

Section A

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

1 (a)

- The largest increase in ionisation energy (I.E.) is found between the 5th and 6th I.E.
- The sixth electron is removed from an inner (principal quantum) shell while the fifth is from the valence (quantum) shell/ the first five electrons are from the valence (quantum) shells.
- It contains five valence electrons.

Thus the element is in Group V and nitrogen is in Group V.

[2]

(b) (i)

$$\begin{aligned}\Delta H_r &= -2(-57) - 2(90) + 11 \\ &= \underline{-55 \text{ kJ mol}^{-1}}\end{aligned}$$

[1]

(ii)

$$\begin{aligned}\Delta H_f &= [+2(90) - 2(57)]/2 \\ &= \underline{+33 \text{ kJ mol}^{-1}}\end{aligned}$$

[1]

(iii)

Enthalpy change of formation of dinitrogen pentoxide, N₂O₅.

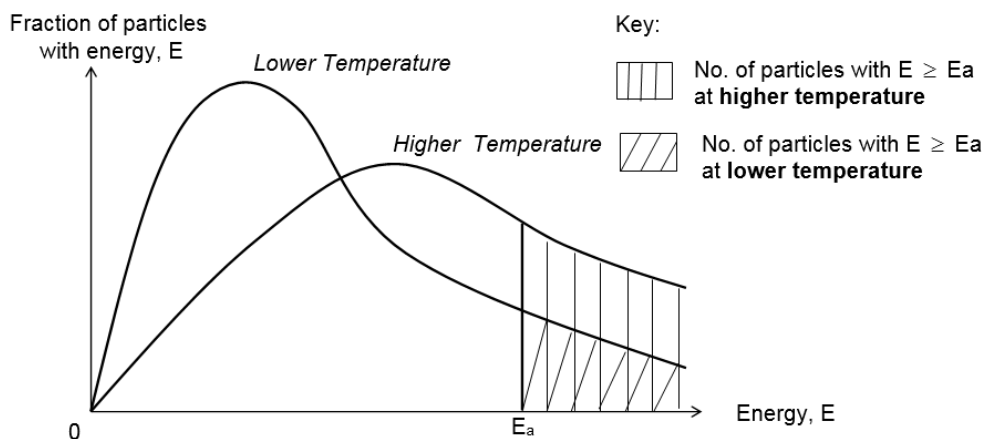
[1]

(c) (i)

- Comparing Experiments 1 and 3, when [NO] is kept constant, while [O₂] doubles, the rate also doubles. Therefore, the reaction is first order wrt [O₂].
- Comparing Experiments 3 and 4, when [O₂] and [NO] are doubled, the rate increased by 8 times. Therefore, the reaction is second order wrt [NO].
- Rate = k[O₂][NO]²

[3]

(ii)



- When temperature of the reaction increases,
 - average kinetic energy of the reacting molecules increases
 - frequency/number of effective collisions with $E \geq E_a$ per unit time taking place in the reaction increases
 - rate of reaction is proportional to the frequency of effective collisions
 - initial rate for Expt 2 is higher than that of Expt 1

[2]

[Total: 10]

2 (a) (i)



[1]

(ii)

An NO_2 molecule contains one lone electron on N while all atoms in CO_2 have an octet structure. This unpaired electron makes NO_2 a free radical hence more reactive than CO_2 .

[1]

(b) (i)

$$K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} \text{ mol dm}^{-3}$$

[1]

(ii)

From the table, the absorbance value for 1.00 mol dm^{-3} of NO_2 is 0.80.

From the graph, the absorbance at equilibrium is 0.60.

$$\text{Equilibrium concentration of } \text{NO}_2 = \frac{1.00}{0.80} \times 0.60 = \underline{0.750 \text{ mol dm}^{-3}}$$

[2]

(iii)

	$\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$	
Initial []	1.00	0.00
Change in []	- 0.375	+ 0.750
Eqm []	0.625	0.750

$$K_c = \frac{(0.750)^2}{(0.625)} = \underline{0.900 \text{ mol dm}^{-3}}$$

[1]

(iv)

When the gas mixture at equilibrium is suddenly compressed, there is a reduction in volume hence an increase in concentration of NO_2 hence the colour is darker.

