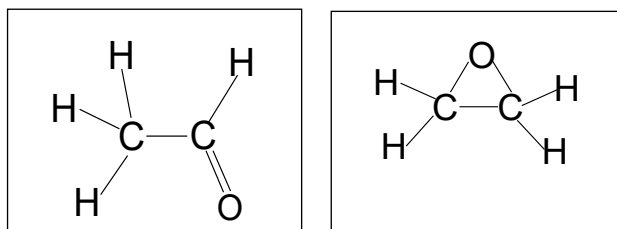




- Q3. D** Using IR absorption data from *Table 14 of the VCE Chemistry Data Book*:  
 1680-1740  $\text{cm}^{-1}$  : C=O acids; present in all four acids.  
 1720-1840  $\text{cm}^{-1}$  : C=O esters; not present in any of the alcohols (other than as part of carboxyl group).  
 2500-3500  $\text{cm}^{-1}$  : O-H acids; presents in all four acids.  
 3200-3600  $\text{cm}^{-1}$  : O-H alcohols; present in three acids but **not** in ethanoic acid.
- Q4. A** During electrolysis, electrons are transferred from the positive electrode to the negative electrode by the power supply.  
 The colour of aqueous solution of copper(II) sulfate is due to the presence of  $\text{Cu}^{2+}(\text{aq})$  ions.  
 The metal produced during the electrolysis of  $\text{CuSO}_4(\text{aq})$  is  $\text{Cu}(\text{s})$  due to reduction at the cathode.  
 (-)  $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$   
 Since the **solution colour remains constant,  $\text{Cu}^{2+}(\text{aq})$  ions must be produced at the anode.**  
 (+)  $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$   
 Since Cu must be oxidised, **the anode – (+) electrode - MUST be made of copper.**  
 However, since the cathode, the (-) electrode, is the site of reduction, it could be either copper or iron, or even other conductors such as carbon (graphite), since the supply of electrons through the circuit prevents any oxidation.
- Q5. D** Since ethanal,  $\text{CH}_3\text{CHO}$ , and ethylene oxide,  $\text{CH}_2\text{O}\cdot\text{CH}_2$ , are structural isomers, the reaction for both processes may be represented by the overall equation  
 $2\text{C}_2\text{H}_4(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{C}_2\text{H}_4\text{O}(\text{g})$ .  
 The molecular structures of the two products are shown below:



The mole ratio of reactants suggests that relative amounts of reactants is not a key factor and temperature and pressure conditions are always significant in industrial processes.

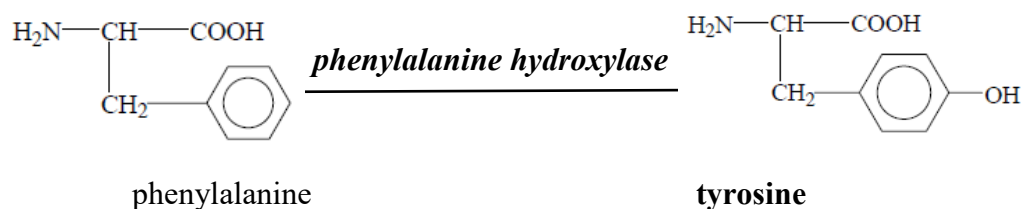
However, the **decisive factor in determining which compound produced** is most probably the **catalyst** used, since **interactions between the reactants and the catalyst surface control the bond breaking and bond making**, which determine the structure of the product.

The catalysts used in the industrial productions are Ag for ethylene oxide and  $\text{PdCl}_2$ , palladium(II) chloride, for ethanal.

