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MARKSCHEME

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CHEMISTRY

Standard Level

Paper 3

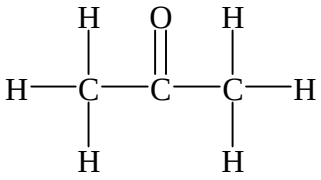
12 pages

OPTION A – HIGHER ORGANIC CHEMISTRY

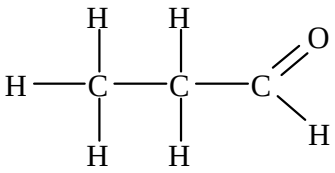
A1. *(Give **[1]** for each correct structure and **[1]** for correct reasoning for each structure.)*

The infra-red absorption at 1700 cm^{-1} indicates $C{=}O$; as **A** cannot be oxidised it must be the alkanone / as **B** is oxidised it must be the alkanal. ***[2]***

Compound **A**



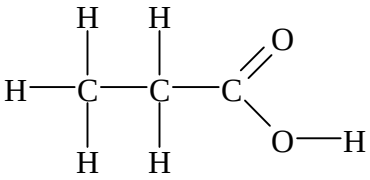
Compound **B**



[2]

C (is formed by oxidation of the alkanal **B** and has acidic properties so) must be an alkanoic acid. ***[1]***

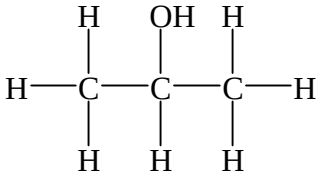
Compound **C**



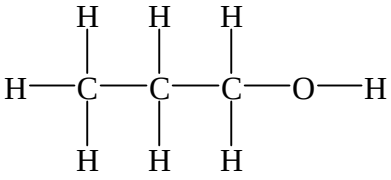
[1]

The infra-red data (3230–3550 cm^{-1}) indicates O—H bond;
M_r value of 60 indicates that **D** and **E** are both alkanols with formula C_3H_8O.
D must be a secondary alkanol as it is formed by reduction of **A**, an alkanone;
E must be a primary alkanol as it is formed from reducing **B**, an alkanal.
*(any two for **[2]**)* ***[2]***

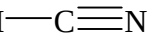
Compound **D**

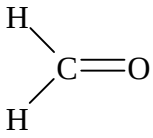


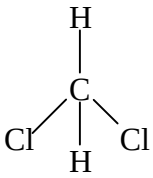
Compound **E**



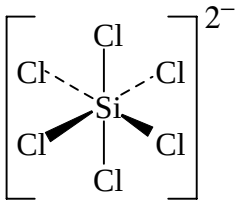
[2]

A2. (a) (i) Linear **OR**  ***[1]***

(ii) Trigonal planar **OR**  ***[1]***

(iii) Tetrahedral **OR**  ***[1]***

(b) (i) Six ***[1]***

(ii) Octahedral **OR**  ***[1]***

OPTION B – HIGHER PHYSICAL CHEMISTRY

B1. (a) $C_2H_5COOH + H_2O \rightleftharpoons C_2H_5COO^- + H_3O^+$

(**OR** $C_2H_5COOH \overset{H_2O}{\rightleftharpoons} C_2H_5COO^- + H^+$) ***[1]***

(b) $K_a = \dfrac{[C_2H_5COO^-] \times [H^+]}{[C_2H_5COOH]}$ ***[1]***

$K_a = 1.35 \times 10^{-5}$ mol dm^{-3} *(units not necessary for mark)* ***[1]***

(c) $1.35 \times 10^{-5} = \dfrac{[H^+]^2}{0.01}$ ***[1]***

$[H^+] = \sqrt{1.35 \times 10^{-5} \times 0.01} = 3.67 \times 10^{-4}$ mol dm^{-3} ***[1]***

(d) For NaOH, $n = 0.01 \times \dfrac{200}{1000} = 0.002$ mol

For acid, $n = 0.01 \times \dfrac{300}{1000} = 0.003$ mol

After reaction, $n = 0.003 - 0.002 = 0.001$ mole of acid remaining. ***[1]***

$[C_2H_5COO^-] = 0.004$ mol dm^{-3}, $[C_2H_5COOH] = 0.002$ mol dm^{-3} ***[1]***

