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MARKSCHEME

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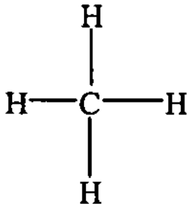
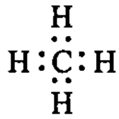
CHEMISTRY

Standard Level

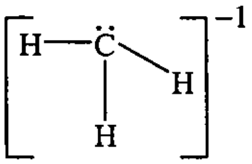
Paper 3

14 pages

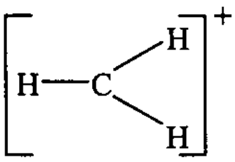
OPTION A – HIGHER ORGANIC CHEMISTRY

A1. (a)  OR  ***[1 mark]***

Tetrahedral, 109½˚ (need both for mark)
(Accept 109°) ***[1 mark]***

(b)  (No penalty if charge is missing) ***[1 mark]***

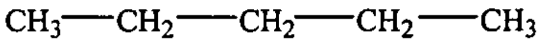
trigonal pyramidal ≃107˚ (need both for mark) ***[1 mark]***
(accept less than 109˚, but not 109˚)

(c)  (No penalty if charge is missing) ***[1 mark]***

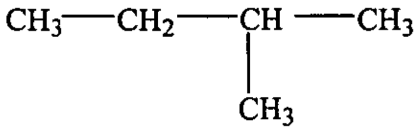
trigonal planar 120˚ (need both for mark) ***[1 mark]***

Total [6 marks]

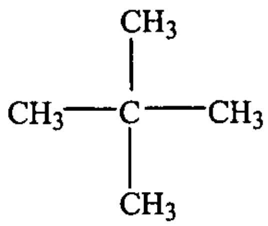
A2. (a) ($M_r = 72$, saturated hydrocarbon, therefore C_5H_{12})



I



II



III

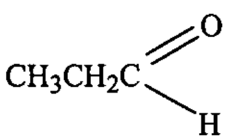
all three: ***[2 marks]***
any two: ***[1 mark]***
only one: ***[0 marks]***

(b) Eliminate I and II ***[1 mark]***
as these would have a major fragment at 29 / as this would produce $C_2H_5^+$ ***[1 mark]***

(c) It would only give one peak ***[1 mark]***
(because all the hydrogens present in III are in the same environment, or are equivalent)

(d) 2840 to 3095 (cm^{-1}) ***[1 mark]***

Total [6 marks]

A3. CH_3CH_2CHO or  or C_2H_5CHO (but not C_3H_6O) ***[1 mark]***

Oxidation product: CH_3CH_2COOH (but not $C_3H_6O_2$) ***[1 mark]***
Reduction product: $CH_3CH_2CH_2OH$ (but not C_3H_8O) ***[1 mark]***

(No marks if only names given; question asks for structural formulas.) ***Total [3 marks]***

OPTION B – HIGHER PHYSICAL CHEMISTRY

B1. (a) Strong base, (almost) fully dissociated
Weak base, partially dissociated
(Need both for mark) *[1 mark]*

(b) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} \text{ (mol dm}^{-3}\text{)}$$ *[1 mark]*

$$1.8 \times 10^{-5} = \frac{x^2}{0.10 - x}$$ *[1 mark]*

$x^2 = 1.8 \times 10^{-6}$, $x = [OH^-] = 1.34 \times 10^{-3}$ (accept 1.3×10^{-3}) mol dm^{-3} *[1 mark]*

NaOH is a strong base therefore $[OH^-] = 0.10$ mol dm^{-3} (therefore $> x$)
(accept $[OH^-]$ is much greater in NaOH) *[1 mark]*

(c) $$K_b = \frac{(0.50)(x)}{(0.10)} = 1.8 \times 10^{-5}$$ *[1 mark]*

$x = [OH^-] = 3.6 \times 10^{-6}$ mol dm^{-3} *[1 mark]*

(pOH = 5.44), pH = 8.56 (no double jeopardy if value of x is incorrect in part (b)) *[1 mark]*

(d) If strong acid is added it reacts with base of buffer (or small amounts of added H^+ ions are nearly all removed by the reaction:)

$H^+ + NH_3 \rightarrow NH_4^+$; need equation and explanation for mark *[1 mark]*

If strong base is added, it reacts with (conjugate) acid of buffer (or...)