- Q6. C** Since  $\text{Fe}^{2+}$  is the reductant, it should be oxidised to  $\text{Fe}^{3+}$   
 $\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{e}^-$   
 $\text{H}_2\text{O}_2$  is reduced, so the  $\text{H}_2\text{O}_2$  molecules must accept the electron released by each  $\text{Fe}^{2+}$  ion in the process of producing a hydroxyl radical,  $\bullet\text{OH}$ , and one other product, according to  
 $\text{H}_2\text{O}_2(\text{aq}) + \text{e}^- \rightarrow \bullet\text{OH} + \text{X}$   
 N.B. the radical  $\bullet\text{OH}$  has the same number of protons and electrons but has one unpaired valence electron.  
 The product X must have O, H and a negative charge, i.e.  $\text{OH}^-(\text{aq})$ .  
 Overall equation  $\text{Fe}^{2+}(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \bullet\text{OH} + \text{OH}^-(\text{aq})$ .
- Q7. C** Using data from *Table 13 of the VCE Chemistry Databook*:  
 Total energy in a 22 g serving which is available from proteins, fats, and carbohydrates  
 $= 5.2 \text{ g} \times 17 \text{ kJ g}^{-1} + 11.3 \text{ g} \times 37 \text{ kJ g}^{-1} + 3.0 \text{ g} \times 16 \text{ kJ g}^{-1}$   
 $= 88.4 + 418.1 + 48.0 \text{ kJ}$   
 $= 554.5 \text{ kJ}$   
 Therefore energy required from other nutrients  $= 569 - 554.5 \text{ kJ}$   
 $= 14.5 \text{ kJ in 22 g sample}$   
 Energy from other nutrients in 500 g jar  $= (14.5 / 22) \times 500$   
 $= \mathbf{330 \text{ kJ}}$  in 500 g container
- Q8. D**  $\alpha$ -eleostearic, stearic and linoleic acid molecules each contain 18 C atoms.  
 Iodine,  $\text{I}_2$ , adds across  $\text{C}=\text{C}$  double bonds in the  $\alpha$ - $\alpha$ -eleostearic acid molecules.  
 The ratio of  $n(\text{I}_2) / n(\alpha\text{-}\alpha\text{-eleostearic acid}) \rightarrow$  number of  $\text{C}=\text{C}$  double bonds in each molecule.  
 $n(\text{I}_2) = 273.9 / 253.8 = 1.08 \text{ mol}$   
 $n(\alpha\text{-}\alpha\text{-eleostearic acid}) = 1.08 / n(\text{C}=\text{C})$   
 If 1  $\text{C}=\text{C}$ ,  $n(\alpha\text{-}\alpha\text{-eleostearic acid}) = 1.08 \text{ mol}$ ;  $M(\alpha\text{-}\alpha\text{-eleostearic acid}) = 100 / 1.08 = 92.6 \text{ g mol}^{-1}$   
 If 2  $\text{C}=\text{C}$ ,  $n(\alpha\text{-}\alpha\text{-eleostearic acid}) = 0.54 \text{ mol}$ ;  $M(\alpha\text{-}\alpha\text{-eleostearic acid}) = 100 / 0.54 = 181 \text{ g mol}^{-1}$   
 If 3  $\text{C}=\text{C}$ ,  $n(\alpha\text{-}\alpha\text{-eleostearic acid}) = 0.36 \text{ mol}$ ;  $M(\alpha\text{-}\alpha\text{-eleostearic acid}) = 100 / 0.36 = 278 \text{ g mol}^{-1}$   
 Since  $\alpha$ -eleostearic acid molecules contain 18 C atoms, 2 O atoms and a 'maximum' of 36 H atoms  
 $M(\alpha\text{-}\alpha\text{-eleostearic acid})$  must be  $278 \text{ g mol}^{-1}$ .  
 $M_r(\alpha\text{-}\alpha\text{-eleostearic acid}) = 278$  and the molecular formula may be represented by  $\text{C}_{18}\text{H}_x\text{O}_2$   
 where 'x' is the number of H atoms in each molecule.  
 Hence  $18 \times 12.0 + 'x' \times 1 + 2 \times 16 = 278$   
 $'x' = 278 - 248 = 30$ , molecular formula is  $\text{C}_{18}\text{H}_{30}\text{O}_2$ .  
 $\alpha$ -eleostearic molecules contain 3  $\text{C}=\text{C}$  double bonds but a **total of 4 double bonds** (including  $\text{C}=\text{O}$ ).

