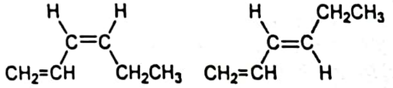
HWA CHONG INSTITUTION
2017 C1 H2 CHEMISTRY PROMOTIONAL EXAM
SUGGESTED SOLUTIONS

Paper 3

1 (a) (i) cis-trans isomerism [1]

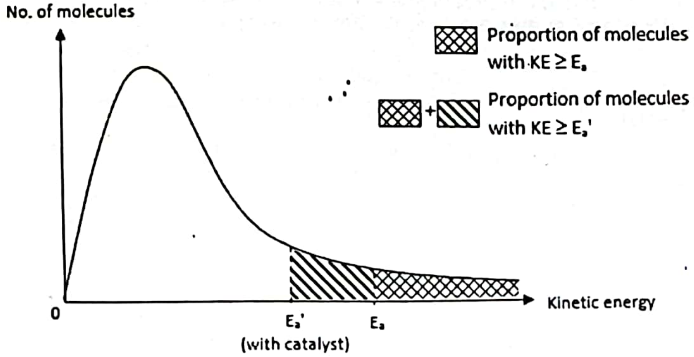


[1]

(ii) Adjacent p orbitals on the first 4 carbons of hexa-1,3-diene / 4 overlapping p orbitals in hexa-1,3-diene [½] allows for delocalisation of π electrons across these carbons [½]. This causes the bond energy of C=C double bonds in hexa-1,3-diene to be lower at 531 kJ mol^{-1} as compared to 608 kJ mol^{-1} for hexa-1,5-diene.

(b) (i) heterogeneous catalyst [1]

(ii)



[1]

(-½ m per mistake)

The platinum catalyst provides an alternative reaction pathway which requires a lower activation energy (E_a') than the uncatalysed reaction (E_a). [1]

As represented by the shaded areas in the Boltzmann diagram, there is an increase in the fraction/proportion/number of reactant particles that have kinetic energy greater than or equal to activation energy E_a' [½]. This increases the frequency of effective collisions and rate constant increases. [½]

(c) (i) $\Delta S_{vaporisation} = \Delta H_{vaporisation} \div$ boiling point

$= +28.3 \div (60 + 273)$ [1]

$= +0.0850$ kJ mol^{-1} K^{-1} [1]

(ii) $CH_2{=}CHCH_2CH_2CH{=}CH_2(l) + 2H_2(g) \rightarrow CH_3CH_2CH_2CH_2CH_2CH_3(l)$ [1]

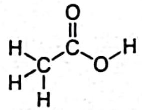
$\Delta H^{o}_{hydrogenation}$

$= \Delta H_{vap(hexa\text{-}1,5\text{-}diene)} + 2BE_{(C=C)} + 2BE_{(H\text{-}H)} - [2BE_{(C\text{-}C)} + 4BE_{(C\text{-}H)}] - \Delta H_{vap(hexane)}$

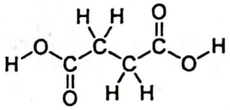
$= +28.3 + 2(608) + 2(436) - 2(350) - 4(410) - 28.9$ [1]

$= -252.6$ kJ mol^{-1} [1]

(d)



From hexa-1,3-diene [1]



From hexa-1,5-diene [1]

$CH_2{=}CHCH_2CH_2CH{=}CH_2 + 10[O] \rightarrow HO_2C(CH_2)_2CO_2H + 2CO_2 + 2H_2O$ [1]

2 (a) (i) The order of reaction with respect to a reactant is the power on its concentration term in the rate equation. The order of reaction must be determined experimentally. [1]

(ii) When the reaction is complete, there is no more NaOH present. Therefore, no NaOH will neutralise the HC*l*.

