

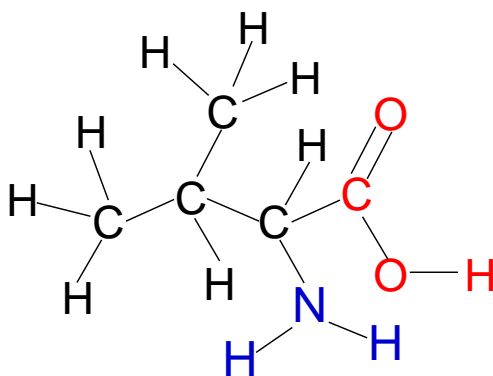
## Suggested Answers

### VCE Chemistry 2014 Year 12 Trial Exam Unit 3/4

#### SECTION A – Multiple Choice Answers

(1 mark per question)

Q1. D Quickly sketch the structure for 2-amino-3-methylbutanoic acid.



This is an amino acid with  $(\text{CH}_3)_2\text{CH}$  as its Z-(side) group, i.e. **valine**. (*Table 8 of the Data Book*).

The systematic of the other amino acids listed are  
glycine – 2-aminoethanoic acid.  
alanine – 2-aminopropanoic acid.  
leucine – 2-amino-4-methylpentanoic acid.

Q2. A  $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}); \Delta H = -566 \text{ kJ mol}^{-1}$  1.  
 $2\text{Cu}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CuO}(\text{s}); \Delta H = -311 \text{ kJ mol}^{-1}$  2.  
The required equation requires CuO on the left hand side, so reverse equation 2.  
 $2\text{CuO}(\text{s}) \rightarrow 2\text{Cu}(\text{s}) + \text{O}_2(\text{g}); \Delta H = +311 \text{ kJ mol}^{-1}$  2A.  
Add equations 1. and 2A.  
 $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) + 2\text{CuO}(\text{s}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{Cu}(\text{s}) + \text{O}_2(\text{g}); \Delta H = -566 \text{ kJ mol}^{-1} + 311 \text{ kJ mol}^{-1}$   
 $2\text{CO}(\text{g}) + 2\text{CuO}(\text{s}) \rightarrow 2\text{Cu}(\text{s}) + 2\text{CO}_2(\text{g}); \Delta H = -255 \text{ kJ mol}^{-1}$   
Divide through by 2 to get the required mole ratio  
 $\text{CO}(\text{g}) + \text{CuO}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{CO}_2(\text{g}); \Delta H = -128 \text{ kJ mol}^{-1}$

Q3. B The **simplest** pathway from an alkene to an ester derived from that alkene is  
1. alkene to alcohol – **addition** reaction with water (steam)  
2. alcohol to carboxylic acid – redox reaction (oxidation of the alcohol, **reduction** of the oxidant).  
3. alcohol + carboxylic acid to ester – **condensation** reaction.  
There is no need for a substitution reaction in this pathway.



**Q7. C**

$$\begin{aligned}
 m(\text{O}) \text{ in sample} &= m(\text{X}_2\text{O}_3) \text{ produced} - m(\text{X}) \\
 &= 1.10 - 0.62 \\
 &= 0.48 \text{ g} \\
 n(\text{O}) \text{ in sample} &= 0.48 \text{ g} / 16.0 \text{ g mol}^{-1} \\
 &= 0.030 \text{ mol}
 \end{aligned}$$

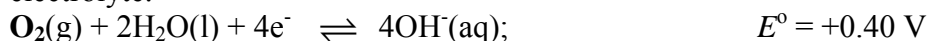
Since there are 3 mol O atoms for every 2 mol X atoms in the oxide

$$\begin{aligned}
 n(\text{X}) &= \frac{2}{3} \times n(\text{O}) = \frac{2}{3} \times 0.30 \\
 &= 0.020 \text{ mol}
 \end{aligned}$$

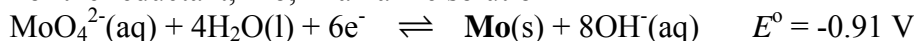
$$\begin{aligned}
 M(\text{X}) &= m(\text{X}) / n(\text{X}) \\
 &= 0.62 \text{ g} / 0.020 \text{ mol} \\
 &= 31 \text{ g mol}^{-1}
 \end{aligned}$$

According to the Periodic Table (Data Book Table 1), the element is **Phosphorus**

**Q8. B** In the molybdenum-air cells the oxidant is  $\text{O}_2(\text{g})$ .  
According to the electrochemical series (Data Book Table 2), in an alkaline electrolyte.



For the reductant, Mo, in alkaline solution



$$\begin{aligned}
 \text{The cell operating voltage} &= E^\circ(\text{oxidant half-cell}) - E^\circ(\text{reductant half-cell}) \\
 &= +0.40 - (-0.91) \\
 &= \mathbf{1.31 \text{ V}}
 \end{aligned}$$

**Q9. B** In this exercise the  $\text{Na}_2\text{CO}_3$  aliquot was titrated with  $\text{HCl}(\text{aq})$ , the pipette should have been rinsed with the  $\text{Na}_2\text{CO}_3(\text{aq})$  and burette with the  $\text{HCl}(\text{aq})$ . Titration flasks should be rinsed with water. In the ensuing calculation the only variable between the four groups should have been the  $V(\text{HCl})$  used in the titration. The impact of the differing volumes of  $\text{HCl}$  will impact in  $c(\text{HCl}) = n(\text{HCl}) / V(\text{HCl})$ .

**Group I** followed the correct rinsing procedures so should have calculated the **correct  $c(\text{HCl})$** .

**Group II** – rinsing the burette with water will leave traces of water which will decrease the concentration of the  $\text{HCl}(\text{aq})$  then added to the burette and lead to a larger titre. So a larger volume of  $\text{HCl}(\text{aq})$  will be required to provide the  $n(\text{HCl})$  to react completely with the  $\text{Na}_2\text{CO}_3$ . Since  $c(\text{HCl})$  is calculated from  $n(\text{HCl}) / V(\text{titre})$ , the **calculated  $c(\text{HCl})$  will be lower than the correct value**.

**Group III** – the effect of rinsing the burette with  $\text{Na}_2\text{CO}_3(\text{aq})$  will be to reduce the concentration of the  $\text{HCl}(\text{aq})$  then added again leading to a larger titre and a **lower than correct calculated  $c(\text{HCl})$** .

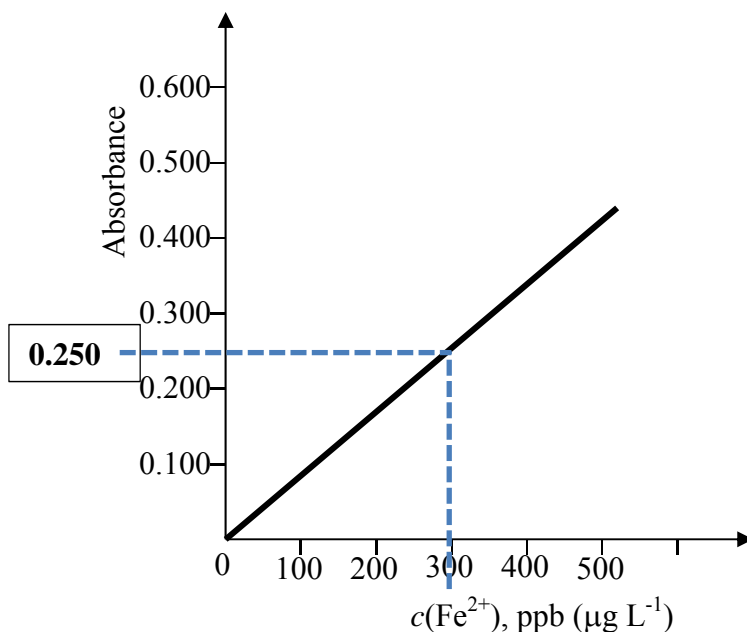
**Group IV** – rinsing the pipette with water will leave traces of water and will cause the amount of  $\text{Na}_2\text{CO}_3$  present in the aliquot then taken using the pipette to be less than it should be. Less  $\text{HCl}(\text{aq})$  will be needed to get to the equivalence point, so a lower titre volume will be recorded leading to a **higher than correct calculated  $c(\text{HCl})$** .

With two groups calculating concentrations lower than the true value and one group calculating a concentration higher than the true value, the **correct  $c(\text{HCl})$  is most likely to be 0.098 M**.

**Q10. B** CH<sub>3</sub>OH - methanol, CH<sub>3</sub>CH<sub>2</sub>OH - ethanol, CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>OH – propan-1-ol, CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>OH – butan-1-ol and (CH<sub>3</sub>)<sub>3</sub>COH – methylpropane-2ol all have a single hydroxyl group so their **relative attractions to the stationary phase will depend on the attraction of their non-polar hydrocarbon sections with a non-polar stationary phase.**

**Methanol - CH<sub>3</sub>OH** will have the weakest attraction to the stationary phase and so exit the gas chromatograph and pass into the mass spectrometer first.