$[H^+] = 1.35 \times 10^{-5} \times \dfrac{0.002}{0.004} = 6.75 \times 10^{-6}$ ***[1]***

$pH = -\log_{10}[H^+] = 5.17$ ***[1]***

B2. (a) The value is positive as a solid is forming a gas which is more disordered. ***[1]***

(b) $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ ***[1]***

$= 178 - \left(298 \times \dfrac{161}{1000}\right) = +130$ kJ mol^{-1} ***[1]***

(c) In a spontaneous reaction the total entropy of a system and its surroundings increases. *(Accept that for a spontaneous reaction ΔG must be less than zero.)* ***[1]***

(d) For the reaction to become spontaneous $\Delta H^\ominus - T\Delta S^\ominus < 0$. ***[1]***

$T = \dfrac{\Delta H^\ominus}{\Delta S^\ominus} = \dfrac{178 \times 10^3}{161} > 1106$ K (833 °C) ***[1]***

OPTION C – HUMAN BIOCHEMISTRY

C1. (a) Retinol will contain an —OH (alkanol) group (***[1]***).
Retinal will contain a —CHO (alkanal) group (***[1]***).
*(If both alkanol and alkanal are given but no structures, award **[1])*** ***[2]***

(b) **Two pairs of electrons (four electrons)** between the two carbon atoms. ***[1[***

(c) M_r for retinol $= (19 \times 12.01) + (30 \times 1.01) + (1 \times 16.00) = 274.5$ ***[1]***
Concentration is $0.30\ \text{g dm}^{-3}$ which is $1.1 \times 10^{-3}\ \text{mol dm}^{-3}$. ***[1]***
(accept $1.09 \times 10^{-3}\ \text{mol dm}^{-3}$ *)*

(d) More fat soluble. ***[1]***
Because the polar O—H bond will be insignificant compared to the bulky non-polar 'tail' of the molecule. ***[1]***
OR Because there is a very low concentration (of retinol in the blood).
OR Non-polar hydrophobic chain will be more soluble in fat than polar water.

C2. (a) Iodine. ***[1]***

(b) *Any **two** from:* acid, —COOH; amine, $—NH_2$; alkoxyalkane (ether), —O—; ***[4]***
(do not accept amide for $—NH_2$*)*

*(Give **[1]** for each correct name and **[1]** for each correct formula. Award no marks for* C_6H_5 *– phenyl.)*

(c) Hormones are chemical messengers **OR** substances that regulate bodily processes such as growth and metabolism. ***[1]***
Hormones are transported by the blood stream. ***[1]***

(d) Thyroxine regulates the rate at which cells use oxygen **OR** controls the rate of carbohydrate metabolism **OR** controls the rate of protein synthesis and breakdown **OR** stimulates energy production in cells. ***[1]***

OPTION D – ENVIRONMENTAL CHEMISTRY

D1. (a) 1000:1 *(do not accept 1:1000)* ***[1]***

(b) Sulfuric acid (accept sulfuric(IV) acid or sulfurous acid). ***[1]***

(No mark if just the formula is given.)

$S + O_2 \rightarrow SO_2$ **OR** $2SO_2 + O_2 \rightarrow 2SO_3$ ***[1]***

$SO_2 + H_2O \rightarrow H_2SO_3$ **OR** $SO_3 + H_2O \rightarrow H_2SO_4$ ***[1]***

(c) Nitric acid (accept nitrous acid or nitric(III) acid). ***[1]***

*(Award **[1 mark]** each for any two different ways, for example:)*

- Use a catalytic converter;
- use a richer petrol:air mixture;
- car sharing;
- switching to a different fuel such as solar power or electricity *etc;*
- thermal exhaust system;
- increase the use of public transport;
- switch to a car with a 'lean-burn' engine. ***[2]***

(d) $CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$ (accept H_2CO_3). ***[1]***

(Accept the full equation with either nitric or sulfuric acid.)