$n_{HCl} = 0.00750 \times 0.020 = 1.5 \times 10^{-4}$ mol $= n_{NH_3}$

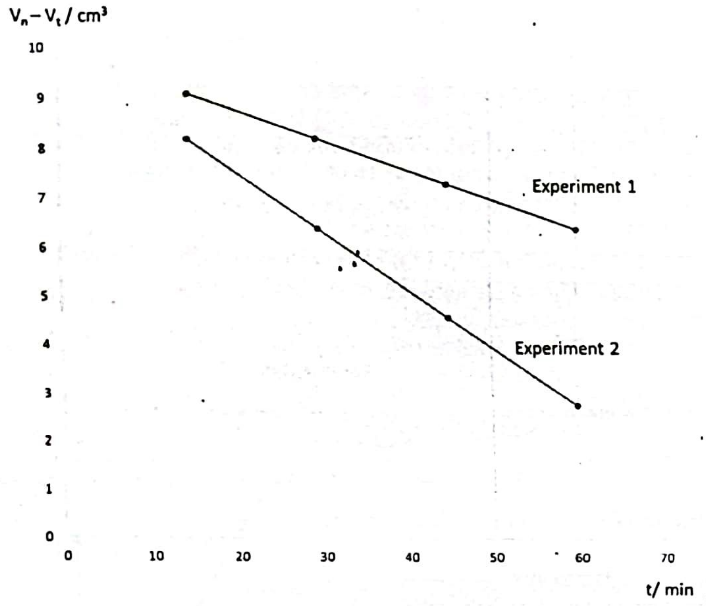
V_n, Volume of NH_3 used $= 1.5 \times 10^{-4} / 0.010 = 0.015$ dm^3 $= 15.0$ cm^3 [1]

(iii) It is directly proportional to remaining [NaOH] left in the mixture. [1]

(iv)

$(V_n - V_t)$ / cm^3	
Experiment 1	Experiment 2
9.10	8.20
8.20	6.40
7.30	4.60
6.40	2.80

[1]



[1]

(v) I:

Since the graph is a decreasing <u>straight line</u>, the rate is independent of [NaOH]. [½] Therefore, the order with respect to NaOH is <u>0</u>. [½]

II:

Gradient of graph in experiment 1 = −0.0600
Gradient of graph in experiment 2 = −0.120

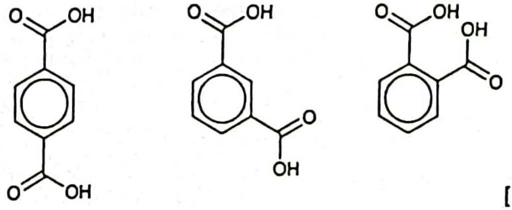
initial rate in experiment 1 / initial rate in experiment 2
= 0.0600 / 0.120 = 0.5 [1 for any reasonable working]

When the concentration of A was halved from 0.20 mol dm^{-3} to 0.10 mol dm^{-3} with [NaOH] kept constant, the initial rate was also halved, therefore the rate is directly proportional to [A] and the order with respect to A is <u>1</u>. [1]

(vi) Rate = k[A] [1]
Units of k = min^{-1} or s^{-1} [1]

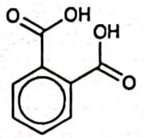
(vii) It will not work because while the mixture is being titrated with HCl, <u>the NaOH will continue to react with A/ reaction has not stopped/ reaction is still ongoing</u>, hence the titration will not give accurate results. [1]

(b) (i)



[1]

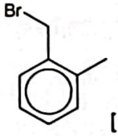
(ii)



[1]

There is <u>intramolecular hydrogen bonding in</u> E which is lacking in the other two. Hence there is less extensive intermolecular hydrogen bonding and the melting point is lower for E. [1]

(iii)

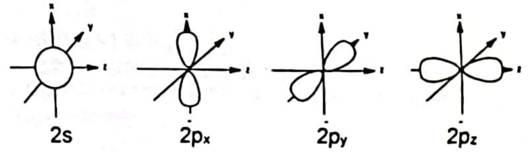


[1]

3 (a) (i) First ionisation energy of the elements in Group 13 <u>decreases</u> [½] down the group.