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$; need equation and explanation for mark *[1 mark]*

because it is a buffer solution *[1 mark]*
Explanation using above equations, or:
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
Equilibrium is shifted to the right on addition of H^+ and to the left on addition of OH^- *[1 mark]*

(In each case the effect is minimised and pH changes only slightly OR remains relatively constant.) ***Total [10 marks]***

B2. (a) rate = $k[\mathrm{ICl}][\mathrm{H_2}]$ (or = $k[\mathrm{ICl}]^1[\mathrm{H_2}]^1$)

[1 mark] for first order in ICl
[1 mark] for first order in $\mathrm{H_2}$

(b) units of k: $\dfrac{\cancel{\text{conc.}}}{\text{time}} \times \dfrac{1}{\text{conc.}^{\cancel{2}}} = \dfrac{1}{\text{conc. time}}$

$= \mathrm{dm^3\,mol^{-1}\,s^{-1}}$ OR ($\mathrm{mol^{-1}\,dm^3\,min^{-1}}$ or…) *[1 mark]*

(c) 1st step is the (slow), rate determining step *[1 mark]*

It consists of one ICl and one $\mathrm{H_2}$ OR it is unimolecular with respect to each of ICl and $\mathrm{H_2}$ (which are the species which appear in the rate expression). *[1 mark]*

Total [5 marks]

OPTION C – HUMAN BIOCHEMISTRY

C1. (a) ***[1 mark]*** each for alkanol (hydroxy) and alkene ***[2 marks]***

(accept "alkyl" as one of the functional groups)

(b) Vitamin C is water-soluble because it is very polar, ***[1 mark]***
and can hydrogen bond to water molecules, ***[1 mark]***
vitamin A is fat-soluble because it contains a long carbon chain so is much less polar. ***[1 mark]***

OR

Vitamin C is water-soluble because it has 4 OH groups ***[1 mark]*** that can hydrogen bond with water molecules ***[1 mark]***. Vitamin A is fat-soluble because it contains mostly hydrocarbon (and only 1 OH group) ***[1 mark]***.

(If the candidate states vitamin A is fat soluble and vitamin C is water soluble, but no explanation is given or the explanation is incorrect, award ***[1 mark]***) ***Total [5 marks]***

C2. (a) Major functions: ***[1 mark]*** each for any two functions: energy source, insulation, protection and cell membrane. ***[2 marks]***

General formula:

$$\begin{array}{l} H_2COCOR_1 \\ \quad | \\ \;HCOCOR_2 \\ \quad | \\ H_2COCOR_3 \end{array}$$

[1 mark]

(R groups need not be different)

Similarity: Both are tri-glycerides (or triesters) (or made up from propan-1,2,3-triol joined to three fatty acids). ***[1 mark]***

Differences: In fats the fatty acids are saturated / contain no C=C double bonds. In oils one or more of the acids contains one or more C=C double bonds. ***[1 mark]***
The long saturated chains in a fat molecule are <u>able to pack more tightly</u> with other fat molecules are more ordered and give higher melting points due <u>to stronger attractive (van der Waal's) forces</u> ***[1 mark]***
than unsaturated chains which do not pack as well (due to the electrons in the π bond(s)). ***[1 mark]***

(b) 14.2 g of iodine $= \dfrac{14.2}{254} = 0.0559$ moles of iodine (accept 0.056). ***[1 mark]***

Therefore, one mole of oil reacts with four moles of iodine $\left(\dfrac{0.0559}{0.014} = 4.0\right)$. ***[1 mark]***