By Le Chatelier's Principle, as pressure increases, the position of equilibrium will shift left to decrease the total number of moles of gas present.

Hence more $\text{N}_2\text{O}_4(\text{g})$ are formed resulting in the mixture turning paler.

[2]

(v)

The forward reaction is endothermic. By Le Chatelier's Principle, as temperature increases, the position of equilibrium will shift right to absorb the heat applied.

There will be a higher $[\text{NO}_2]$ / [products] and a lower $[\text{N}_2\text{O}_4]$ / [reactants] thus the value of K_c would be larger.

[2]

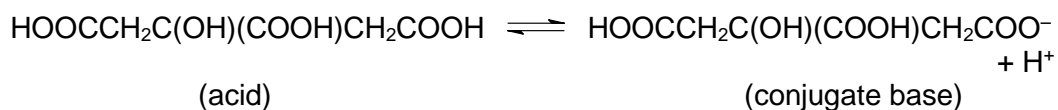
[Total: 10]

3 (a)

A Brønsted acid is a species which acts as a proton donor and a Brønsted base is a proton acceptor.

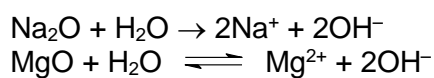
[1]

(b)

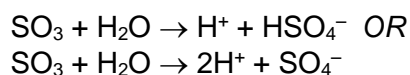


[2]

(c)



NaOH is much more soluble than $\text{Mg}(\text{OH})_2$. Hence, the $[\text{OH}^-]$ and pH is higher than $\text{Mg}(\text{OH})_2$.



H^+ will be produced when SO_3 is shaken with water and hence the pH is the lowest.

[3]

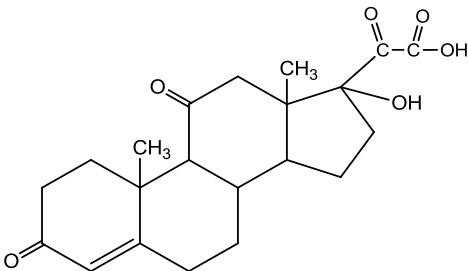
[Total: 6]

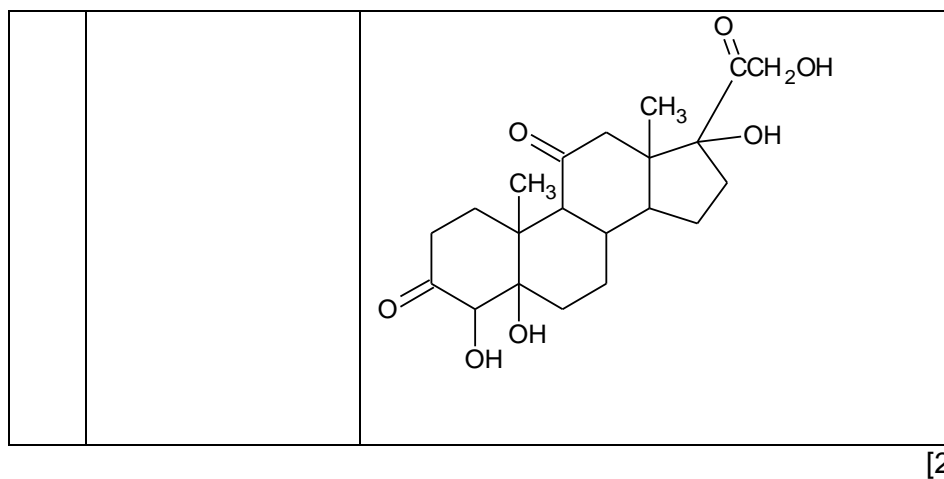
4 (a) (i)

The restricted rotation of $\text{C}=\text{C}$ is further restricted by a ring which makes trans isomer unlikely to exist.

