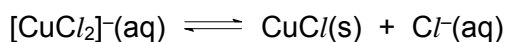


- 1 (a) (i) Nuclear charge / proton number increases from Fe to Cu. } [1]
- However, additional electrons are being added to the inner 3d subshell. As such, there is an increase in shielding effect caused by the increasing number of d electrons from Fe to Cu. } [1]
- Hence, effective nuclear charge remains fairly constant from Fe to Cu. [1]
- (ii) Fe uses both the 3d and 4s electrons while Ca only uses the 4s electrons for metallic bonding. [1]
- The ionic radius of Fe is also smaller than that of Ca, resulting in higher charge density. [1]
- This results in stronger metallic bonding between Fe ions and the valence electrons. [1]
- (iii) density = mass / volume } [1]
- Fe and Cu have greater atomic mass } [1]
- and smaller atomic radius. [1]
- (b)  $2\text{Cu}^+(\text{aq}) \longrightarrow \text{Cu}(\text{s}) + \text{Cu}^{2+}(\text{aq})$  [1]
- State symbols not required*
- $E^\ominus(\text{Cu}^+/\text{Cu}) = +0.52 \text{ V}$   
 $E^\ominus(\text{Cu}^{2+}/\text{Cu}^+) = +0.15 \text{ V}$
- $E_{\text{cell}}^\ominus = +0.52 - (+0.15) = +0.37 \text{ V}$  [1]
- (c) (i)  $\text{I}^-$  and  $\text{Cu}^{2+}$  undergo a redox reaction to produce the white precipitate copper(I) iodide, CuI, and brown solution  $\text{I}_2$ . } [1]
- $2\text{I}^-(\text{aq}) + \text{Cu}^{2+}(\text{aq}) \longrightarrow \text{CuI}(\text{s}) + \text{I}_2(\text{aq})$
- $\text{S}_2\text{O}_3^{2-}$  then reduces  $\text{I}_2$  to  $\text{I}^-$  (colourless solution), itself oxidises to  $\text{S}_4\text{O}_6^{2-}$  (redox reaction). } [1]
- $2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \longrightarrow 2\text{I}^-(\text{aq}) + \text{S}_4\text{O}_6^{2-}(\text{aq})$
- State symbols not required*
- (ii) Cu and  $\text{Cu}^{2+}$  undergo a redox reaction (or comproportionation) to form a colourless Cu(I) complex,  $[\text{CuCl}_2]^-$ . } [1]
- $\text{Cu}(\text{s}) + \text{Cu}^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \longrightarrow 2[\text{CuCl}_2]^- (\text{aq})$

Element	Cu	Cl
% by mass	64.1	35.9
$A_r$	63.5	35.5
No. of moles	$64.1/63.5$ $= 1.009$	$35.9/35.5$ $= 1.011$
Simplest whole no. ratio	1	1

[1]

The white precipitate is CuCl.

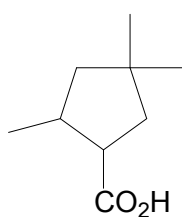


[1]

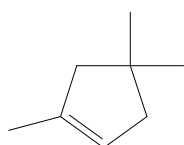
*State symbols not required*

(d) Information	Type of reaction	Deduction(s)
On treatment with hot acidified concentrated $\text{KMnO}_4$ , <b>H</b> produced a single compound <b>J</b> , $\text{C}_8\text{H}_{14}\text{O}_3$ .	Oxidative cleavage	<b>H</b> contains a <u><math>\text{C}=\text{C}</math> / alkene</u> .  Since a single compound is formed (without loss of C), <b>H</b> is a <u>cycloalkene</u> .
<b>J</b> evolved $\text{CO}_2$ with $\text{Na}_2\text{CO}_3(\text{aq})$ ,	Acid–base	<b>J</b> contains <u><math>\text{RCO}_2\text{H}</math> / carboxylic acid</u> .
<b>J</b> gave an orange precipitate with 2,4–DNPH,	Condensation	<b>J</b> contains a <u>ketone</u> . ( <b>J</b> cannot contain an aldehyde since <b>J</b> is produced from strong oxidation of <b>H</b> with $\text{KMnO}_4$ )
and gave a yellow precipitate with alkaline aqueous iodine.	Oxidation / tri-iodomethane reaction	<b>J</b> has a <u><math>\text{CH}_3\text{CO}-</math></u> structure ( <b>J</b> cannot have a $\text{CH}_3\text{CH}(\text{OH})-$ structure since <b>J</b> is produced from strong oxidation of <b>H</b> with $\text{KMnO}_4$ )

