across Period 3.

Across the period from Na to S, electronegativity of the elements increases so the electronegativity difference between the element and oxygen in the oxides decreases.

**(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 $NH_3$: trigonal pyramidal bond angle of $NH_3$: 107°

shape of $NH_4^+$: tetrahedral bond angle of $NH_4^+$: 109.5°

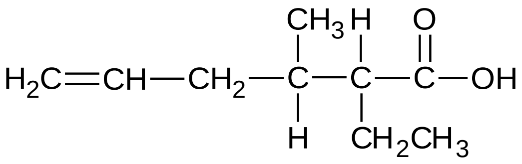
There are different number of bond pairs and lone pairs of electrons around the central N atom in both $NH_4^+$ and $NH_3$, with four bond pair and zero lone pairs of electrons in $NH_4^+$, and three bond pairs and one lone pair of electrons in $NH_3$.

By VSEPR theory, these electron pairs are arranged in a manner to minimise repulsion with lone pair-bond pair repulsion > bond pair-bond pair repulsion. Hence, the shapes and bond angles are different.

[5]

[Total: 13]

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

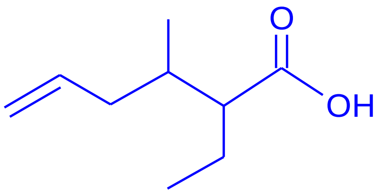


$$H_2C{=}CH{-}CH_2{-}\underset{H}{\overset{CH_3}{C}}{-}\underset{CH_2CH_3}{\overset{H}{C}}{-}\overset{O}{\overset{\|}{C}}{-}OH$$

**M**

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

[1]

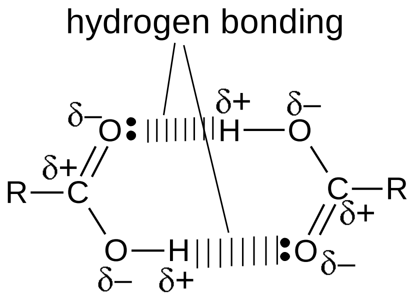


In the liquid state, **M** forms a dimer, $(C_8H_{15}COOH)_2$.

**(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]

$$K_c = \frac{[N_2O_3]^2}{[N_2O_4][NO]^2}\ \text{mol}^{-1}\ \text{dm}^3$$

**(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]

$$K_c = \frac{\left(\frac{0.0511}{5}\right)^2}{\left(\frac{0.153}{5}\right)\left(\frac{0.307}{5}\right)^2}$$

$$= \frac{(0.01022)^2}{(0.0306)(0.0614)^2}$$

$= 0.905 \text{ mol}^{-1} \text{ dm}^3$

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

- temperature is increased,
- the vessel is compressed.

[2]

- temperature is increased,

With an increase in temperature, by Le Chatelier's Principle, position of equilibrium shifts left to decrease the temperature by favouring the endothermic reverse reaction that absorbs heat.

- the vessel is compressed.

Total pressure increases when the container is compressed. By Le Chatelier's Principle, position of equilibrium shifts right to decrease the total pressure by reducing the total moles of gas molecules.

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

- temperature is increased
- the vessel is compressed.

[1]