**Q11. B**



Absorbance 0.250  $\rightarrow$   $c(\text{Fe}^{2+})$  in 150 mL diluted solution = 300  $\mu\text{g L}^{-1}$   
 5.0 mL of the original 250 mL test solution had been diluted to 150 mL, i.e. diluted by a factor of 30.

Hence  $c(\text{Fe}^{2+})$  in original 250 mL of solution = 30 x 300  
 = 9.00x10<sup>3</sup>  $\mu\text{g L}^{-1}$

$m(\text{Fe}^{2+})$  in test solution = 9.00x10<sup>3</sup>  $\mu\text{g L}^{-1}$  x 250x10<sup>-3</sup> L  
 = 2.25x10<sup>3</sup>  $\mu\text{g}$

To convert  $\mu\text{g}$  to mg divide by 1000 (Data Book Table 4)

$m(\text{Fe}^{2+})$  in test solution = 2.25x10<sup>3</sup> / 1000  
 = **2.25 mg**

**Alternatively:**

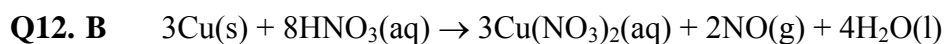
$m(\text{Fe}^{2+})$  in 150 mL of diluted solution = 300 x (150/1000) = 45.0  $\mu\text{g}$

$m(\text{Fe}^{2+})$  in 5 mL of original solution = 45.0  $\mu\text{g}$

$m(\text{Fe}^{2+})$  in 250 mL of original solution = 45.0 x (250/5) = 2.25x10<sup>3</sup>  $\mu\text{g}$

Since 1000  $\mu\text{g}$  = 1 mg

$m(\text{Fe}^{2+})$  in 250 mL of original solution =) = 2.25x10<sup>3</sup> / 1000 = 2.25 mg



6.75 g *xs* at STP

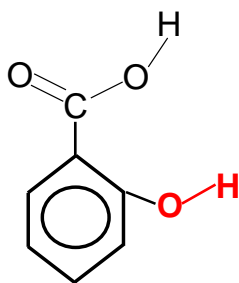
$$n(\text{Cu}) \text{ added} = 6.75 \text{ g} / 63.5 \text{ g mol}^{-1} \\ = 0.106 \text{ mol}$$

$$n(\text{NO}) \text{ produced} = \frac{2}{3} \times n(\text{Cu}) \\ = \frac{2}{3} \times 0.106 \\ = 0.0707 \text{ mol}$$

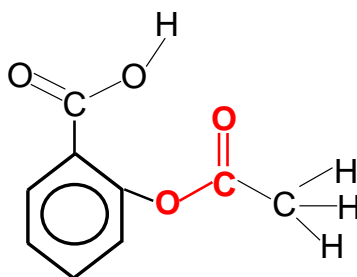
$$n(\text{NO}) \text{ collected} = V(\text{NO}) \text{ collected} / V_m(\text{STP}) \\ = 630 \times 10^{-3} \text{ L} / 22.4 \text{ L mol}^{-1} \\ = 0.0281 \text{ mol}$$

$$\% \text{ NO collected} = [n(\text{NO}) \text{ collected} / n(\text{NO}) \text{ produced}] \times 100 \\ = [0.0281 / 0.0707] \times 100 \\ = \mathbf{39.7 \%}$$

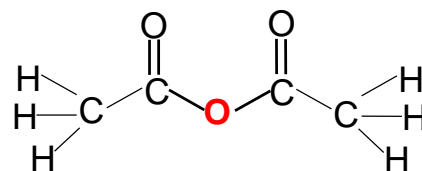
**Q13. A** The compounds shown in the question are



Salicylic acid



Aspirin (acetylsalicylic acid)



Ethanoic anhydride

Salicyl alcohol is not shown – its structure is like salicylic acid but with  $-\text{CH}_2\text{OH}$  instead of  $-\text{COOH}$

The benzene ring in salicylic acid and aspirin contains 4 H atoms, all of which are ‘different’ bonding environments. The bond environment must consider the whole molecule not just the atoms involved in a specific bond.

Salicylic acid: 6 different H environments  $\rightarrow$  6 peaks

Aspirin: 6 different H environments  $\rightarrow$  6 peaks

Ethanoic anhydride has only one H environment, with respect to the rest of the molecule all 6 H atoms are chemically equivalent. It would have only one peak (other than TMS) on its  $^1\text{H}$  NMR spectrum.

**Q14. B** 10.25 mL of 0.1020 M HCl(aq) was used to convert Na<sub>2</sub>CO<sub>3</sub> to NaHCO<sub>3</sub>  
HCl(aq) + Na<sub>2</sub>CO<sub>3</sub>(aq) → NaHCO<sub>3</sub>(aq) + NaCl(aq)

$$\begin{aligned}n(\text{Na}_2\text{CO}_3) \text{ present} &= n(\text{HCl}) \text{ required to reach phenolphthalein endpoint.} \\ &= c(\text{HCl}) \times V(\text{HCl}) \\ &= 0.1020 \text{ mol L}^{-1} \times 10.25 \times 10^{-3} \text{ L} \\ &= 1.046 \times 10^{-3} \text{ mol}\end{aligned}$$

$$\begin{aligned}n(\text{NaHCO}_3) \text{ produced from Na}_2\text{CO}_3 &= n(\text{Na}_2\text{CO}_3) \\ &= \mathbf{1.046 \times 10^{-3} \text{ mol}}\end{aligned}$$

25.25 mL of 0.1020 M HCl(aq) was required to react with all the NaHCO<sub>3</sub> – that initially present and that produced from Na<sub>2</sub>CO<sub>3</sub>.

$$\begin{aligned}\text{HCl(aq)} + \text{NaHCO}_3\text{(aq)} &\rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)} \\ n(\text{NaHCO}_3) \text{ reacting} &= n(\text{HCl}) \text{ added between endpoints.} \\ &= 0.1020 \times 25.25 \times 10^{-3} \\ &= \mathbf{2.586 \times 10^{-3} \text{ mol}}\end{aligned}$$

NaHCO<sub>3</sub> in bath salts is the difference between the amount reacting in the second titration and the amount produced from Na<sub>2</sub>CO<sub>3</sub>.

$$\begin{aligned}n(\text{NaHCO}_3) \text{ in 50 mL bath salts} &= n(\text{NaHCO}_3) \text{ reacting} - n(\text{NaHCO}_3) \text{ from Na}_2\text{CO}_3 \\ &= 2.586 \times 10^{-3} - 1.046 \times 10^{-3} \\ &= \mathbf{1.540 \times 10^{-3} \text{ mol}}\end{aligned}$$

*Alternatively*

10.25 mL of 0.1020 M HCl(aq) was required in the phenolphthalein titration to convert the Na<sub>2</sub>CO<sub>3</sub> initially present in the aliquot of bath salts solution to NaHCO<sub>3</sub>. This means that in the methyl orange titration, 10.25 mL of the added 0.1020 M HCl(aq) reacted with the NaHCO<sub>3</sub> produced from Na<sub>2</sub>CO<sub>3</sub>.

The remainder of the second titre, i.e. 25.25 – 10.25 = **15.10 mL of 0.1020 M HCl(aq) reacted with the NaHCO<sub>3</sub> initially present in the aliquot of bath salts solution.**

$$\begin{aligned}n(\text{NaHCO}_3) \text{ in aliquot of bath salts solution} &= n(\text{HCl}) \text{ reacting with that NaHCO}_3 \\ &= 0.1020 \times 15.10 \times 10^{-3} \\ &= \mathbf{1.540 \times 10^{-3} \text{ mol}}\end{aligned}$$

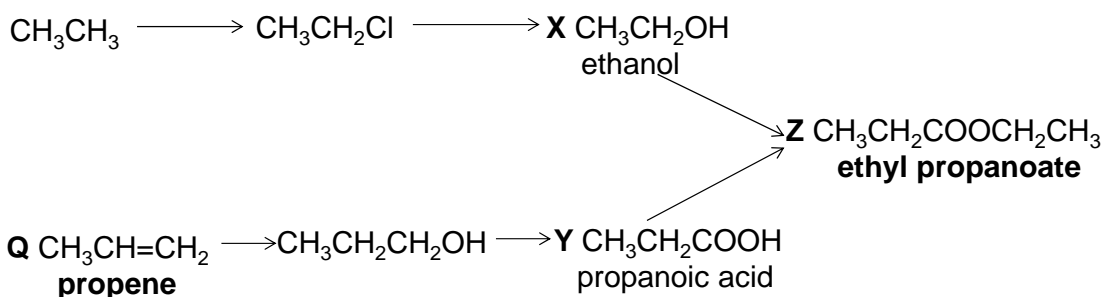
**Q15. D** X and Y are both organic compounds used to produce another organic compound Z. The pathway can be consistent with the production of an ester, Z, from an alcohol, X, and a carboxylic acid, Y.