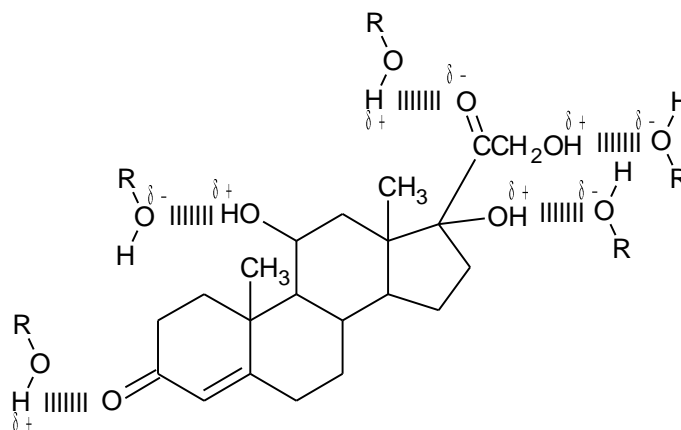
[2]

(ii)

Reaction		
I	heating with acidified $\text{K}_2\text{Cr}_2\text{O}_7$	
II	adding alkaline KMnO_4 at 10°C	

**(b)**

Cortisone forms extensive H-bonds with ethanol due to 3 –OH groups/ 2 C=O groups.



[2]

(c)

Cortisone : 3 PCl_5

$$\text{No. of mol of cortisone} = \frac{1 \times 10^{-3}}{360}$$

$$= 2.78 \times 10^{-6} \text{ mol}$$

$$\text{No. of mol of } \text{PCl}_5 = 3 \times 2.78 \times 10^{-6} = 8.33 \times 10^{-6} \text{ mol}$$

$$\text{Mass of } \text{PCl}_5 \text{ needed} = 8.33 \times 10^{-6} \times 208.5 = \underline{1.74 \text{ mg}}$$

[3]

(d)

Ketone, alkene, secondary alcohol and ester.

[1]

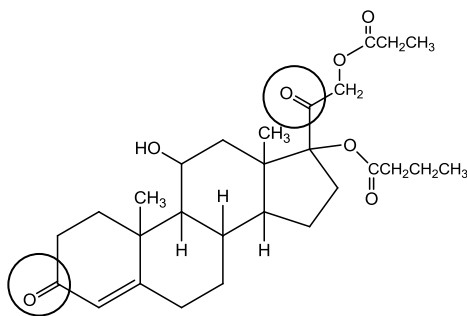
(e)

Hydrocortisone is not suitable to be taken orally.
 Hydrocortisone contains two ester functional groups which would be susceptible to acidic hydrolysis in stomach owing to the acidic condition.

[2]

(f)

Orange ppt will be observed. Two moles.



[2]

[Total: 14]

Section B

Answer **two** questions from this section on separate answer paper.

1 (a) (i)

2,4-DNPH

Orange ppt would be observed.

[2]

(ii)

H₂(g) with Ni catalyst, heat or NaBH₄ in methanol.

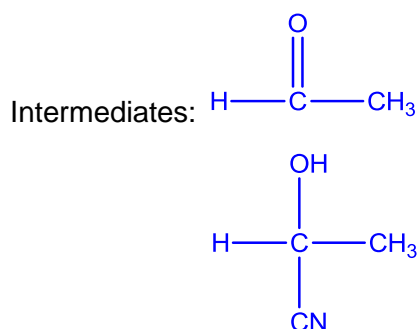
[1]

(b) (i)

Step 1: K₂Cr₂O₇ in dilute H₂SO₄, heat with distillation

Step 2: HCN with trace amount of KCN or NaOH; cold (OR 10 to 20°C)

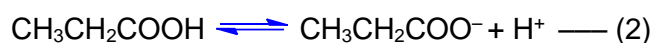
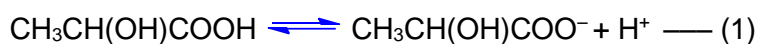
Step 3: Dilute H₂SO₄; heat under reflux



[4]

(ii)

Lactic acid has a larger K_a as it is a stronger acid.