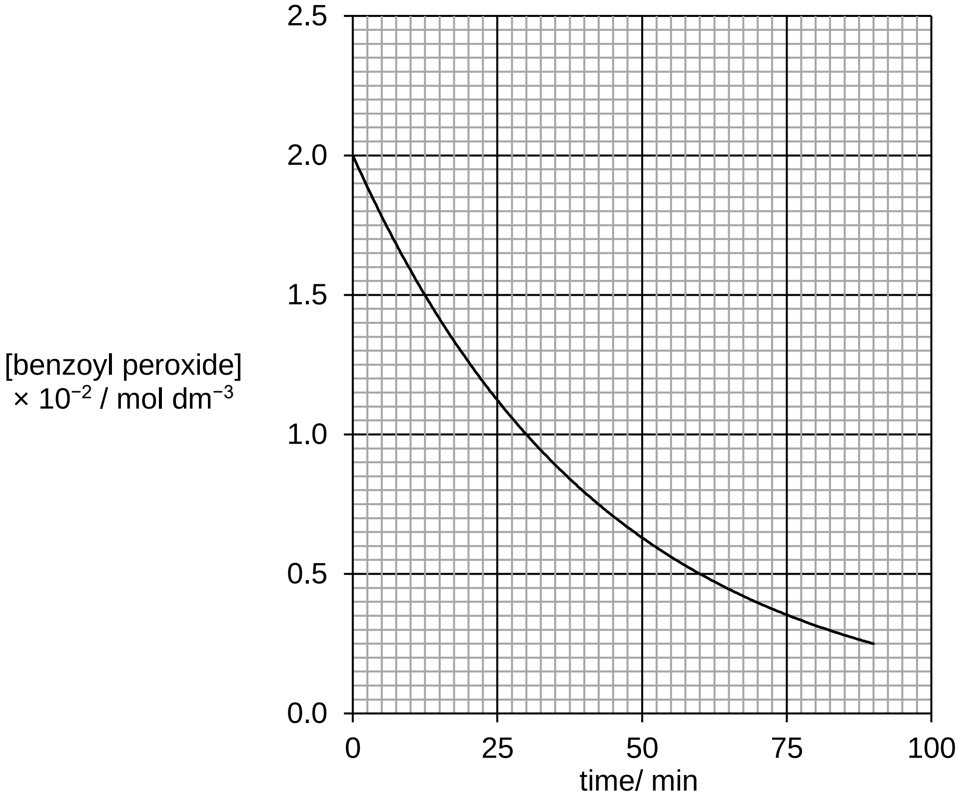
- temperature is increased

$K_c$ decreases.

- the vessel is compressed.

$K_c$ remains constant / no change.

**(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.



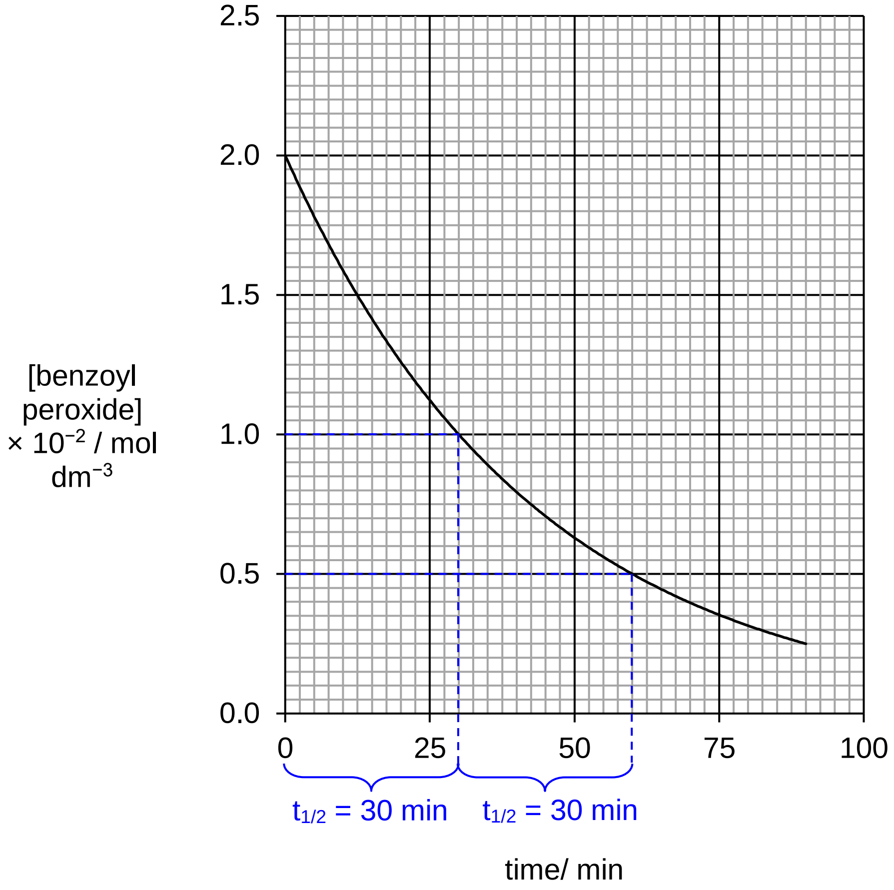
**(i)** Explain in terms of particles why the rate of decomposition decreases with time.

[1]

As the decomposition proceeds, the number of reactant particles (or benzoyl peroxide molecules) per unit volume decreases. This results in a decrease in the frequency of effective collisions, which is proportional to the rate of reaction.