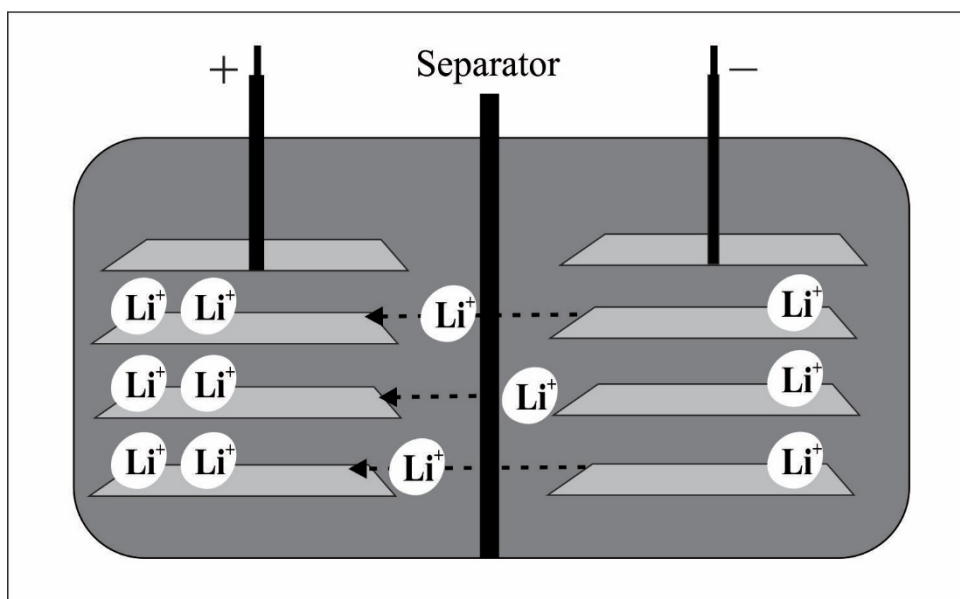
- Q9. B**  $2\text{NaN}_3 \rightarrow 2\text{Na} + 3\text{N}_2$   
**Redox.**  $\text{Na}^+$  is reduced since oxidation number of Na decreases from +1 to 0; N must be oxidised.  
 $10\text{Na} + 2\text{KNO}_3 \rightarrow \text{K}_2\text{O} + 5\text{Na}_2\text{O} + \text{N}_2$   
**Redox.** Na is oxidised since oxidation number increases from +1 to 0; N is reduced +5 to 0.  
 $\text{Na}_2\text{O} + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3$   
**No change in oxidation numbers.**  
 $\text{K}_2\text{O} + \text{Na}_2\text{O} + \text{SiO}_2 \rightarrow \text{K}_2\text{Na}_2\text{SiO}_4$   
**No change in oxidation numbers.**

- Q10. D** *Table 17 of the VCE Chemistry Data Book* indicates that the side groups for the structures for cysteine, serine and threonine show no clear link with the side group on phenylalanine.  
 Tyrosine's structure reflects the gain of a hydroxyl group by phenylalanine molecules:

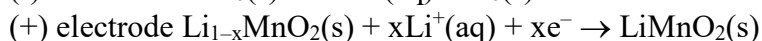
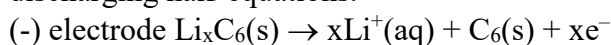


- Q11. A** Taurine –  $\text{C}_2\text{H}_7\text{NSO}_3$  – molar mass  $125.1 \text{ g mol}^{-1}$   
 $m(\text{taurine}) = 6.39 \times 10^{-3} \text{ mol} \times 125.1 \text{ g mol}^{-1}$   
 $= 0.799 \text{ g}$   
 $m(\text{caffeine}) \text{ in drink} = 0.799 / 12.5$   
 $= 0.0640 \text{ g}$   
 $m(\text{caffeine}) = (4.65 / 100) \times m(\text{guarana})$   
 $= 0.0465 \times m(\text{guarana})$   
 $m(\text{guarana}) = m(\text{caffeine}) / 0.0465$   
 $= 0.0640 / 0.0465$   
 $= \mathbf{1.37 \text{ g}}$

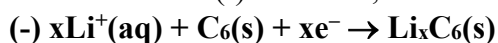
- Q12. A** Consider the alternatives.
- A. Energy greater than the activation energy is not, in isolation, a guarantee that reaction will occur. The orientations with which particles collide must be those that facilitate bond breaking.**
- B.** Higher concentration means there are more particles present in a fixed volume. This increases the frequency of collisions and the frequency of successful collisions leading to increased rate of reaction. However, the ‘energy’ of the reactant particles is not affected, so the proportion of successful collisions does not change.
- C.** Higher temperature means the kinetic energy of the reactant particles increases so the frequency of collisions and frequency of successful collisions increase. Also, because the energy of the particles is higher, a greater proportion of the collisions are successful.
- D.** Larger surface area of the reactants increases the number of particles available to collide. This increases the frequency of collisions and successful collisions leading to increased rate of reaction. However, the ‘energy’ of the reactant particles is not affected, so the proportion of successful collisions does not change. So the mechanism of the impacts of higher surface area and higher concentrations on reaction rate are very similar.
- Q13. B** In all cells, cations move towards the cathode. When the cell is discharging, electrons move from the anode (-) to the cathode (+). On the discharge cell representation, the left-hand electrode is the cathode and positive.