**X** – **ethanol** produced from the reaction of  $\text{CH}_3\text{CH}_2\text{Cl}$  with  $\text{OH}^-$ (aq) - (substitution).

**Y** – **propanoic acid** from the oxidation of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  and acidified  $\text{Cr}_2\text{O}_7^{2-}$ (aq) – (oxidation/redox).

**Z** – **ethyl propanoate** from the reaction between  $\text{CH}_3\text{CH}_2\text{OH}$  and  $\text{CH}_3\text{CH}_2\text{COOH}$  – (condensation).

**Q** – **propene**, since  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  is produced directly from  $\text{CH}_3\text{CH}=\text{CH}_2$  by reaction with  $\text{H}_2\text{O}$  in the presence of  $\text{H}_3\text{PO}_4$  catalyst – (addition)



**Q16. A** The analytical process referred to is Atomic Absorption Spectroscopy (AAS), which is most suitable for measuring amounts of metals extracted into or present in solution, hence could be used in the determination of the amount of potassium in a sports drink.

The analytical techniques used in the other options would be.

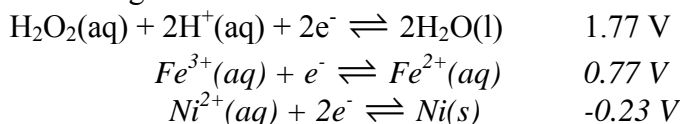
B. IR spectroscopy

C.  $^{13}\text{C}$  NMR spectroscopy

D. Gas chromatography or redox titration.

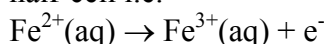
- Q17. D** In order for the cell to generate 1.0 V at 25°C, 101.3 kPa and for 1 M solutions, the difference between the  $E^\circ$  values of the two half-cells must be 1.00 V. Since the  $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$  half-cell has an  $E^\circ$  value of +0.77 V, the other half cell must have an  $E^\circ$  value either 1.00 V greater than +0.77 V, i.e. +1.77 V, or 1.00 V less than +0.77 V, i.e. -0.23 V.

According to the electrochemical series this is consistent with



In a galvanic cell, electrons move spontaneously from the anode (-) to the cathode (+).

So the electrode signs indicate that oxidation is occurring in the  $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$  half-cell i.e.



Since electrons leave the site of oxidation and go to the site of reduction, the left-hand half-cell must contain the oxidant, in this case  $\text{H}_2\text{O}_2(\text{aq}), \text{H}^+(\text{aq})$ , i.e. 1.00 V higher up on the electrochemical series than the reductant  $\text{Fe}^{2+}(\text{aq})$ .

**$\text{H}_2\text{O}(\text{l})$  is the product of the half-reaction in half-cell 1**, because the oxidant  $\text{H}_2\text{O}_2(\text{aq})$  is reduced to  $\text{H}_2\text{O}(\text{l})$  according to  $\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$ .

*Alternatively:*

Since  $E(\text{cell}) = E^\circ(\text{oxidant half-cell}) - E^\circ(\text{reductant half-cell})$

$$\begin{aligned} 1.00 \text{ V} &= E^\circ(\text{oxidant}) - E^\circ(\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})) \\ &= E^\circ(\text{oxidant}) - (0.77 \text{ V}) \end{aligned}$$

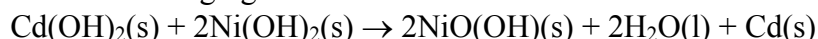
$$\begin{aligned} \text{Hence } E^\circ(\text{oxidant}) &= 1.00 + 0.77 \\ &= +1.77 \text{ V} \end{aligned}$$

From the electrochemical series  $\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l}); E^\circ = +1.77 \text{ V}$

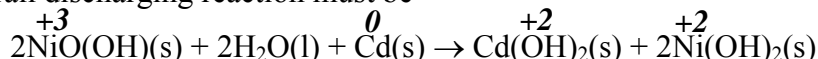
- Q18. B** For both X and Y the  $[\text{H}_3\text{O}^+]$  decreases at time 't' because of the increase in volume.
- The fact that for **X** the  $[\text{H}_3\text{O}^+]$  stays constant after dilution suggests that it is a **strong acid** and was **fully ionised** in solution prior to dilution.
- For **Y** the rise in  $[\text{H}_3\text{O}^+]$  after dilution suggests that it is a **weak acid**. As a weak acid,  $\text{HA}(\text{aq})$ , **only a small amount has ionised prior to dilution**. Whilst the concentrations of  $\text{A}^-(\text{aq})$  and  $\text{HA}(\text{aq})$  also decrease **on dilution**, the concentration fraction  $\{[\text{A}^-][\text{H}_3\text{O}^+] / [\text{HA}]\}$  becomes  $< K$ .
- To get back to equilibrium, **ionisation of the acid increases, causing the  $[\text{H}_3\text{O}^+]$  to increase until equilibrium is again established**.
- X - Hydrochloric acid**,  $\text{HCl}(\text{aq})$ , is a strong acid.
- Y - Methanoic acid**,  $\text{HCOOH}(\text{aq})$ , is a weak acid. ( $K_a = 1.8 \times 10^{-4}$ )
- Since both acids have the same initial pH, hence  $[\text{H}_3\text{O}^+]$ , and  $\text{HCl}(\text{aq})$  is fully ionised but  $\text{HCOOH}(\text{aq})$  is only partially ionised,  **$\text{HCOOH}(\text{aq})$  will have the higher initial concentration**.
- $\text{pH } 3.00 \rightarrow c(\text{HCl}) = 0.0010 \text{ M}$
- $\text{pH } 3.00 \rightarrow c(\text{HCOOH}) = \{[\text{H}_3\text{O}^+]^2 / K_a\} = \{[0.0010]^2 / 1.8 \times 10^{-4}\} = 0.0056 \text{ M}$
- Correct Answer B



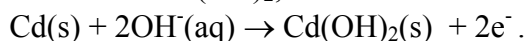
**Q19. C** Given the overall recharging reaction



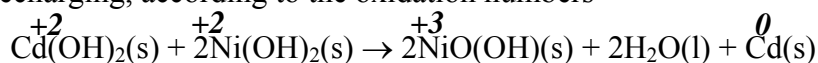
The overall discharging reaction must be



Since oxidation occurs at the anode and, according to the oxidation numbers Cd is oxidised to Cd(OH)<sub>2</sub>, the oxidation half-equation during discharging must be



**Q20. D** During recharging, according to the oxidation numbers



**Cd(OH)<sub>2</sub> is reduced** and during recharging (electrolysis) reduction occurs **at the (-) electrode**.

Since the **negative terminal of power supply must be attached to the (-) terminal of the battery** it must be **connected to the electrode containing Cd(OH)<sub>2</sub>**.

During recharging a voltage greater than that generated during discharging must be applied to the cell to force the electrons to flow in the opposite direction.

Hence a **voltage greater than 1.4 V** must be applied.

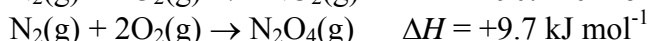
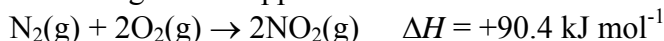
**Q21. A** From time t, the concentration of one species gradually increases and the concentration of the other species gradually decreases until equilibrium is reached again. This indicates the change was not a change in volume since that would cause an instantaneous concentration increase or decrease for both species prior to the gradual adjustments back to equilibrium.

**The gradual changes in concentration** of both species after time t suggest a **change in temperature** was imposed.

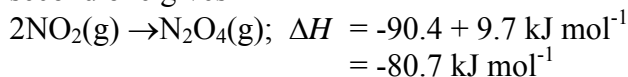
The change in concentration for the **top curve** is significantly greater, implying that was the **species is on the side with more particles**, i.e. the top curve is for NO<sub>2</sub>.

**The amount of NO<sub>2</sub> has increased**, as a result of the imposed change, **whilst the amount of N<sub>2</sub>O<sub>4</sub> has decreased**.