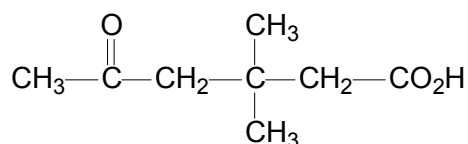
[6]



**G**



**H**

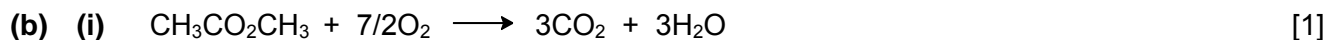
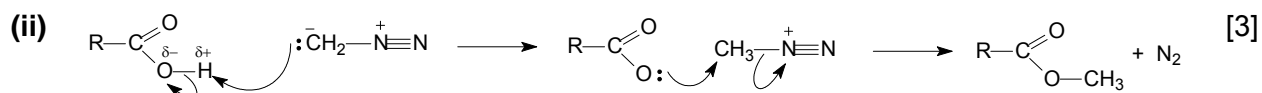


**J**

*Do not accept*  *for structure of G as G is a secondary carboxylic acid*

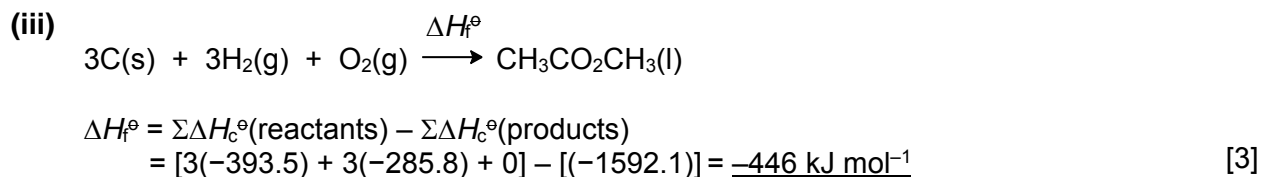
[Total: 20]

2 (a) (i) B [1]



*Accept equation multiplied through by 2*

(ii) The amount of heat absorbed or evolved when one mole of substance is formed from its constituent elements in their standard states at 298 K and 1 atm. [2]



(c) Heat each compound separately with NaOH(aq), and then add I<sub>2</sub>(aq) to the resulting solution. [1]

A yellow precipitate (CHI<sub>3</sub>) is observed for HCO<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>. [1]

No (yellow) precipitate is observed for CH<sub>3</sub>CO<sub>2</sub>CH<sub>3</sub>. [1]

(d) (i) **W** (aluminium) burns in O<sub>2</sub> with an intense white flame to give a white solid of Al<sub>2</sub>O<sub>3</sub>. [1]

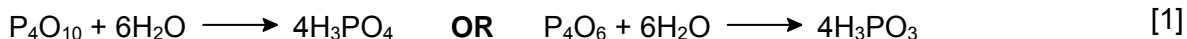
**Z** (sulfur) burns in O<sub>2</sub> on gentle heating with a pale blue flame to give a colourless gas of SO<sub>2</sub>. [1]

(ii) The oxide of **X** (SiO<sub>2</sub>) has a giant molecular structure. Large amount of energy is required to break the strong covalent bonds between Si and O atoms. [1]

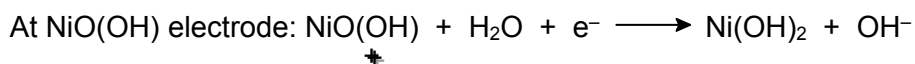
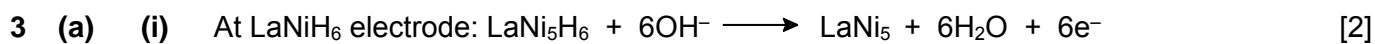
The oxide of **Y** (P<sub>4</sub>O<sub>10</sub> or P<sub>4</sub>O<sub>6</sub>) has a simple molecular structure. Less energy is required to break the weak van der Waal's forces of attraction between the molecules. [1]

(iii) The oxide of **X** (SiO<sub>2</sub>) is insoluble in water. Hence, the pH of the resulting solution is 7. [1]