**(ii)** Use the graph to show that the overall reaction is first order.

[1]



**(iii)** The initial rate of the reaction is $4.62 \times 10^{-4}$ 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]

rate = *k*[benzoyl peroxide]

$k = \frac{4.62\times10^{-4}}{2.0\times10^{-2}} = 0.0231\ min^{-1}$

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

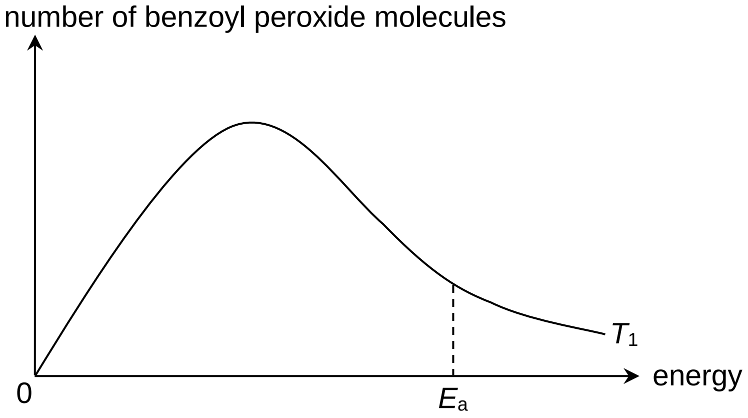
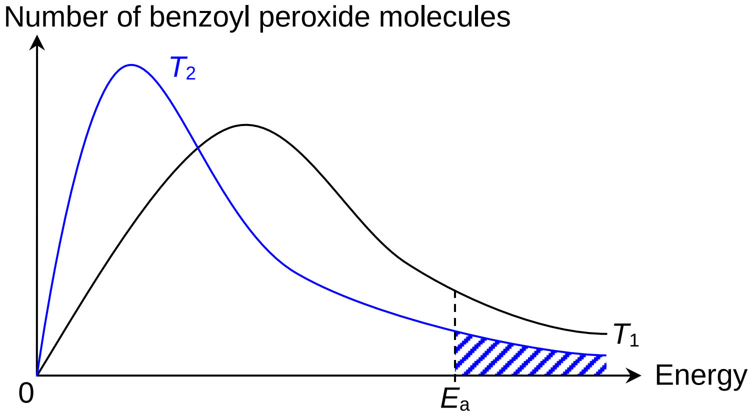


**Fig. 3.1**

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.

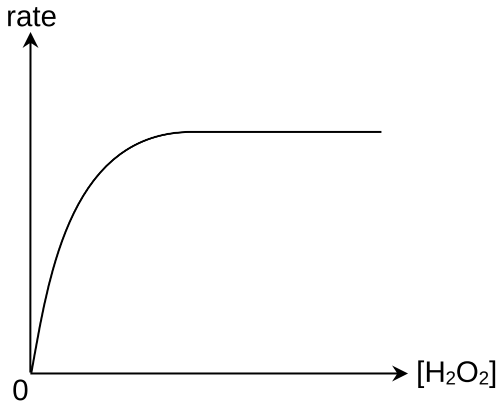


**Fig. 3.2**

**(i)** Define the term *catalyst*.

[1]

A catalyst is a substance that increases the rate of reaction by providing an alternative pathway with lower activation energy. It remains chemically unchanged at the end of a reaction.

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

[2]

At high concentration of $H_2O_2$, the active sites on enzymes are fully occupied. The rate of decomposition is independent of the concentration of $H_2O_2$/ zero order w.r.t. $H_2O_2$. The rate of formation of catalase-$H_2O_2$ (enzyme-substrate) complex reaches a maximum.

[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]

A crystalline polymer has regions where the polymer chains are packed closely together in a regular, organised manner/ have polymer chains that are highly ordered and regularly arranged.

**(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.

[5]

Thermoplastics have linear or branched structures with weak intermolecular forces between chains, allowing them to soften and melt upon heating, as well as resulting in greater flexibility but lower tensile strength.

Thermosets have cross-links between chains, creating a rigid, inflexible network/ high tensile strength that does not melt upon heating and decomposes/ chars at high temperatures.

Hence, polymer A is a thermoplastic and polymer B is a thermoset.

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

[1]

Polymer A could be used in packaging materials (e.g. plastic bags, containers, pipes, liners, and coatings), containers, and flexible products.

Polymer B could be used in high-strength, heat-resistant applications like electrical insulators and automotive parts.

**(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]

Polymer A can be melted and reformed. Hence it is more environmentally friendly as it can be recycled for other uses after disposal.

Polymer B's cross-linked structure prevents it from being remelted, making recycling impossible after disposal. Hence, it contributes to waste and must be disposed of in landfills or incinerated.

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

Describe the bonding between the carbon atoms in ethene in relation to the $\sigma$ and $\pi$ bonds present.

Draw a diagram to show how the orbitals overlap to form the $\pi$ bond. Label the $\pi$ bond.

[3]

The C=C bond in ethene consists of:

- a $\sigma$ bond formed from the head–on overlapping of bonding orbitals of C atoms and
- a $\pi$ bond formed from the side–on overlapping of 2p–orbitals of C atoms.