According to the supplied thermochemical information

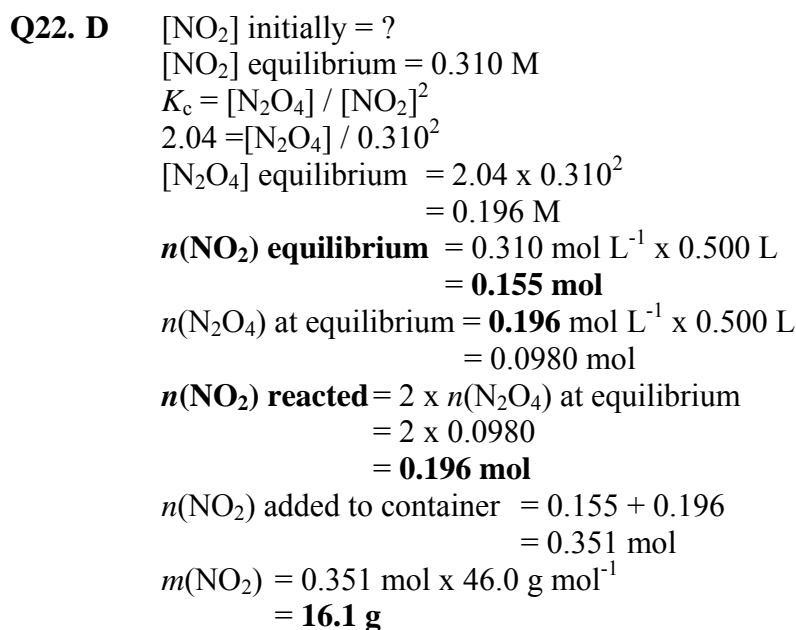


Reversing the first equation (also changing sign of ΔH) and adding it to the second one gives



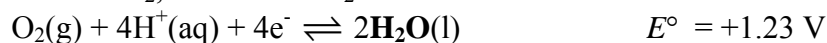
*So in the equilibrium  $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$  the forward reaction is exothermic.*

Since the **temperature change favours the reverse endothermic reaction** it must have been a **temperature increase**.

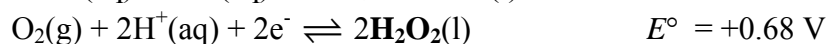
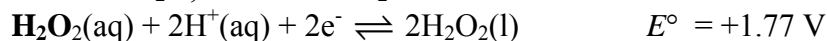


**Q23. B** Species which can act as both oxidants and reductants can be identified on the electrochemical series. (Data Book Table 2).  
This shows that  **$\text{H}_2\text{O}$ ,  $\text{H}_2\text{O}_2$  and  $\text{Sn}^{2+}$  can all act as both oxidants and reductants**

$\text{H}_2\text{O}$  – reduced to  $\text{H}_2$ , oxidised to  $\text{O}_2$



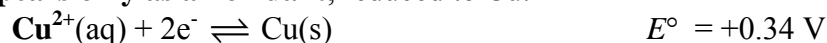
$\text{H}_2\text{O}_2$  – reduced to  $\text{H}_2\text{O}$ , oxidised to  $\text{O}_2$



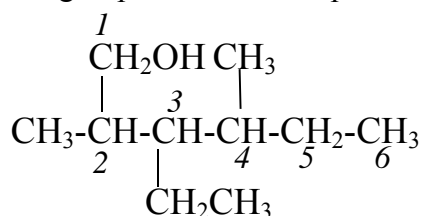
$\text{Sn}^{2+}$  – reduced to  $\text{Sn}$ , oxidised to  $\text{Sn}^{4+}$



**$\text{Cu}^{2+}$  appears only as an oxidant**, reduced to  $\text{Cu}$ .



**Q24. D** Identify the longest continuous run of C atoms numbered so that the hydroxyl, -OH group has the lowest possible number



6 carbons in a continuous run → **hexan** .. since all C-C bonds are single bonds

Hydroxyl -OH group on C-1

2 methyl -CH<sub>3</sub> groups at C-2 and C-4

1 ethyl -CH<sub>2</sub>CH<sub>3</sub> group at C-3

Hence **2,4-dimethyl-3-ethylhexan-1-ol**

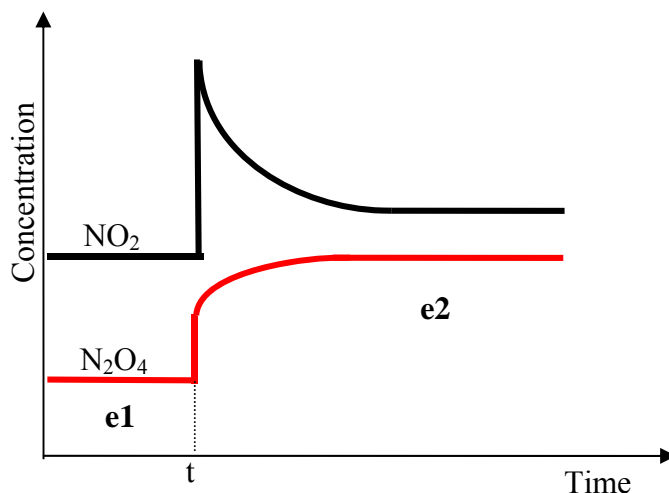
**Q25. B** The monoprotic acid may be represented by HA, so the reaction with NaOH is  
 $\text{HA(aq)} + \text{NaOH(aq)} \rightarrow \text{NaA(aq)} + \text{H}_2\text{O(l)}$   
 $n(\text{NaOH}) \text{ used} = c(\text{NaOH}) \times V(\text{NaOH})$   
 $= 1.000 \times 27.48 \times 10^{-3}$   
 $= 2.748 \times 10^{-2} \text{ mol}$   
 $n(\text{HA}) \text{ in } 25.0 \text{ mL aliquot} = n(\text{NaOH})$   
 $= 2.748 \times 10^{-2} \text{ mol}$  ①  
 $n(\text{HA}) \text{ in sample} = (2.748 \times 10^{-2} / 25) \times 200$   
 $= 0.2198 \text{ mol}$   
 According to the mass spectrum  $M(\text{HA}) = 60.0 \text{ g mol}^{-1}$   
 $m(\text{HA}) = n(\text{HA}) \times M(\text{HA})$   
 $= 0.2198 \times 60.0$   
 $= \mathbf{13.2 \text{ g}}$

**Q26. C** Because **solid NaOH is not a primary standard**, the concentration of aqueous solutions of NaOH cannot be accurately determined from the mass dissolved. Aqueous solutions of NaOH can be standardised against standard solutions of hydrochloric acid. The HCl(aq) is itself standardised by titration against an aqueous solution of a primary standard, in this case  $\text{Na}_2\text{CO}_3$ . The reaction sequence was:

1. a solution of the primary standard  $\text{Na}_2\text{CO}_3$  was made and used to standardise the 'x' M HCl(aq)
2. the standardised HCl(aq) was used to standardise the 'y' M NaOH(aq)
3. aliquots of the diluted vinegar sample were titrated with the standardised NaOH(aq)

Alternatives A, B and C are all chemically correct statements but the **most relevant** to this analysis was **C – sodium hydroxide is not a primary standard**. This analysis did NOT involve back titration which usually involves titration to determine the amount of 'excess' reactant.

- Q27. B** When the volume of the equilibrium mixture was halved, the pressure and concentration of each species immediately doubles. The effect of this change is represented on the concentration-time diagram below, consistent with Le Chatelier's principle that the system will compensate for the pressure increase by moving to compensate for the change by favouring the side with fewer particles.

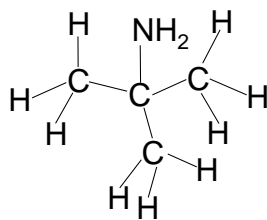


Compare the amounts and concentrations of  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  present at the equilibrium positions **e1** - before the volume change, and **e2** - after the volume change is interesting.

The concentration-time graph shows clearly that  $[\text{NO}_2]_{\text{e2}} > [\text{NO}_2]_{\text{e1}}$ , overall the  **$[\text{NO}_2]$  increases**. After the change the system returns to equilibrium but the  $[\text{NO}_2]$  does **not** drop to its value prior to the imposed change.

As the system returns to equilibrium  $\text{NO}_2$  is converted into  $\text{N}_2\text{O}_4$ , i.e. the mass of  $\text{NO}_2$  decreases so it follows that  $m(\text{NO}_2)_{\text{e2}} < m(\text{NO}_2)_{\text{e1}}$ ; overall the  **$m(\text{NO}_2)$  decreases**.

- Q28. C** methyl-2-propanamine



– semistructural formula  $(\text{CH}_3)_3\text{CNH}_2$

– molecular formula:  $\text{C}_4\text{H}_{11}\text{N}$

$$n(\text{C}_4\text{H}_{11}\text{N}) = 365 \times 10^{-6} \text{ g} / 73.0 \text{ g mol}^{-1} \quad \text{..... to convert } \mu\text{g to g divide by } 10^6 \\ = 5.00 \times 10^{-6} \text{ mol}$$

$$n(\text{C}) = 4 \times 5.00 \times 10^{-6} \\ = 2.00 \times 10^{-5} \text{ mol}$$

$$N(\text{C}) = 2.00 \times 10^{-5} \times 6.02 \times 10^{23} \\ = \mathbf{1.20 \times 10^{19}} \text{ atoms}$$

- Q29. D** With all initial concentrations at 0.1 M, the starting pH in the titration curves should be
- very close to 1 for HCl(aq), a strong acid
  - significantly higher than 1 but less than 7 for CH<sub>3</sub>COOH(aq), a weak acid base.
  - very close to 13 for NaOH(aq), a strong base
  - significantly less than 13 but greater than 7 for NH<sub>3</sub>(aq), a weak acid base.