The oil contains four C=C double bonds. ***[1 mark]***

Total [10 marks]

OPTION D – ENVIRONMENTAL CHEMISTRY

D1. This is the trapping of heat in the atmosphere / greenhouse gases act as a one-way filter *[1 mark]*
Greenhouse gases: CH_4 or water vapour or CCl_2F_2 (**must** specify a greenhouse gas to score the mark) *[1 mark]*
The incoming short wavelength (or higher energy) solar radiation penetrates the earth, but the outgoing longer wavelength (lower energy) radiation is absorbed by greenhouse gases and reradiated towards earth, causing a rise in temperature of the atmosphere. OR Solar radiation that is radiated back from the surface of the earth is of longer wavelength (infra-red radiation). *[1 mark]*
This is absorbed by the greenhouse gases in the atmosphere and prevented from escaping (so the heat is retained in the atmosphere). *[1 mark]*
Particulates reflect sunlight, thus reducing earth's temperature (or reduce the amount of radiation reaching the earth's surface). *[1 mark]*

Total [5 marks]

D2. Fresh water is treated to remove suspended particles, *[1 mark]*
and remove/destroy objectionable odours (accept 'to remove soluble material'). *[1 mark]*
(Also accept removal of metal ions as Ca^{2+}, but not heavy metal ions).

Primary treatment: consists of filtering, flocculation and sedimentation (adding of chemicals such as $Al_2(SO_4)_3$ to speed up sedimentation) *[1 mark]*
(Accept two of the three for ***[1 mark]***) *[1 mark]*
Involves holding tanks or ponds where sewage is allowed to settle and solids removed as sludge *[1 mark]*
Secondary treatment consists of biological processes that use bacteria to break down organic materials (accept filters and activated-sludge process) *[1 mark]*
Tertiary treatment consists of one or more specialised chemical and/or physical processes. *Accept any two of:* carbon bed/charcoal filter, ion-exchange, chemical precipitation, reverse osmosis, electrodialysis. *[1 mark]* *[1 mark]*
Effectiveness of treatments:
Primary: Removes suspended particles OR insoluble material (such as rubbish, soil particles).
Secondary: Removes most of the organic matter. *[1 mark]*
Tertiary: Charcoal filtration removes organic molecules difficult to remove by other means OR nitrates by reverse osmosis OR… *[1 mark]*
Phosphates and nitrates need advanced treatment to be removed because these are water soluble (not removed in earlier treatment) **and** due to increasing concern about the health risks posed.

Total [10 marks]

OPTION E – CHEMICAL INDUSTRIES

E1. (a) Alloys: Stainless steel OR titanium steel OR Cr steel OR… *[1 mark]*
Use: Cutlery, sinks etc., OR gas turbines, spacecraft OR ball bearings OR… *[1 mark]*

(b) Polymers: Polythene OR silicone OR PVC OR… *[1 mark]*
Use: Plastic bags, bottles etc., OR high temperature gaskets OR pipes OR… *[1 mark]*

Total [4 marks]

E2. (a) K_c decreases with temperature (or less products with increasing temperature OR increasing temperature favours reverse reaction); *[1 mark]*
thus exothermic reaction. *[1 mark]*
No mark for just saying exothermic without explanation. Award *[1 mark]* if exothermic stated and a 'plausible' explanation is attempted.