Down the group, number of <u>quantum shells increases</u> despite <u>increasing nuclear charge.</u> [½]
The <u>outermost electrons</u> are <u>further away from the nucleus / electrostatics forces of attraction between the nucleus and the outermost electron is weaker.</u> [½]
<u>Less energy</u> is required to remove this electron [½]

(ii) [1m for 2s orbital]
[1m for $2p_x$, $2p_y$, $2p_z$ orbitals]



(b) (i) AlF_3 has a <u>giant ionic lattice</u> [½] with strong <u>electrostatic forces of attraction / ionic bonds between Al^{3+} and F^- ions</u> [½].

$AlCl_3$ has a <u>simple molecular structure</u> [½] with <u>(weak) dispersion forces</u> [½] between molecules.

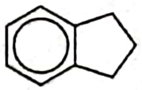
A <u>larger amount of energy</u> [½] is required to overcome the <u>stronger</u> [½] ionic bonds in AlF_3, giving it a high melting point.
(OR
Ionic bonds are much stronger than dispersion forces, therefore more energy is required to break these bonds and the melting point of AlF_3 is much higher.)

(ii) [energy cycle 3m, deduct ½ for every mistake]

$$\begin{tikzcd}
Al^{3+}(g) + 3F^-(g) \arrow[r, "LE"] \arrow[d, "\begin{array}{l}-4690 + 3(-506)\\ = -6208\end{array}"] & AlF_3(s) \\
Al^{3+}(aq) + 3F^-(aq) & Al(s) + 3/2\ F_2(g) \arrow[l, "\begin{array}{l}-538 + 3(-335)\\ = -1543\end{array}"'] \arrow[u, "-1510"']
\end{tikzcd}$$

By Hess's Law,
LE = –4690 + 3(–506) + 538 – 3(–335) + –1510
LE = –6175 kJ mol⁻¹ [1] *(ecf with wrong cycle but correct application of Hess Law)*

(c) (i)

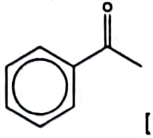


[1]

(ii)

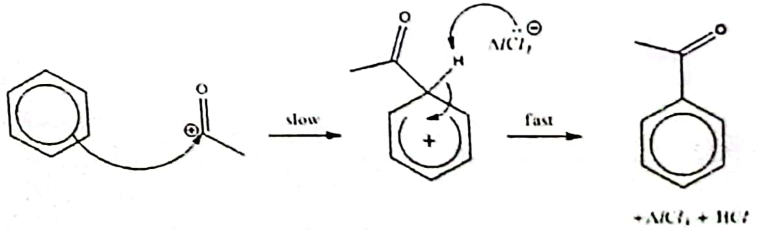
Z: $CH_3\overset{+}{C}{=}O$ [1]

Compound Y:



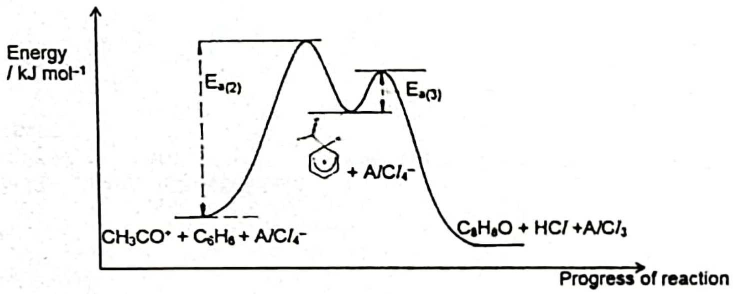
[1]

(iii) Electrophilic substitution



[2 marks for writing the correct mechanism]

(iv)



[2 marks. *1/2 mark will be deducted for each mistake*]

(d)