Finishing pH values close to 1 and 13 reflect titration with a strong acid and a weak base respectively.

Finishing pH values less than 13 but greater than 7, and greater than 1 but less than 7, reflect titration with a weak base and a weak acid respectively.

Titration curve A shows the titration of a weak acid by a strong base – alternative C.

Titration curve B shows the titration of a strong acid by a strong base – alternative B.

Titration curve C shows the titration of a strong acid by a weak base – alternative A.

Titration curve D shows the titration of a strong base by a strong acid – alternative B.

**Reaction between NH<sub>3</sub>(aq) and CH<sub>3</sub>COOH(aq) i.e. between a weak base and a weak acid is not represented in the titration curves shown.**

- Q30. D** Consider the alternatives

A. *not rinsing the precipitate with water during collection.* This means that **some soluble species may be caught in the precipitate and not flushed** out leading to a **higher than true measured  $m(\text{precipitate})$  and calculated percentage over 100.**

B. *not drying the precipitate fully prior to weighing.* This means that **water will remain in the precipitate** leading to a **higher than true measured  $m(\text{precipitate})$  and calculated percentage over 100.**

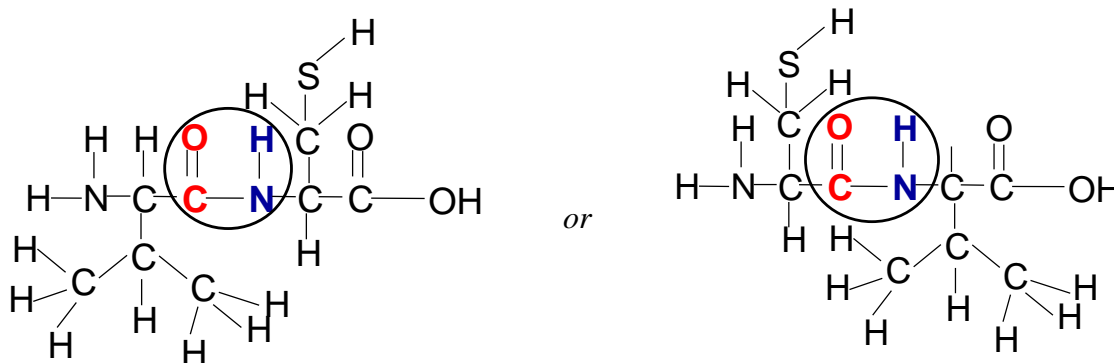
C. *incorrectly recording the weight of the fertiliser as 1.798 g rather than the correct 1.978.* This means that when calculating % sulfur =  $[m(\text{sulfur}) / m(\text{sample})] \times 100$ , **dividing by 1.798 rather than the correct 1.978** will produce a **calculate percentage over 100.**

D. *not converting all the sulfur in the sample to sulfate prior to precipitation.* This means that the amount of sulfate produced hence  **$m(\text{precipitate})$  collected will be lower than it should be** leading to a **calculated percentage less than 100.**

## SECTION B - Short Answer (Answers)

### Question 1 (16 marks)

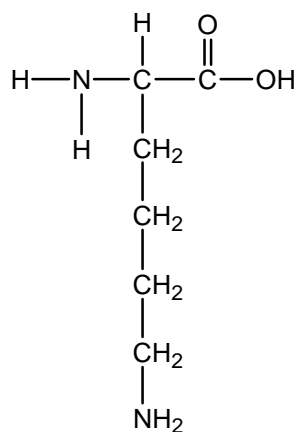
- a. In the hydrolysis reaction **water reacted with the peptide groups, CO-NH** ①, which were converted into **carboxyl, COOH, and amino, NH<sub>2</sub> groups** ①
- b. A tripeptide is formed from three amino acid residues. If each of the three amino acids was present only once in each molecule of X, it would be a tripeptide, however the **chromatogram does not indicate the relative number of each of the three amino acids in the molecule hence it may or may not be a tripeptide.** ① Also a tripeptide need not give three spots on the chromatogram since it can be formed from a single amino acid or from two amino acids.
- c. The sulfur containing amino acid in X and Y is cysteine (cys) – (Data Book Table 8 for structure). Two dipeptides are possible: from reaction between –COOH on valine and –NH<sub>2</sub> on cysteine, or between –COOH on cysteine and –NH<sub>2</sub> on valine.



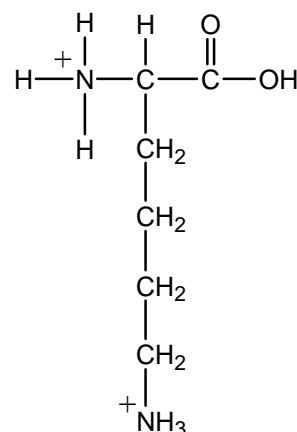
① for –CH<sub>2</sub>SH (cysteine) and –CH(CH<sub>3</sub>)<sub>2</sub> (valine) side groups with all bonds shown.

① for correct overall structure and peptide group correctly circled.

- d. To have a charge of +2 in solution at pH 3, the **amino acid must have two groups that can be protonated (accept H<sup>+</sup>(aq)) in acidic solution.** Lysine ①, has **two basic NH<sub>2</sub> groups both of which will be protonated to –<sup>+</sup>NH<sub>3</sub>** ① giving an overall charge of +2.



Lysine



Lysine at pH 3

- e. In chromatography the **mobile phase carries the components in a mixture over the stationary phase. Components are separated according to the relative attractions to the stationary and mobile phases.** ① The component most strongly attracted to stationary phase, in this case histidine, moves the least distance (slowest) ①. The component least strongly attracted to the stationary phase, in this case glycine, moves the greatest distance (fastest) ①.

① for appropriate mention of mobile and stationary phases.

① for identification of glycine as being least strongly attracted to the stationary phase.

① for identification of histidine as being most strongly attracted to the stationary phase.

The second and third marks can be awarded for accurate comparison of any two amino acids in the chromatogram.

f.

	Proteins	Nucleic acids
Type of bond associated with primary structure. ① for both correct	<b>Covalent</b>	<b>Covalent</b>
Atoms between which primary structure bonds occur.	<b>C and N in peptide link</b> ①	<b>C on one nucleotide to O to P on adjacent nucleotide</b> ①
Types of bonds associated with secondary structure. ① for both correct	<b>Hydrogen bonding</b>	<b>Hydrogen bonding</b>
Atoms between which secondary structure bonds occur.	<b>O on one peptide group and H on a different peptide group.</b> ①	<b>H and N, and H and O on complementary nitrogen bases.</b> ①

### Question 2 (16 marks)

a. i.  $m(\text{MHCM}) = 0.95 \times 28000 \times 10^3$   
 $= 2.66 \times 10^7$  ①

The unit ppm(m/V) is equivalent to  $\text{mg L}^{-1}$

$c(\text{in mg L}^{-1}) = m(\text{in mg}) / V(\text{in L})$ , hence

$$V(\text{solution}) = m(\text{mg}) / c(\text{mg L}^{-1})$$

$$= 2.66 \times 10^7 \times 10^3 / 1$$

$$= 2.66 \times 10^{10} \text{ L} \quad \dots\dots \text{to convert L to GL divide by } 10^9 \text{ (Data Book Table 4)}$$

$$= 27 \text{ GL } ① \text{ (2 sig figs)}$$

ii. 1.00 ppm = 1.00 mg  $\text{C}_8\text{H}_{16}\text{O}$  in one litre of solution

$$M(\text{C}_8\text{H}_{16}\text{O}) = 128.0 \text{ g mol}^{-1}$$

$$n(\text{C}_8\text{H}_{16}\text{O}) \text{ in one L} = 1.00 \times 10^{-3} \text{ g} / 128.0 \text{ g mol}^{-1}$$

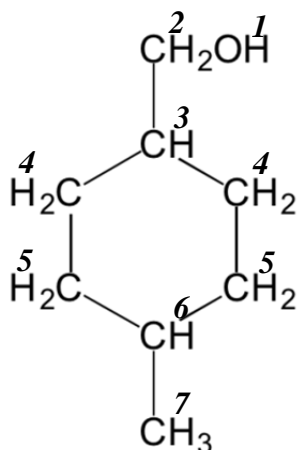
$$= 7.8 \times 10^{-6} \text{ mol}$$

$$c(\text{C}_8\text{H}_{16}\text{O}) = 7.8 \times 10^{-6} \text{ mol L}^{-1} ① \text{ or } 7.8 \times 10^{-6} \text{ M}$$

- b. In the **initial stages** of the spill, the levels of MCHM in the water would have been very high and some of this **highly concentrated solution may have entered the domestic water supply** ①. **Flushing thoroughly would effectively wash this through the pipes and ensure that the water was diluted below dangerous levels of MCHM and safe for domestic use.** ①

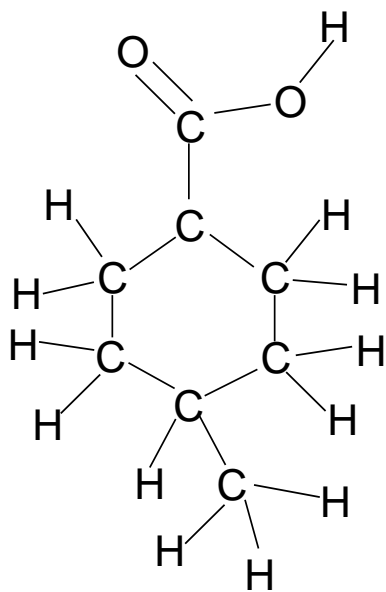
c. **7 peaks** ①

The seven different H environments are indicated on the diagram below.