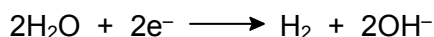
The oxide of **Y** (P<sub>4</sub>O<sub>10</sub> or P<sub>4</sub>O<sub>6</sub>) reacts readily in water to produce a strongly acidic solution of pH 2. [1]



[Total: 20]

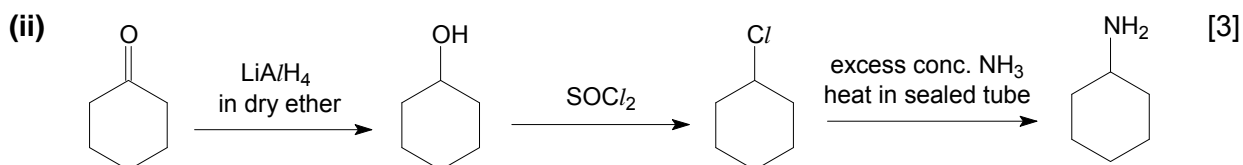
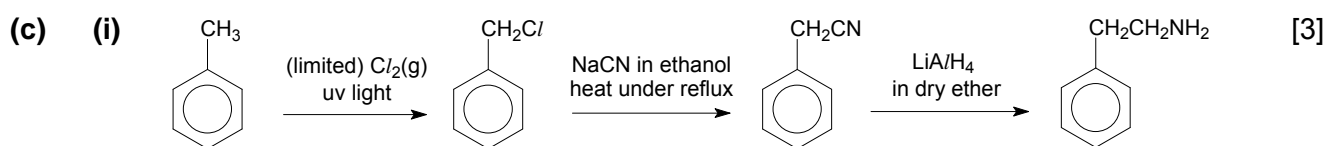


OR



$E^\ominus_{\text{cell}} = +1.07 - (-0.76)$   
 $= \underline{+1.83 \text{ V} > 0}$  (feasible)

Since it is feasible for the battery to discharge electricity, the  $\text{Ce}^{4+}/\text{Ce}^{3+}$  half-cell can be replaced with  $\text{Br}_2/\text{Br}^-$  half-cell. [1]



(d) (i) Since equal volume of  $\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_2$  and  $\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_3^+$  are mixed, concentration of both species are halved.

$$K_b = \frac{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_3^+][\text{OH}^-]}{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_2]}$$

$$10^{-4.3} = \frac{(0.400)[\text{OH}^-]}{0.250} \quad [1]$$

$$[\text{OH}^-] = 3.13 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{pOH} = -\log(3.13 \times 10^{-5}) = 4.5$$

$$\text{pH} = \underline{9.5} \quad [1]$$

- (ii) Since  $pK_b(\text{AMP}) = 4.3$ ,  $pK_a(\text{conjugate acid of AMP}) = 9.7$ .

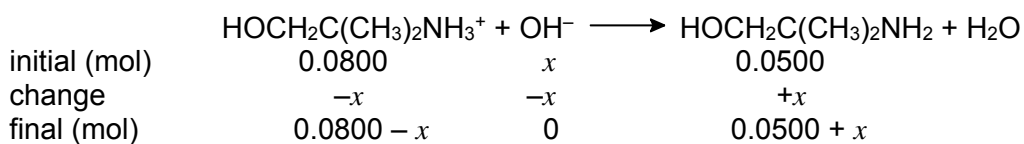
When pH of the buffer = 9.7, the buffer solution is at its maximum buffering capacity.

$$\text{Hence } \frac{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_2]}{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_3^+]} = 1. \quad [1]$$

$$\text{initial } n(\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_3^+) = 100/1000 \times 0.800 = 0.0800 \text{ mol}$$

$$\text{initial } n(\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_2) = 100/1000 \times 0.500 = 0.0500 \text{ mol}$$