Reagents		
Adding $KMnO_4$, H_2SO_4(aq), heat	purple $KMnO_4$ is decolourised	purple $KMnO_4$ is not decolourised
Adding Br_2 in CCl_4	Reddish brown Br_2 is decolourised	Br_2 remains reddish brown
Adding aq bromine	Yellow-orange/ orange/ yellow Br_2(aq) is decolourised	Br_2(aq) remains yellow-orange/ orange/ yellow

[1] reagent and conditions [1] observations

4 (a) (i) Mole fraction of CO = 0.3 / 2 = 0.15
Mole fraction of H_2O = 0.3 / 2 = 0.15
Mole fraction of CO_2 = 0.7 / 2 = 0.35
Mole fraction of H_2 = 0.7 / 2 = 0.35 [1]

Average molecular mass

$= 0.15 \times (12.0+16.0) + 0.15 \times 18.0 + 0.35 \times (12.0+16.0\times2) + 0.35 \times 2.0$
$= 23.0$ [1]

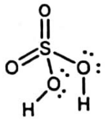
(ii) $pV = nRT$

density = $(pM_r) / RT$
$= (6.50 \times 101325 \times 23.0) / (8.31 \times 323)$ [1]
$= 5.64 \times 10^3$ g m^{-3} [1]

(b) **(i)** At high pressure, the molecules are closer together, and the intermolecular forces of attraction become significant. [1] At some point, the kinetic energy of the particles is no longer large enough to overcome the intermolecular forces, and the gas liquefies. [1]

(ii) The ethanol molecules added can form hydrogen bonds with the phenol groups present and this increase the solubility of polyphenols. [1]

(c) **(i)**



[1]

Tetrahedral wrt S [½], bent wrt O [½]

(ii)

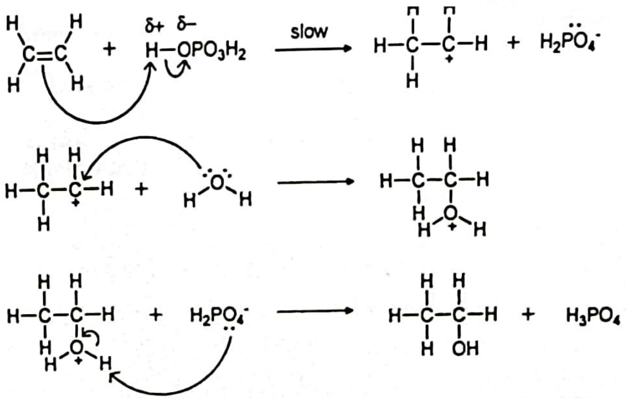
$$\begin{tikzcd} 3O_2(g) + CH_2{=}CH_2(g) + H_2O(l) \arrow[r, "\Delta H^{\circ}_r"] \arrow[d, "-1411"'] & C_2H_5OH(l) + 3O_2(g) \arrow[d, "-834"] \\ 2CO_2(g) + 3H_2O(l) & 2CO(g) + 3H_2O(l) + O_2(g) \arrow[l, "-283 \times 2"'] \end{tikzcd}$$

[2 for correct energy cycle]: minus ½ for every mistake

$\Delta H^{\circ}_r = -1411 + 2\times283 + 834 = -11.0$ kJ mol^{-1}
[1 final answer, ecf based on cycle]

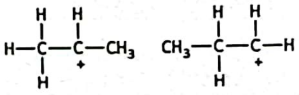
(d) **(i)** Electrophilic addition [1]

(ii)



[1] x 3 for each step, including lone pairs, dipoles, curly arrows

(iii)



(major)

[1]

The intermediate on the left is more stable [½] as it has more electron-donating alkyl groups. [½]

(iv) Bubble the gas separately into $Br_2(aq)$ or Br_2 in CCl_4 [1]
Yellow-orange $Br_2(aq)$ / Reddish-brown Br_2 decolourised for propene, no decolourisation of $Br_2(aq)$ for propane. [1]

OR

Add $KMnO_4(aq)$, $H_2SO_4(aq)$, heat [1]
Purple $KMnO_4$ decolourised for propene, no decolourisation of $KMnO_4$ for propane. [1]