D2. (a) (i) As the temperature increases the solubility of oxygen decreases. ***[1]***

(ii) As organic pollutants decompose they use up available oxygen so the amount of dissolved oxygen decreases. ***[1]***

(iii) Nitrates and phosphates act as nutrients and increase the growth of algae. As the algae die they use up dissolved oxygen (eutrophication). ***[1]***

(b) The BOD is the quantity of oxygen (in ppm) utilised when the organic matter in a fixed volume of water is decomposed biologically over a set time period (usually five days). ***[1]***

(c) Amount of $Na_2S_2O_3$ in 10 cm^3 of 0.100 $mol\,dm^{-3}$ $Na_2S_2O_3$ is $\frac{10}{1000} \times 0.100 = 1.00 \times 10^{-3}$ moles. ***[1]***

One mole of O_2 reacts to give two moles of MnO_2 which give two moles of I_2 which react with four moles of $S_2O_3^{2-}$ so that the amount of oxygen present in $1000 cm^3$ is $\frac{1}{4} \times 1.00 \times 10^{-3} = 2.50 \times 10^{-4}$ moles. ***[1]***

Mass of 2.50×10^{-4} moles of O_2 is $32 \times 2.50 \times 10^{-4} = 8.00 \times 10^{-3}$ g.

Concentration of dissolved oxygen is 8.00×10^{-3} $g\,dm^{-3}$ (or 8 $mg\,dm^{-3}$). ***[1]***

OPTION E – CHEMICAL INDUSTRIES

E1. (a) (i) Carbon. ***[1]***

(ii) Contains higher percentage of iron. ***[1]***

(b) (i) Oxygen and powdered lime (calcium oxide / calcium carbonate). ***[2]***
(do not accept metals such as chromium)

(ii) The impurities are oxidised **OR** oxidation takes place. ***[1]***
The oxidised impurities combine with the lime to form slag **OR** an acid–base reaction takes place (accept equation). ***[1]***

(c) It is more expensive to produce aluminium from its ores as it requires more energy (even though Al is more abundant in the earth's crust than Fe). ***[1]***

E2. (a) Crude oil was formed from marine organisms which contained sulfur (in their amino acids). ***[1]***

(b) Sulfur can poison many of the catalysts used in the refining processes (by reacting irreversibly with their reactive sites). ***[1]***
OR When the oil is burned SO_2 is produced which leads to acid rain.

(c) $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$ *(accept other balanced combinations of an alkane and an alkene)*. ***[1]***
Larger molecules are broken down into smaller more useful molecules (the alkane is used as gasoline and the alkene as feedstock for polymers). ***[1]***

(d) Isomerisation involves **rearrangement** to form another isomer. ***[1]***
Alkylation involves the **combination** of alkanes and alkene (to form higher-grade gasolines). ***[1]***

(e) (i) $C_6H_{14} \rightarrow C_6H_6 + 4H_2$ ***[1]***

(ii) Haber process (manufacture of ammonia). ***[1]***

OPTION F – FUELS AND ENERGY

F1. (a) Methane / CH_4. ***[1]***

(b) Carbon monoxide **OR** hydrogen. *(accept correct formulas)* ***[1]***

(c) Any **two** from:
- particulates (soot);
- C_xH_y (accept HC or hydrocarbons);
- CO (do not accept SO_x or NO_x). ***[2]***

(d) Biomass is produced (continuously) from waste products or quick growing crops, therefore there is no need to use foreign exchange to import oil or other fuels. ***[1]***
OR Because fossil fuels are running out / biomass is obtained from recyclable materials.

F2. (a) Splitting of an (unstable) nucleus. ***[1]***

(b) There is a small mass loss which is converted into a large amount of energy. ***[1]***

(c)

X	**n**	b	**1**
Y	**Pu**	c	**0**
Z	**e**	d	**0**
a	**92**	e	**–1**

[4]

*(Award **[½]** for each, round **down**.)*

(d) To prevent radioactivity from escaping. ***[1]***
Closed loop primary coolant: water, heavy water, sodium, CO_2. ***[1]***

(e) $\frac{1.2\times10^{-12}}{1.5\times10^{-13}} = 8 = 2^n$ therefore number of half-lives (n) is 3. ***[1]***

Age of object is $3\times5730 = 1.7\times10^4$ years (17 190 years). ***[1]***