Let  $x$  be  $n(\text{OH}^-)$  added



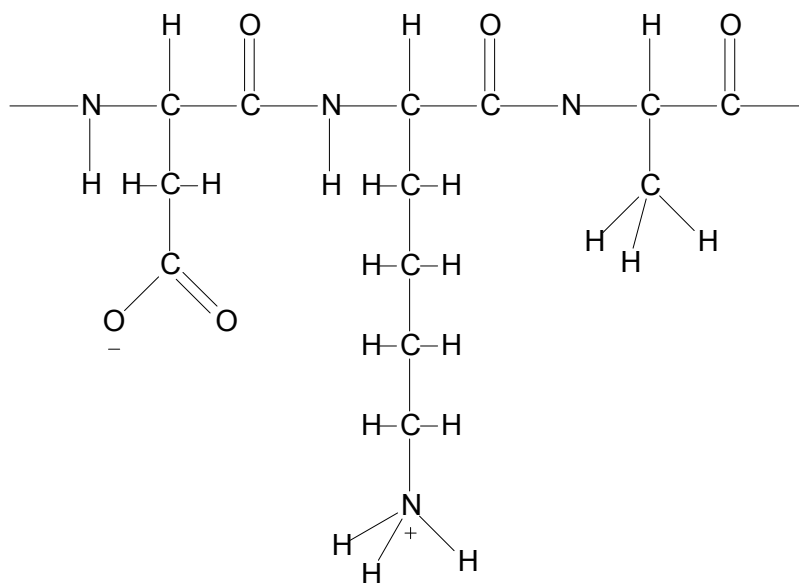
$$\text{Since } \frac{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_2]}{[\text{HOCH}_2\text{C}(\text{CH}_3)_2\text{NH}_3^+]} = 1,$$

$$0.0800 - x = 0.0500 + x$$

$$x = 0.015 \text{ mol}$$

$$\text{mass of NaOH added} = 0.015 \times (23.0 + 16.0 + 1.0) = \underline{0.600 \text{ g}} \quad [1]$$

(e) (i)



- (ii)
- Ionic bonding between charged R groups containing the  $-\text{CO}_2^-$  groups,  $-\text{NH}_3^+$  groups. [1]  
Example: Between lysine (containing  $-\text{NH}_3^+$ ) and aspartic acid (containing  $-\text{CO}_2^-$ )
  - Hydrogen bonding between polar R groups containing the carboxyl groups ( $-\text{CO}_2\text{H}$ ), amino groups ( $-\text{NH}_2$ ) or hydroxyl ( $-\text{OH}$ ) groups. [1]  
Example: Between aspartic acid and serine or between lysine and serine.

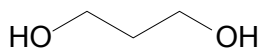
- (iii) Lactic acid dissociates to give  $H^+$  which may protonate the carboxylate group (in glutamic acid) or the amine group (in lysine), disrupting ionic bonds between the charged R groups. [1]

**OR**

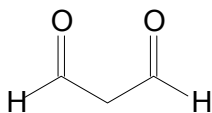
disrupting the hydrogen bonding between the polar R groups (e.g. lysine and serine, leading to denaturation.

[Total: 20]

4 (a) (i)



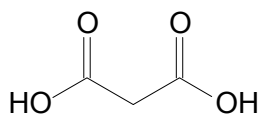
**E**



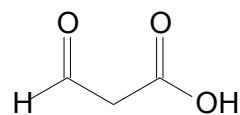
**F**

[2]

(ii)



OR



[1]

Accept "propanedioic acid"

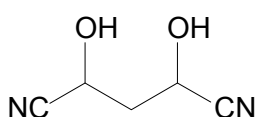
Accept "3-oxopropanoic acid"

(iii)  $n(1,3\text{-dibromopropane}) = 9.0 / 201.8 = 0.0446 \text{ mol}$   
 mass of **F** =  $0.67 \times 0.0446 \times 72.0 = \underline{2.15 \text{ g}}$

[1]

[1]