A quick check to show that the H atoms labelled 4 and 5 are in different chemical environments is their relative distances from the -OH functional group.

d. i.



① for overall structure showing all bonds.

ii. When MHCM is oxidised, acidified Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>(aq) is reduced to Cr<sup>3+</sup>(aq). The half-equation for this reaction is





e. i.  $m(\text{C}) = 40.0/100 \times 1000$   
 $= 400 \text{ g}$   
 $m(\text{H}_2\text{O}) = 1000 - 400$   
 $= 600 \text{ g}$

According to Table 13 of the Data Book,  $\Delta H_c(\text{C}) = 394 \text{ kJ mol}^{-1}$

$n(\text{C}) = 400 / 12.0$   
 $= 33.3 \text{ mol}$  ①

Energy released from coal = energy available from C content – energy required to vaporise  $\text{H}_2\text{O}$

Energy available from C =  $33.3 \text{ mol} \times 394 \text{ kJ mol}^{-1}$   
 $= 1.31 \times 10^4 \text{ kJ}$  ①

$n(\text{H}_2\text{O}) = 600 / 18.0$   
 $= 33.3 \text{ mol}$  ①

Energy required to vaporise water =  $33.3 \text{ mol} \times 41.0 \text{ kJ mol}^{-1}$   
 $= 1.37 \times 10^3 \text{ kJ}$  ①

Energy released by 1.0 kg of brown coal =  $1.31 \times 10^4 - 1.37 \times 10^3$   
 $= 1.18 \times 10^4 \text{ kJ}$

Heat of combustion =  $1.18 \times 10^4 \text{ kJ} / 1000 \text{ g}$   
 $= 11.8 \text{ kJ g}^{-1}$  ①

- ii. Only around 30 per cent of the chemical energy of the coal is converted to electrical energy. The rest is lost, mainly as heat energy, in the energy conversions in the power station.

Economic advantage – **less coal needed for the production of electrical energy hence electricity should be cheaper for consumers.** ①

Environmental advantage – **reduced emissions of the greenhouse gas  $\text{CO}_2$ .** ①

- iii. Plant material from which coal was formed (over millions of years) contained **proteins**, some of which were formed from **amino acids with side-chains containing sulfur** ①, e.g. cysteine, methionine. Sulfur burns in air to produce  $\text{SO}_2$ .

### Question 3 (9 marks)

- a. i. **Cathode; Negative(-)** ①

- ii. The **strongest oxidant** present in the half-cell was the **metal cations** ①, and hence they **reduced in preference to water** at the cathode. ①

- b. i.  $Q = It = 3.20 \times 5.30 \times 60$   
 $= 1.02 \times 10^3 \text{ C}$

$n(\text{e}^-) = Q / F = 1.02 \times 10^3 / 96500$   
 $= 0.0105 \text{ mol}$  ①

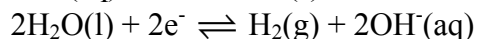
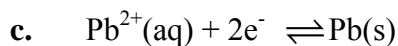
Divalent metal  $\rightarrow \text{X}^{2+}(\text{aq})$  ions.

Reduction half-equation is  $\text{X}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{X}(\text{s})$

$n(\text{X}) = n(\text{e}^-) / 2 = 0.0105 / 2$   
 $= 5.27 \times 10^{-3} \text{ mol}$  ①

$M(\text{X}) = m(\text{X}) / n(\text{X})$   
 $= 1.09 / 5.27 \times 10^{-3}$   
 $= 207 \text{ g mol}^{-1}$  ①

- ii. **Lead** ① According to Date Book Table 1 (periodic table),  $A_r(\text{Pb}) = 207.2$



During electrolysis, the stronger reductant  $\text{Pb}^{2+}(\text{aq})$  is preferentially reduced and Pb is deposited at the cathode. However if the electrolysis was allowed to run for an extended time, the **concentration of  $\text{Pb}^{2+}(\text{aq})$  will eventually drop to a level 1 such that  $\text{H}_2\text{O}$  is preferentially reduced and  $\text{H}_2(\text{g})$  is produced at the cathode. 1**

#### Question 4 (10 marks)

a. 1 for two of statements 2., 3., and 5. all of which are correct.

2. *The products of an exothermic reaction have a lower chemical energy content because chemical energy is converted into thermal energy*

3. *Since thermal energy is converted to chemical energy in an endothermic reaction, the products have a higher chemical energy content and are higher than the reactants on an energy profile.*

5. *Increasing temperature increases the kinetic energy of all particles and so increases the proportion of fruitful collisions, hence increasing the rate of reaction.*

b. 11 x 3 for a clear explanation of why each of the three identified statements is incorrect.

1. *Exothermic reactions always start spontaneously whereas endothermic reactions require a source of energy to start.*

All chemical reactions require a source of energy to start. The **reactant molecules must have energy greater than the activation energy to enable the bonds in the reactant particles to break 1**. If a reaction is spontaneous it means that the **prevailing conditions provide energy greater than the activation energy for that reaction. 1**

4. *In the presence of catalyst the energy required to break reactant bonds is decreased but the energy released when product bonds form is not affected.*

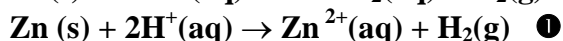
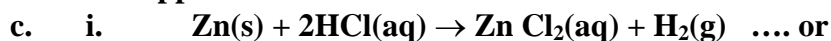
A catalyst lowers the **activation energy of a reaction but does not change the  $\Delta H$ . 1** Since  $\Delta H$  reflects the difference between the energy released when product bonds are formed and the energy used to break reactant bonds, the **presence of a catalyst decreases both energies – required for bond breaking, released in bond making- equally. 1**

6. *At chemical equilibrium either an exothermic reaction or an endothermic reaction will be occurring.*

At **equilibrium the rates of the forward and reverse reactions are occurring at the same rate. 1** If the forward reaction is exothermic, the reverse reaction must be endothermic, so at equilibrium **BOTH an exothermic and a reverse reaction are occurring. 1**

7. *The rate of an exothermic reaction increases as it proceeds but the rate of an endothermic reaction decreases as it proceeds.*

As reaction proceeds, **reactant concentration decreases**. This means that the **number of fruitful collisions decreases and the reaction slows down. 1** This happens in both exothermic and endothermic reactions. 1



ii. The reaction using **zinc powder 1** would be faster since this will provide a **greater surface area for reaction and more successful collisions** (collisions with energy greater than the activation energy) **between Zn and  $\text{H}^+(\text{aq})$  ions. 1**

**Question 5 (14 marks)****a. C<sub>6</sub>H<sub>5</sub>COOK** ① (C<sub>6</sub>H<sub>5</sub>COO<sup>-</sup>K<sup>+</sup>)**b. i.** Equilibrium equation is C<sub>6</sub>H<sub>5</sub>COOH(aq) + H<sub>2</sub>O(l) ⇌ C<sub>6</sub>H<sub>5</sub>COO<sup>-</sup>(aq) + H<sub>3</sub>O<sup>+</sup>(aq)

or



$$K_a = [\text{C}_6\text{H}_5\text{COO}^-][\text{H}_3\text{O}^+] / [\text{C}_6\text{H}_5\text{COOH}] \quad \text{① or}$$

$$K_a = [\text{C}_6\text{H}_5\text{COO}^-][\text{H}^+] / [\text{C}_6\text{H}_5\text{COOH}] \quad \text{or}$$

$$6.4 \times 10^{-5} = [\text{C}_6\text{H}_5\text{COO}^-][\text{H}_3\text{O}^+] / 0.100 \quad \text{Since } K_a(\text{C}_6\text{H}_5\text{COOH}) = 6.4 \times 10^{-5}$$

(Data Book, Table 12)