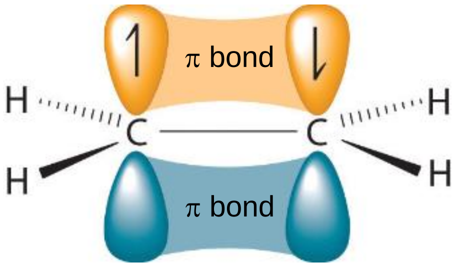


Fig. 4.1 shows a possible reaction pathway to produce ethene from ethane.

$$CH_3CH_3 \xrightarrow{\text{step 1}} \text{compound } \mathbf{C} \xrightarrow{\text{step 2}} \text{ethene}$$

**Fig. 4.1**

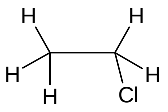
**(ii)** State the reagents and conditions for steps 1 and 2.

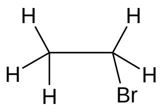
[2]

step 1: (limited) $Cl_2$ or $Br_2$, uv light or heat
step 2: KOH or NaOH in ethanol, heat (under reflux)

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

[1]





or

Poly(ethylene-vinyl acetate), PEVA, is a copolymer of ethene and vinyl acetate.

Fig. 4.2 shows the structure of vinyl acetate.

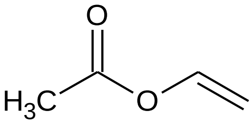


**Fig. 4.2**

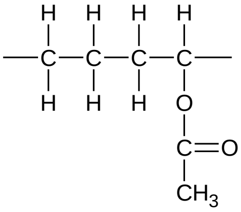
**(iv)** Identify the functional groups present in Fig. 4.2. [1]

Ester, alkene

**(v)** State the type of polymerisation that produces PEVA. [1]

Addition

**(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]

Nanoparticles are defined as particles with all three dimensions in 1−100 nm in diameter.

**(ii)** Explain how the unique properties of nanoparticles enhance the performance of the catalyst. [1]

The large surface area to volume ratio of the platinum nanoparticles enhances the catalyst's performance by providing more active sites for catalytic reactions, improving the efficiency of converting harmful gases like carbon monoxide and nitrogen oxides into less harmful substances like carbon dioxide and nitrogen.

[Total: 20]

## Section B

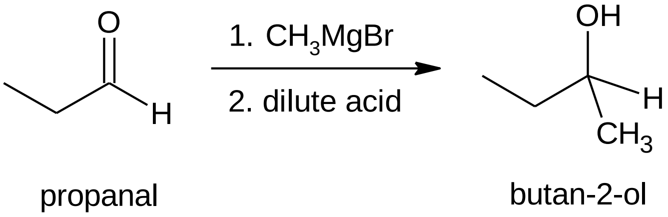
Answer **one** question from this section in the spaces provided.

**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.



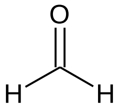
**(i)** State the IUPAC name of the reactant that can be converted to butan-2-ol using lithium aluminium hydride in dry ether.

[1]

Butanone

**(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]

| **element** | **% composition** | **moles** | **ratio** |
|---|---|---|---|
| Ni | 34.4 | $\frac{34.4}{58.7}$ = 0.586 | 1 |
| C | 28.1 | $\frac{28.1}{12}$ = 2.342 | 4 |
| O | 37.5 | $\frac{37.5}{16}$ = 2.344 | 4 |

Empirical formula = $NiC_4O_4$

Mass of empirical formula = 58.7 + 12.0 × 4 + 16.0 × 4 = 170.7

Since mass of empirical formula = formula mass,
Molecular formula = $NiC_4O_4$

**(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]

Relative atomic mass of Ni in the sample
$= \frac{75.4}{100} \times 58 + \frac{22.5}{100} \times 60 + \frac{2.1}{100} \times 78$ = 58.87 (to 2 d.p.)

**(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]

$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$

**(ii)** Calculate the amount of electrons transferred in this reaction. [1]

Amount of NO gas produced = $\frac{1.36}{24}$ = 0.056667 mol
Amount of electrons transferred = 0.056667 × 3 = 0.17 mol

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

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

[2]

Oxidation half equation: $Ni \rightarrow Ni^{n+} + ne^-$
Reduction half equation: $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$

Amount of nickel used = $\frac{5}{58.7}$ = 0.085179 mol

Using the oxidation half equation, $\frac{\text{amount of electrons transferred}}{\text{amount of nickel used}} = \frac{n}{1} = \frac{0.17}{0.085179}$
Hence, $n = 1.9958 \approx 2$
The final oxidation state of nickel is +2.