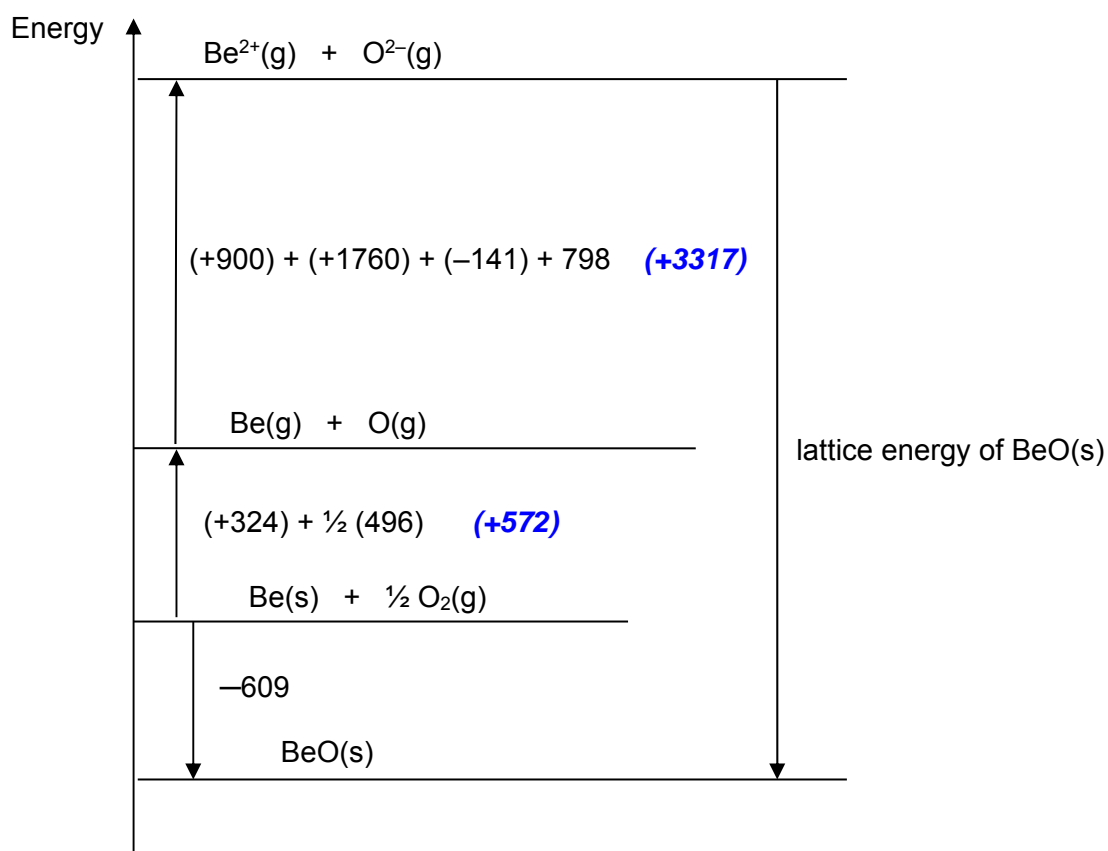
(iv)



**G**

[1]

(b) (i)



[2]

Lattice energy of  $\text{BeO}(\text{s})$   
 =  $-(3317 + 572 + 609)$   
 =  $\underline{-4498 \text{ kJ mol}^{-1}}$

[1]

- (ii) Theoretical calculation assumes pure ionic character.  
 But  $\text{Be}^{2+}$  ion is small and highly charged, hence it has high polarising power  
 $\Rightarrow \text{BeO}$  exhibits covalent character  
 $\Rightarrow$  Attraction is stronger, so observed value is more exothermic. } [1]

- (iii) Given  $\text{LE} \propto \frac{q_+q_-}{r_+ + r_-}$   
 ionic charge of  $\text{Be}^{2+} >$  ionic charge of  $\text{Na}^+$   
 ionic radius of  $\text{Be}^{2+} <$  ionic radius of  $\text{Na}^+$  } [1]

Stronger attraction between oppositely charged ions in  $\text{BeO}$   
 $\Rightarrow \text{LE}(\text{BeO}) >$  of  $\text{LE}(\text{Na}_2\text{O})$  in magnitude } [1]

- (iv)  $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \longrightarrow 2\text{NaOH}(\text{aq})$   
 Sodium oxide dissolves in water to produce sodium hydroxide } [1]

$\text{Cl}_2(\text{g}) + 2\text{NaOH}(\text{aq}) \longrightarrow \text{NaCl}(\text{aq}) + \text{NaClO}(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
 Chlorine undergoes disproportionation reaction when reacted with  $\text{NaOH}$ . } [1]

*State symbols not required*

- (c) (i)  $\text{CrO}_4^{2-} + 8\text{H}^+ + 3\text{e}^- \longrightarrow \text{Cr}^{3+} + 4\text{H}_2\text{O}$   
 $\text{Fe}^{2+} \longrightarrow \text{Fe}^{3+} + \text{e}^-$   


---

 $\text{CrO}_4^{2-} + 3\text{Fe}^{2+} + 8\text{H}^+ \longrightarrow \text{Cr}^{3+} + 3\text{Fe}^{3+} + 4\text{H}_2\text{O}$  [1]

- (ii) chromium(III) hydroxide **OR**  $\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3$  **OR**  $\text{Cr}(\text{OH})_3$   
 $2[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \longrightarrow 2[\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3] + 3\text{CO}_2 + 3\text{H}_2\text{O}$  [1]

$\text{Cr}^{3+}(\text{aq})$  undergoes hydrolysis with water liberating  $\text{H}^+(\text{aq})$   
 Undergoes acid-base reaction with  $\text{Na}_2\text{CO}_3(\text{aq})$  } [1]

- (d) (i) • a state function that measures the degree of disorder / randomness in a system [1]  
**OR**  
 • gives a measure of the extent to which particles and energy are distributed within the system **OR**  
 • the greater the disorder / randomness, the larger is the entropy.