The electron-withdrawing -OH group disperses the negative charge on the conjugate base of lactic acid / lactate ion hence stabilising the conjugate base of lactic acid / lactate ion. The equilibrium position of reaction (1) shifts right producing more H⁺ ions resulting in lactic acid being a stronger acid.

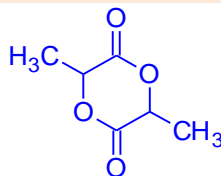
OR

Intramolecular hydrogen bond can be formed in the lactate ion between the carboxylate ion and the H of the alcohol group, hence stabilising the

conjugate base of lactic acid / lactate ion. Thus the equilibrium position of reaction (1) shifts right producing more H^+ ions resulting in lactic acid being a stronger acid.

[2]

(iii)



[1]

(c) (i)

volume of NaOH = 19.00 cm³

$$\begin{aligned}\text{no of moles of sodium hydroxide} &= \frac{19}{1000} \times 0.5 \\ &= 9.50 \times 10^{-3} \text{ mol}\end{aligned}$$

$\text{HA} \equiv \text{NaOH}$

no of moles of lactic acid = $9.50 \times 10^{-3} \text{ mol}$

$$\begin{aligned}\text{initial concentration of lactic acid} &= 9.50 \times 10^{-3} \div \frac{20}{1000} \\ &= \underline{0.475 \text{ mol dm}^{-3}}\end{aligned}$$

[2]

(ii)

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

[1]

(iii)

$$\begin{aligned}[\text{H}^+] &= 10^{-2.10} \\ &= 0.0079432 \text{ mol dm}^{-3}\end{aligned}$$

$$[\text{H}^+] = [\text{A}^-] = 0.0079432 \text{ mol dm}^{-3}$$

$$\begin{aligned}K_a &= \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \\ &= \frac{[0.0079432][0.0079432]}{[0.475]} \\ &= \underline{1.33 \times 10^{-4} \text{ mol dm}^{-3}}\end{aligned}$$

[2]

(iv)

Cresol red

AND

Its pH transition range lies within the sharp pH change over the equivalence point.

[1]

(d) (i)

The plot of $\ln [\text{chymotrypsin}]$ vs time is a straight line / has constant gradient. It confirms the agreement with the integrated first order equation and hence first order kinetics with respect to chymotrypsin.

The use of excess sodium hydroxide means that the concentration of sodium hydroxide is effectively constant hence it does not contribute to the change in rate of reaction. Hence reaction is overall first order.

[2]

(ii)

$$\text{gradient} = \frac{2.10 \times 10^{-5} - 1.10 \times 10^{-5}}{2000 - 14400} = -8.06 \times 10^{-10}$$

$$k = \underline{8.06 \times 10^{-10}}$$

[2]

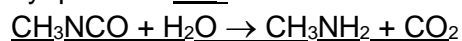
[Total: 20]

2 (a) (i)

+3

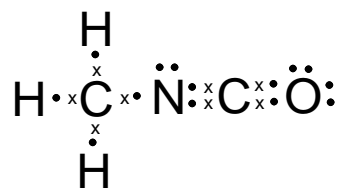
[1]

(ii)

by-product: CO₂

[2]

(iii)



[1]

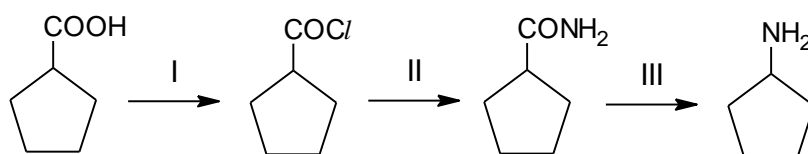
(iv)

By the VSEPR theory, there are 2 bond pairs and 1 lone pair of electrons around the N atom in CH₃NCO so the shape around N is bent.