$3Ni + 2NO_3^- + 8H^+ \rightarrow 3Ni^{2+} + 2NO + 4H_2O$

**(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*.

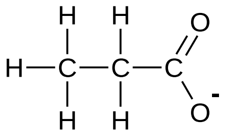
[1]

An Arrhenius acid is a hydrogen-containing substance that ionises and releases hydrogen ions in aqueous solution.

**(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]

$CH_3CH_2COOH + H_2O \rightleftharpoons$  $+ H_3O^+$

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

[1]

Phenolphthalein/ thymol blue

**(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.

[2]

Role: Reducing agents
Reactivity: Reactivity increases down the group

**(e)** Amides and esters are carboxylic acid derivatives.

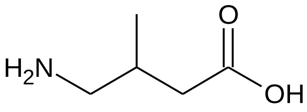
**(i)** DCC is used in the formation of amides when carboxylic acids react with amines.

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

[2]

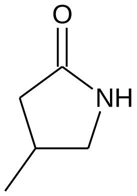
Type of reaction: Condensation
Role of DCC: catalyst

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

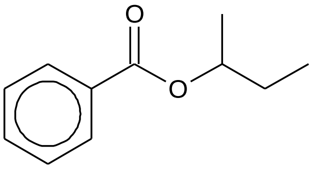


**W**

[1]



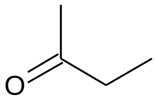
**(iii)** Compound **X** contains an ester functional group.

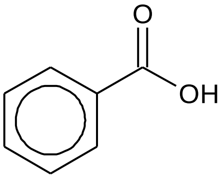


**X**

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

[2]



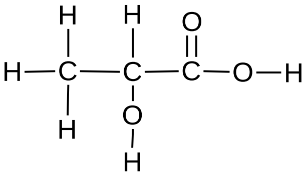


[Total: 20]

**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]

2-hydroxypropanoic acid

**(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]

$[H^+] = 10^{-2.30} = 0.00501$ mol $dm^{-3}$

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

[1]

Lactic acid is a weak acid as it is not fully dissociated since the concentration of $H^+$ ions is smaller than concentration of lactic acid.

**(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]

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

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

[1]

$K_a = (0.005011)^2 / (0.180)$
$= 1.40 \times 10^{-4}$ mol $dm^{-3}$

**(v)** Define *buffer solution*.

[1]

A buffer solution is one which is capable of maintaining a fairly constant pH when small amounts of acid or base are added to it.

**(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**.

[1]

Given that for the acidic buffer to be operating at its maximum buffering capacity, $[HA] = [A^-]$

$\Rightarrow$ Volume of NaOH to be added = ½ x 25.0 = 12.5 $cm^3$

**(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.

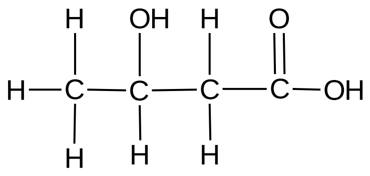
You may use HA and $A^-$ to represent lactic acid and lactate ion respectively.

[2]

$A^- + H^+ \rightarrow HA$

The added $H^+$ is removed by $A^-$ to give HA. Hence, pH remains fairly constant.

**(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**.

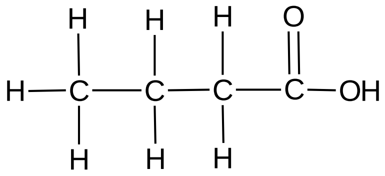
[1]

Elimination

**(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]



**V**

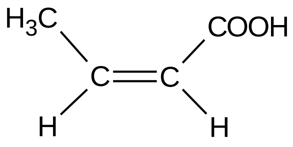
**(iii)** Name the type of isomerism in **Y** and **Z**.

[1]

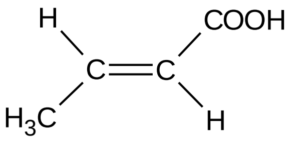
Cis−trans isomerism

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

[1]



**Y (cis isomer)**



**Z (trans isomer)**

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

[2]

Test: Add liquid bromine in $CCl_4$ to X and W in test tubes at room temperature.

Observations: Decolourisation of orange-red liquid bromine seen for X only. No decolourisation observed for W.

**(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.

[1]

pH = 7 AND green colour

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

[1]

$Al_2O_3$ does not react with water due to very exothermic $\Delta H_{latt}$ and therefore, it is extremely difficult to break the ionic lattice structure.

**(iii)** $Al_2O_3$ is amphoteric in nature.

Write equations for its separate reactions with aqueous $HCl$ and NaOH.

[2]

$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$

[Total: 20]