**ii.** Apply the standard weak acid assumptions – minimal ionisation of the acid, hence [C<sub>6</sub>H<sub>5</sub>COOH]<sub>eqm</sub> = 0.100 M  
 – minimal effect from the self-ionisation of water, hence [C<sub>6</sub>H<sub>5</sub>COO<sup>-</sup>]<sub>eqm</sub> = [H<sub>3</sub>O<sup>+</sup>]<sub>eqm</sub>

$$6.4 \times 10^{-5} = [\text{H}_3\text{O}^+]^2 / 0.100 \rightarrow [\text{H}_3\text{O}^+]^2 = 0.100 \times 6.4 \times 10^{-5} \quad \text{①}$$

$$[\text{H}_3\text{O}^+] = \sqrt{(0.100 \times 6.4 \times 10^{-5})}$$

$$= 2.53 \times 10^{-3} \text{ M} \quad \text{①}$$

$$\text{pH} = -\log(2.53 \times 10^{-3})$$

$$= 2.60 \quad \text{①}$$

**c. i.** n(C<sub>6</sub>H<sub>5</sub>COOH) used = 1.56 g / 122.0 g mol<sup>-1</sup>

$$= 1.28 \times 10^{-2} \text{ mol}$$

$$\text{Energy released} = 1.28 \times 10^{-2} \text{ mol} \times 3227 \text{ kJ mol}^{-1} \quad \text{①}$$

$$= 41.3 \text{ kJ}$$

$$= 4.13 \times 10^4 \text{ J}$$

$$\text{Calibration factor} = 4.13 \times 10^4 \text{ J} / 19.6^\circ\text{C}$$

$$= 2.11 \times 10^3 \text{ J } ^\circ\text{C}^{-1} \quad \text{①①}$$

**ii.** The **calibration factor** calculated using the specific heat of water would be **lower** ① because it would **not account for the energy absorbed by the calorimeter components.** ①

**d. i.** Energy released by fuel = Calibration factor x ΔT

$$= 3.17 \text{ kJ } ^\circ\text{C}^{-1} \times 17.8^\circ\text{C}$$

$$= 56.4 \text{ kJ} \quad \text{①}$$

According to Table 13 of the Data Book, ΔH<sub>c</sub>(C<sub>5</sub>H<sub>12</sub>) = -3509 kJ mol<sup>-1</sup>

$$n(\text{C}_5\text{H}_{12}) = 56.4 \text{ kJ} / 3509 \text{ kJ mol}^{-1}$$

$$= 1.61 \times 10^{-2} \text{ mol} \quad \text{①}$$

$$m(\text{C}_5\text{H}_{12}) \text{ added to the calorimeter} = 1.61 \times 10^{-2} \text{ mol} \times 72.0 \text{ g mol}^{-1}$$

$$= 1.16 \text{ g} \quad \text{①}$$

**ii.** **Incomplete combustion** of pentane due to not adding sufficient or excess oxygen to the calorimeter. ①

**Question 6 (28 marks)**

b.  $n(\text{CH}_3\text{CH}_2\text{OH}) = 1.02 / 46.0$   
 $= 0.0222 \text{ mol}$

Energy released per mol =  $1.04 \text{ kJ} / 0.0222 \text{ mol}$   
 $= 46.9 \text{ kJ mol}^{-1}$

Since the reaction is exothermic  $\Delta H = -46.9 \text{ kJ mol}^{-1}$

① for correct numerical answer; ① for correct sign and units.

c.  $n(\text{CH}_2=\text{CH}_2)$  initially =  $44.6 \text{ g} / 28.0 \text{ g mol}^{-1}$   
 $= 1.593 \text{ mol}$

$n(\text{CH}_2=\text{CH}_2)$  reacted in getting to equilibrium =  $(5.00/100) \times 1.593$   
 $= 0.080 \text{ mol}$

$n(\text{CH}_2=\text{CH}_2)$  at equilibrium =  $1.593 - 0.080$   
 $= 1.513 \text{ mol}$  ①

$n(\text{H}_2\text{O})$  initially =  $21.6 \text{ g} / 18.0 \text{ g mol}^{-1}$   
 $= 1.20 \text{ mol}$

$n(\text{H}_2\text{O})$  reacted in getting to equilibrium =  $n(\text{CH}_2=\text{CH}_2)$  reacted in getting to equilibrium  
 $= 0.080 \text{ mol}$

$n(\text{H}_2\text{O})$  at equilibrium =  $1.20 - 0.080$   
 $= 1.12 \text{ mol}$  ①

$n(\text{CH}_3\text{CH}_2\text{OH})$  at equilibrium =  $n(\text{CH}_2\text{CH}_2)$  reacted in getting to equilibrium  
 $= 0.080 \text{ mol}$  ①

$K = [\text{CH}_3\text{CH}_2\text{OH}] / \{[\text{CH}_2=\text{CH}_2][\text{H}_2\text{O}]\}$   
 $= (0.080/2.0) / \{(1.513/2.0) \times (1.120/2.0)\}$   
 $= 0.094$  ① ( $\text{M}^{-1}$ )

- d. The investigation conditions use a higher temperature ( $300 \text{ }^\circ\text{C}$ ) and a lower pressure ( $4.75 \times 10^4 \text{ kPa}$ ) than the industrial production ( $275 \text{ }^\circ\text{C} / 5.05 \times 10^4$ ).

Since the forward reaction is exothermic, the **lower temperature will favour the forward** reaction, thus giving a **higher yield of ethanol** ①

The **lower pressure will favour the side with more particles**, i.e. the reactant side, thus giving a **lower yield of ethanol**. ①

However since there is **not enough information to determine relative extents of the two effects**, it is **not possible to say whether the yield increases or decreases, just that it might be different**. ①

- e. Higher concentrations allow for more effective collisions (those with energy greater than the activation energy) between reacting particles. **Initially the forward reaction is at its maximum rate** and the reverse reaction has yet to begin. **As the forward reaction proceeds, its rate decreases as the concentrations of ethene and water decrease**. ① **As the concentration of ethanol increases, the rate of the reverse reaction increases**. ① **Eventually the rates of the forward reaction and the reverse reaction are equal** and the system has reached equilibrium. ①

- f. i. Spectrum 1 – an **IR spectrum**.  
It shows a **broad absorption band in the range 2500-3300 cm<sup>-1</sup>**, characteristic of **O-H in carboxylic acids** ① and a **strong absorption in the range 1670-1750 cm<sup>-1</sup>**, characteristic of **C=O**. ① (*Table 7 in Data Book gives absorption band wave numbers*).  
The only carboxylic acid produced from ethanol is **ethanoic acid CH<sub>3</sub>COOH** ①
- Spectrum 2 – a **high resolution <sup>1</sup>H NMR spectrum**.  
It shows a quartet at **chemical shift 4.1 ppm** consistent with **RCOOCH<sub>2</sub>R**, i.e. an **ester**. ① The only ester than can be produced using ethanol as the only ‘starting’ organic compound is **ethyl ethanoate, CH<sub>3</sub>COOCH<sub>2</sub>CH<sub>3</sub>**. ① (*Table 5 in Data Book gives <sup>1</sup>H NMR chemical shifts*).  
The **structure of CH<sub>3</sub>COOCH<sub>2</sub>CH<sub>3</sub>** is consistent with the presence of a **singlet, quartet and triplet** in the high resolution <sup>1</sup>H NMR spectrum, **CH(singlet)<sub>3</sub>COOCH(quartet)<sub>2</sub>CH(triplet)<sub>3</sub>**. ①
- ii. **Dichromate ions, Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>(aq) / potassium dichromate, K<sub>2</sub>CrO<sub>7</sub>(aq)** ①  
**Sulfuric acid, H<sub>2</sub>SO<sub>4</sub>(l)** ①  
*Acidified Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>(aq) is used to oxidise ethanol to ethanoic acid.*  
*H<sub>2</sub>SO<sub>4</sub>(l) is used as a catalyst in the condensation reaction between CH<sub>3</sub>CH<sub>2</sub>OH(l) and CH<sub>3</sub>COOH(l) to produce CH<sub>3</sub>COOCH<sub>2</sub>CH<sub>3</sub>.*
- g. i. **C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>(aq) → 2CH<sub>3</sub>CH<sub>2</sub>OH(l) + 2CO<sub>2</sub>(g)** ①  
ii. Ethanol, CH<sub>3</sub>CH<sub>2</sub>OH, molecules contain a **polar hydroxyl group, -OH**, and a **non-polar ethyl group, -CH<sub>2</sub>CH<sub>3</sub>** ①  
The polar hydroxyl group allows them to form **hydrogen bonds with water molecules** and so dissolve in water. ①  
The non-polar ethyl group allows ethanol to dissolve in non-polar octane through **dispersion force attraction to the C<sub>8</sub>H<sub>18</sub> molecules**. ①
- iii. **CH<sub>3</sub>CH<sub>2</sub>OH(l) + 3O<sub>2</sub>(g) → 2CO<sub>2</sub>(g) + 3H<sub>2</sub>O(l)** ①  
*NB (aq) is not an acceptable state for ethanol in a combustion reaction.*
- h. i. Ethanol is oxidised at the **anode** which is **negative (-)** in fuel cell. ①  
ii. **CH<sub>3</sub>CH<sub>2</sub>OH(l) + 3H<sub>2</sub>O(l) → 2CO<sub>2</sub>(g) + 12H<sup>+</sup>(aq) + 12e<sup>-</sup>** ①  
*NB. Since the overall redox reaction for the fuel cell would be same as the combustion reaction, the fuel ethanol is oxidised to CO<sub>2</sub>.*