- (ii) In reaction I, there is no change in number of particles in aqueous solution, } [1]  
 whereas in reaction II, there is an increase of 3 particles.

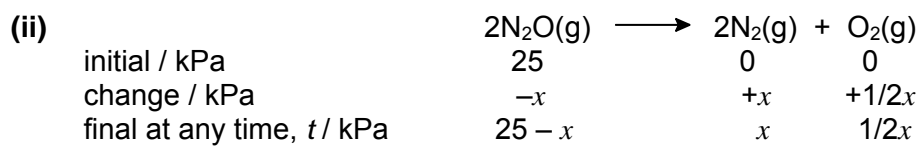
$\Rightarrow$  Increase in number of ways of arrangement and energy distribution of the particles  
 $\Rightarrow \Delta S_r^\ominus$  is more positive [1]

[Total: 20]





(b) (i) total pressure,  $P$ , when reaction is complete =  $3/2 \times 25 = \underline{37.5 \text{ kPa}}$  [1]



$$25 - x + x + 1/2x = P$$

$$25 + 1/2x = P$$

$$x = 2P - 50$$

[1]

Hence, partial pressure of  $\text{N}_2\text{O}$  at any time,  $t$ , is

$$25 - x = 25 - (2P - 50)$$

$$= 25 - 2P + 50$$

$$= \underline{75.0 - 2P \text{ (shown)}}$$

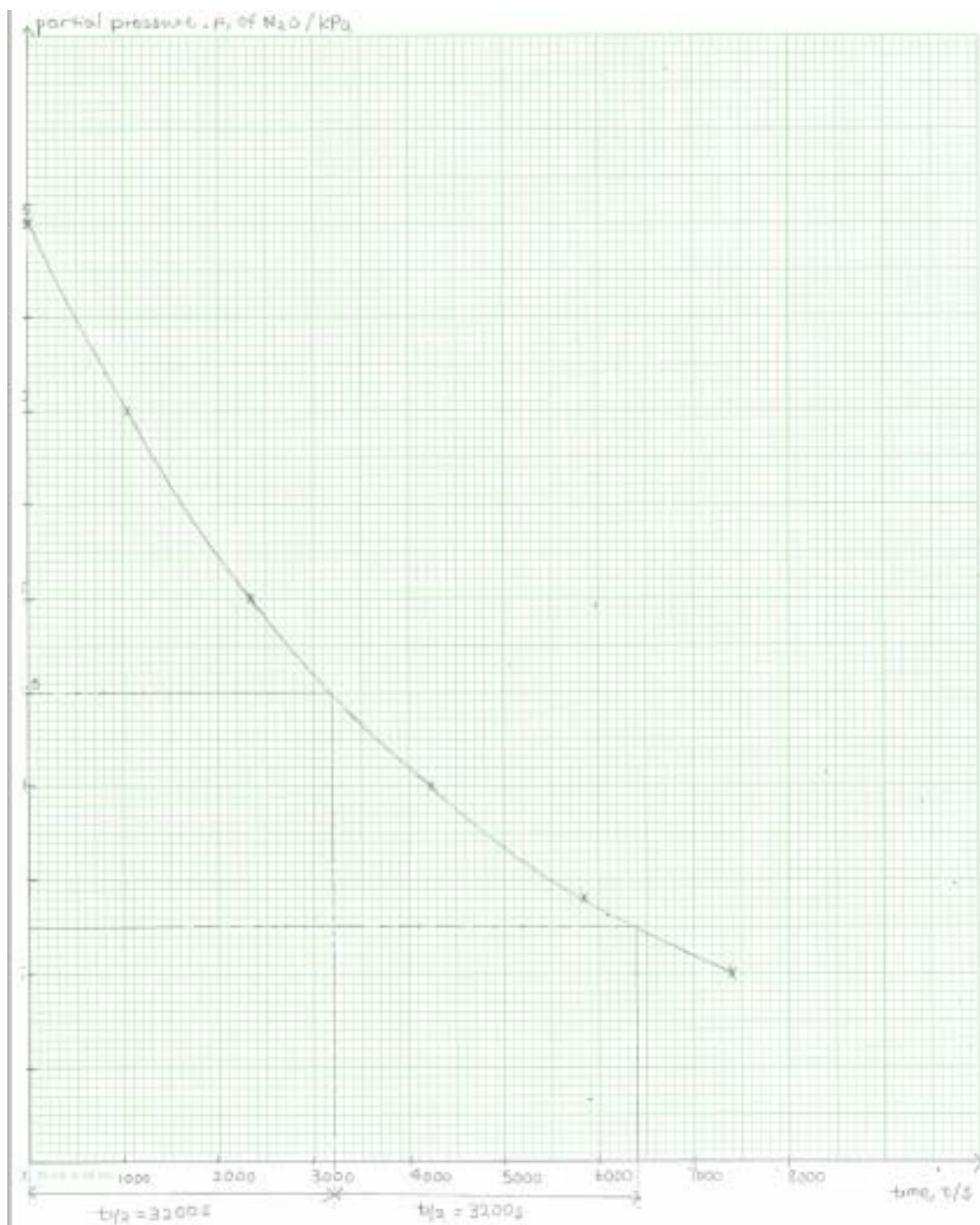
[1]