Since lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion, the angle around N is 109.5° < x < 120°

[2]

(v)

I: PCl₅(s), room temperatureII: NH₃III: Br₂ and NaOH followed by H₂O

[4]

(b) (i)

Substitution.

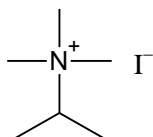
[1]

(ii)

Giant ionic structure and ionic bonding.

[1]

(iii)



[1]

(c) (i)

To separate samples of the compounds, add KMnO₄ in dilute H₂SO₄ and heat.

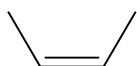
Purple solution of KMnO₄ decolourises for both but-1-ene and but-2-ene but effervescence is only observed for but-1-ene.

[2]

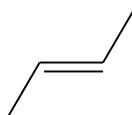
(ii)

There is restricted rotation at the C=C bond of but-2-ene and there are two different substituents attached to each carbon of the double bond.

Geometric isomers:



cis-but-2-ene



trans-but-2-ene

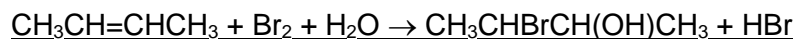
[2]

(iii)

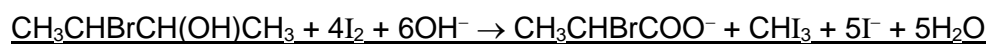
Orange/brown aqueous bromine solution decolourises.

Yellow ppt formed on warming with alkaline aqueous iodine.

Equation:



OR



[3]

[Total: 20]

3 (a)

Procedure:

1. Weigh the original sample first.
2. Add aqueous sodium hydroxide in excess.
3. Only aluminium oxide will dissolve to form a soluble complex:
Equation for reaction: $\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$
4. The mixture is then filtered.
5. Dry the residue and re-weigh the sample again.
6. If there is contamination, then there should be a difference in mass.

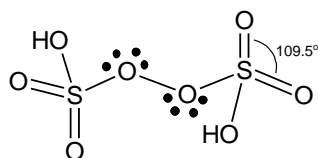
[3]

(b) (i)

The molecular formulae suggest that the structure of chlorosulfonic acid is derived from that of sulfuric acid, with –O atom being replaced by –Cl atom. Hence the extent of hydrogen bonding is lesser between chlorosulfonic acid molecules and hence requires less energy to overcome, giving it a lower boiling point.

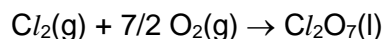
[2]

(ii)



[2]

(c) (i)



[1]

(ii)

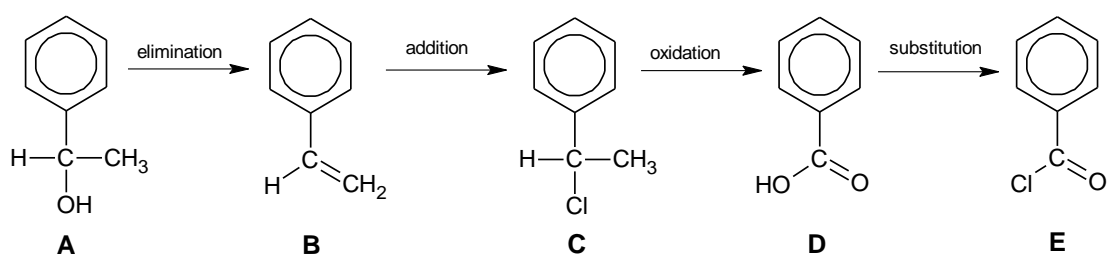
Bond energy of $\text{Cl} - \text{Cl} = 244 \text{ kJ mol}^{-1}$
 Bond energy of $\text{O}=\text{O} = 496 \text{ kJ mol}^{-1}$
 $-546 = 244 + 7/2(496) - [2 \times 269 + 6(\text{Cl}=\text{O})]$
 Bond energy of $\text{Cl}=\text{O} = \underline{+331 \text{ kJ mol}^{-1}}$

[2]

(iii)

Vaporisation of $\text{Cl}_2\text{O}_7(\text{l})$

[1]

(d)

[9]

[Total: 20]