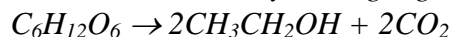
### Question 7 (8 marks)

- a.
1. When one metal is added to an aqueous solution of the cations of another metal, the **likelihood of reaction depends on the relative reducing strengths of the two metals.**
  2. When a **reaction does occur**, the **metal added is a stronger reductant than the metal associated with the cations in the aqueous solution used.**
  3. When a **reaction does not occur**, the **metal added is a weaker reductant than the metal associated with the cations in the aqueous solution used.**  
① for one of the above points 1, 2 or 3
  4. **Q(s) reacts with  $P^{2+}(aq)$ ,  $R^{2+}(aq)$  and  $S^{2+}(aq)$  hence it is the strongest reductant.** ①
  5. **R(s) does not react with any of  $P^{2+}(aq)$ ,  $Q^{2+}(aq)$  or  $S^{2+}(aq)$  hence it is the weakest reductant.** ①
  6. **S(s) reacts with  $P^{2+}(aq)$  and  $R^{2+}(aq)$  but not  $Q^{2+}(aq)$ , hence is a stronger reductant than P(s) and R(s) but a weaker reductant than Q(s).**
  7. **P(s) reacts with  $R^{2+}(aq)$  but not  $Q^{2+}(aq)$  or  $S^{2+}(aq)$ , hence it is a stronger reductant than R, but a weaker reductant than Q(s) and S(s).**
  8. **Order of increasing reducing strength is R, P, S, Q**  
①① for any *two* of points 6, 7 and 8.
- b. **Two – R and P – would have positive  $E^\circ$  values** ①  
Since **P does not react with 1 M HCl(aq)**, the reductant is **above  $2H^+(aq) + 2e^- \rightarrow H_2(g)$ ,  $E^\circ = 0.0 V$**  on the electrochemical series and has a **positive  $E^\circ$  value.** Since **R is a weaker reductant than P** it would also be not expected to react with 1 M HCl(aq) and **also have a positive  $E^\circ$  value.** ① OR  
Since **S reacts with 1 M HCl(aq)**, the reductant is **below  $2H^+(aq) + 2e^- \rightarrow H_2(g)$ ,  $E^\circ = 0.0 V$**  on the electrochemical series and has a **negative  $E^\circ$  value.** Since **Q is a stronger reductant than S** it would also be expected to react with 1 M HCl(aq) and also have a **negative  $E^\circ$  value.** ①  
In terms of the electrochemical series the reduction half-equations would be in the order  
 $R^{2+}(aq) + 2e^- \rightleftharpoons R(s)$   
 $P^{2+}(aq) + 2e^- \rightleftharpoons P(s)$   
 $2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$   
 $S^{2+}(aq) + 2e^- \rightleftharpoons S(s)$   
 $Q^{2+}(aq) + 2e^- \rightleftharpoons Q(s)$
- c. Because the conditions used,  $25^\circ C$ , 101.3 kPa and 1 M solutions, are those on which predictions based on the electrochemical series are most likely to occur, the most likely reason is the **rate of reaction between  $Cl_2(g)$  and  $Fe^{2+}(aq)$  was very slow.** ①  
*Alternatively:*  $Cl_2$  may preferentially react with  $SCN^-(aq)$ .

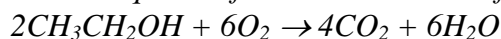
**Question 8 (11 marks)**

- a. i. Bioethanol is produced by the fermentation of glucose obtained from sugar cane or other crops. The combined **amount CO<sub>2</sub> released in the combustion of ethanol, and fermentation of glucose, equates to the amount of CO<sub>2</sub> consumed in photosynthesis during the plant's growth.** ①

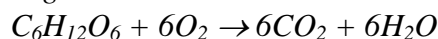
*This can be shown by adding together the equation for fermentation*



*and the equation for the combustion of ethanol doubled*

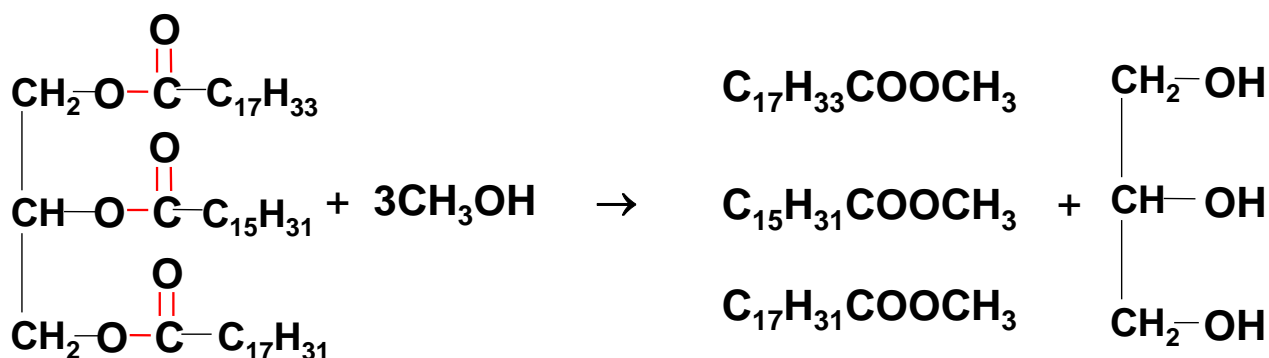


*to give*



*which is the reverse of the equation for photosynthesis.*

- ii. Both land and water are required for the growth of crops for the production of biofuels. **Lack of water during drought and the need to use fertile land for food crops reduces the likelihood of sustainable biofuel production.** ①
- b. In transesterification 1 mol of the triglyceride reacts with 3 mol of the alcohol (methanol) to produce 3 mol of biodiesel (methyl esters) and 1 mol of glycerol.



- i. **Methanol, CH<sub>3</sub>OH** ①

- ii. **Glycerol, C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>** ①

- iii. Three different biodiesels were produced. These can be identified from hydrocarbon tails on the ester groups in the triglyceride, using Table 8 in the Data Book, because they are the same as the hydrocarbon tails on the associated fatty acids. The hydrocarbon tail on a saturated fatty acid in C<sub>n</sub>H<sub>2n+1</sub>, as in C<sub>17</sub>H<sub>35</sub> and for each C=C double bond on a saturated fatty acid 2 less H atoms will be present, e.g. for one C=C double bond, a monounsaturated compound, C<sub>n</sub>H<sub>2n-1</sub>, as in C<sub>17</sub>H<sub>33</sub> ① ①

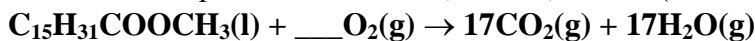
So the monounsaturated biodiesel product is C<sub>17</sub>H<sub>33</sub>COOCH<sub>3</sub>.

- c. Since palmitic acid is  $C_{15}H_{31}COOH$  (Table 9 Data Book), the formula for methyl palmitate is  $C_{15}H_{31}COOCH_3$

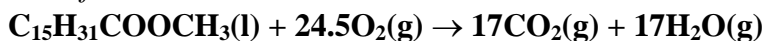
$$n(C_{15}H_{31}COOCH_3) = 0.631 \text{ g} / 270.0 \text{ g mol}^{-1} \\ = 2.34 \times 10^{-3} \text{ mol}$$

$$\text{Energy released per mol } C_{15}H_{31}COOCH_3 = 23.5 \text{ kJ} / 2.34 \times 10^{-3} \\ = 1.01 \times 10^4 \text{ kJ mol}^{-1} \text{ ①}$$

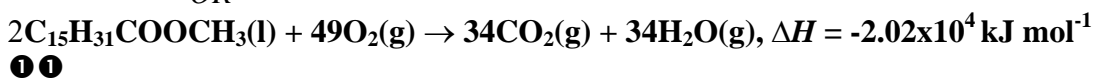
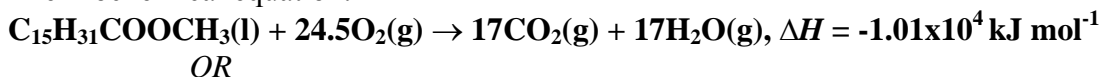
Combustion equation – balance C, then H, then O (discounting for O in the fuel)



There are 51 'O' on the right, on the left there are 2 'O' in the fuel so 49 'O' must come from  $O_2$



Thermochemical equation:



- d. i. Nuclear fuels have **high energy densities**, i.e. significantly more energy per gram of fuel than other fuel sources. ①
- ii. **Radioactive waste** has long half-lives and needs to be **stored in secure leak-proof containers** for thousands of years. ①

### End of Suggested Answers