(iii)

$P$ / kPa	27.5	30.0	32.5	34.0	35.0
$t$ / s	1030	2360	4230	5870	7420
$p$ of $\text{N}_2\text{O}$ / kPa	<u>20</u>	<u>15</u>	<u>10</u>	<u>7</u>	<u>5</u>

[1]

(iv)



[2]

Since  $t_{1/2}$  is constant at 3200 s, the order of reaction w.r.t.  $N_2O$  is 1.

[1]

(v) rate =  $k p_{N_2O}$

[1]

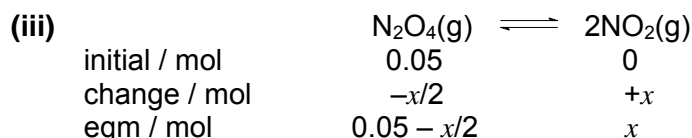
$$\begin{aligned} t_{1/2} &= \frac{\ln 2}{k} \\ k &= \frac{\ln 2}{t_{1/2}} \\ &= \frac{\ln 2}{3200} = 2.17 \times 10^{-4} \text{ s}^{-1} \end{aligned}$$

[1]

[1]

(c) (i)  $n(\text{N}_2\text{O}_4) = 4.60 / 92.0 = \underline{0.0500 \text{ mol}}$  [1]

(ii)  $pV = nRT$   
 $n = pV / RT$   
 $= \frac{101 \times 10^3 \times 1.48 \times 10^{-3}}{8.31 \times 300} = \underline{0.0600 \text{ mol}}$  [1]



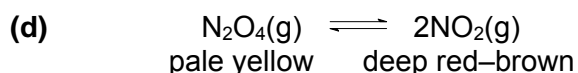
$0.05 - x/2 + x = 0.06$   
 $x = 0.02$  [1]

$n(\text{N}_2\text{O}_4) \text{ dissociated} = x/2 = 0.02/2 = 0.01$   
 $\% \text{ of } \text{N}_2\text{O}_4 \text{ dissociated} = 0.01 / 0.05 \times 100 = \underline{20.0 \%}$  [1]

(iv)  $K_p = \frac{p_{\text{NO}_2}^2}{p_{\text{N}_2\text{O}_4}}$  [1]

$p(\text{NO}_2) = 0.02/0.06 \times 1.00$   
 $= 1/3 \text{ atm}$   
 $p(\text{N}_2\text{O}_4) = 0.04/0.06 \times 1.00$   
 $= 2/3 \text{ atm}$  [1]

$K_p = \frac{(1/3)^2}{2/3} = 1/6 \approx \underline{0.17 \text{ (shown)}}$  [1]



When the equilibrium mixture is suddenly compressed in a gas syringe,  $[\text{N}_2\text{O}_4]$  and  $[\text{NO}_2]$  increase due to the reduced volume. [1]

Compression of the gas also results in an increase in pressure. The position of the above equilibrium shifts left to decrease pressure by producing fewer gas molecules. The [1]  
 mixture becomes paler as  $[\text{N}_2\text{O}_4]$  increases.

[Total: 20]