(b) At high temperature K_c is low, thus less [Product] *[1 mark]*
at low temperature K_c is high (high [Product]) but reaction is slow *[1 mark]*
A catalyst lowers the activation energy (allowing more particles to participate in the reaction) *[1 mark]*

Total [5 marks]

E3. Catalytic cracking: converts heavier or long (high molar mass) alkanes or hydrocarbons to lighter / smaller or short-chain molecules using a catalyst. *[1 mark]*

The lighter hydrocarbons are (more easily vapourised) more useful as gasoline and in greater demand. *[1 mark]*

$C_{12}H_{26} \rightarrow C_9H_{20} + C_3H_6$
(or $C_{12}H_{26} \rightarrow C_8H_{18} + 2C_2H_4$ OR **any** acceptable cracking equation)

Condition: Requires heat

[1 mark] for appropriate starting material
[1 mark] for products (must be an alkane and alkene)
[1 mark] for balancing the equation
[1 mark] for condition

Total [6 marks]

OPTION F – FUELS AND ENERGY

F1. (a) Coal and oil formed from plant and marine organisms or dead organic matter *[1 mark]*

High pressure and heat (changes these into coal and oil) *[1 mark]*

OR

Remains of dead plants (coal) and sea creatures (oil) were buried, compressed and heated in the absence of air for millions of years.

(b) (i)

$$\begin{array}{rl} CO(g) \rightarrow C(s) + \tfrac{1}{2}O_2(g) & \Delta H_1 = +111\text{ kJ} \\ \underline{C(s) + 2H_2(g) + \tfrac{1}{2}O(g) \rightarrow CH_3OH(l)} & \Delta H_2 = -239\text{ kJ} \\ \underline{CO(g) + 2H_2(g) \rightarrow CH_3OH(l)} & \Delta H = \Delta H_1 + \Delta H_2 \\ & \quad = -128\text{ kJ} \end{array}$$

[1 mark] to set up equations

[1 mark]

(unit must be included to score mark)

OR $\Delta H_f = \sum \Delta H_{f(\text{product})} - \sum \Delta H_{f(\text{reactant})}$
$= -239 - (-111)$ *[1 mark]*
$= -128$ kJ *[1 mark]*

(ii) $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ *[1 mark]*
(must be balanced for mark; states not required)
(accept $CH_3OH + \tfrac{1}{2}O_2 \rightarrow CO_2 + 2H_2O$)

(iii) $Q = ms\Delta T$

$= 500\text{ kg} \times 4.18\dfrac{\text{kJ}}{\text{kg °C}} \times (100.0 - 25.0)\text{ °C}$

$= 1.57 \times 10^5$ kJ (accept 156750 kJ) *[1 mark]*

(iv) $\Delta H\,(CH_3OH) = -715.0\text{ kJ mol}^{-1}$

number of moles $= \dfrac{156750\text{ kJ}}{715.0\text{ kJ mol}^{-1}} = 219.2$ mol *[1 mark]*

therefore mass of methanol
$= n \times M_{CH_3OH} = 219.2\text{ mol} \times (12.01 + 16.00 + 4(1.01))\text{ g mol}^{-1}$
$(= 219.2\text{ mol} \times 32.05\text{ g mol}^{-1})$
$= 7.026$ kg (or 7026 g)

accept 7.03 kg *[1 mark]*

(If $M_r = 32$, then 7.02 kg)

Total [8 marks]

F2. (a) $^{234}_{91}\text{Pa} \rightarrow {}^{0}_{-1}\text{e} + {}^{234}_{92}\text{U}$ (accept $^{0}_{-1}\beta$ for $^{0}_{-1}\text{e}$) ***[1 mark]***

(b) 350 s is 5 half-lives. So fraction remaining $= \left(\frac{1}{2}\right)^5 = \frac{1}{32}$ OR… ***[1 mark]***

Total [2 marks]

F3. Any three from the following, ***[1 mark]*** each:
Through spent fuel (which is highly radioactive)
through radioactive fuel OR nuclear fuel cycle
through the cooling system
through the containment building
through the control rods
(accept accidents or meltdown (which can release radioactive materials)) ***[max 3 marks]***

Proper storage or disposal of spent fuel
(or spent fuel stored in pools of water before proper disposal)

Radioactive fuel in (airtight), reinforced containment building OR effective shielding using concrete, lead, steel

Use of two cooling loops OR use of a secondary cooling system Any two for ***[2 marks]***

Total [5 marks]