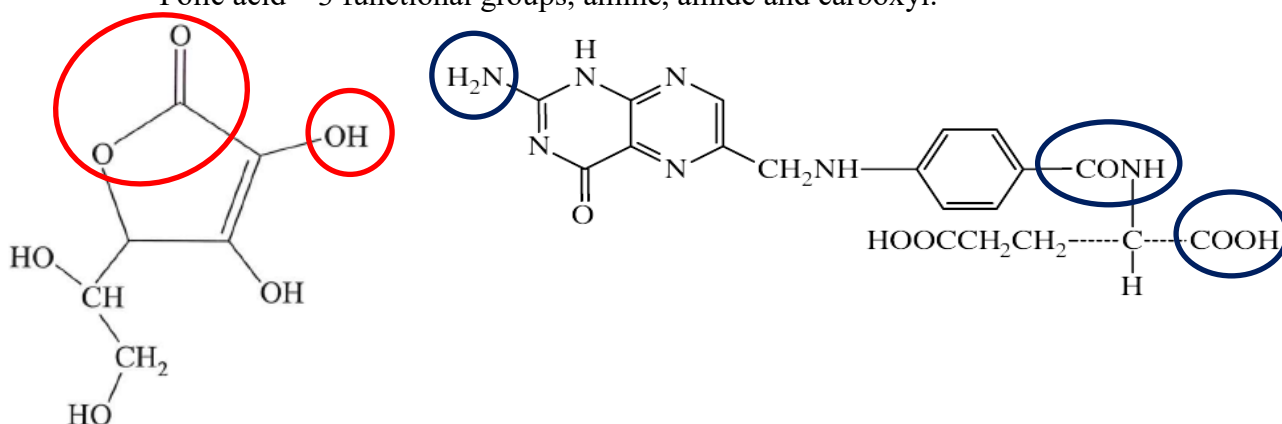
Since the discharge reaction is  $\text{Li}_x\text{C}_6(\text{s}) + \text{Li}_{1-x}\text{MnO}_2(\text{s}) \rightarrow \text{C}_6(\text{s}) + \text{LiMnO}_2(\text{s})$ , the discharging half-equations involve the conversion of  $\text{Li}_x\text{C}_6$  to  $\text{C}_6$  and the conversion of  $\text{Li}_{1-x}\text{MnO}_2$  to  $\text{LiMnO}_2$ . This suggests that  $\text{Li}^+$  is released at one electrode and  $\text{Li}^+$  is gained at the other electrode, which is consistent with the discharging half-equations.



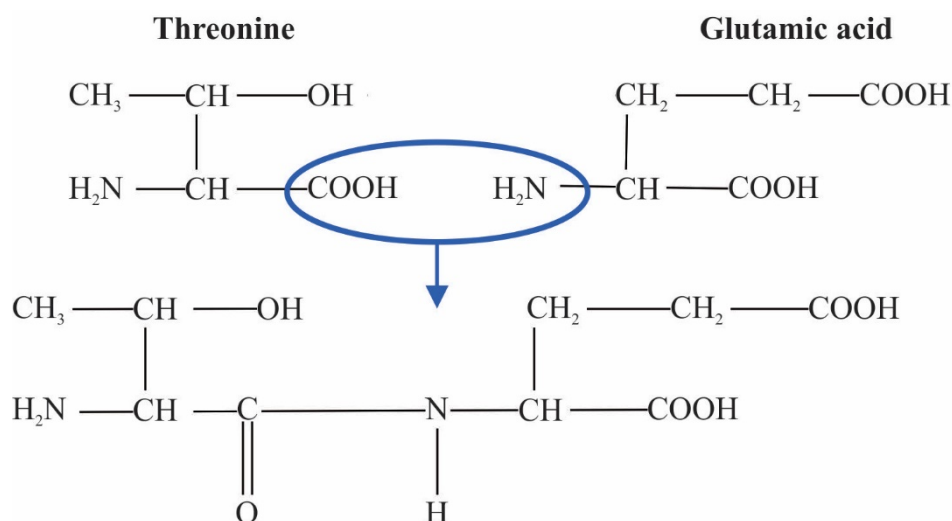
Hence during recharging, when electrons are forced to move from the (+) electrode to the (-) electrode, the half-equations would be



- Q14. C A. (Refer to Table 10: VCE Chemistry Data Book) Vitamin C – 2 functional groups, ester and hydroxyl.  
Folic acid – 3 functional groups, amine, amide and carboxyl.



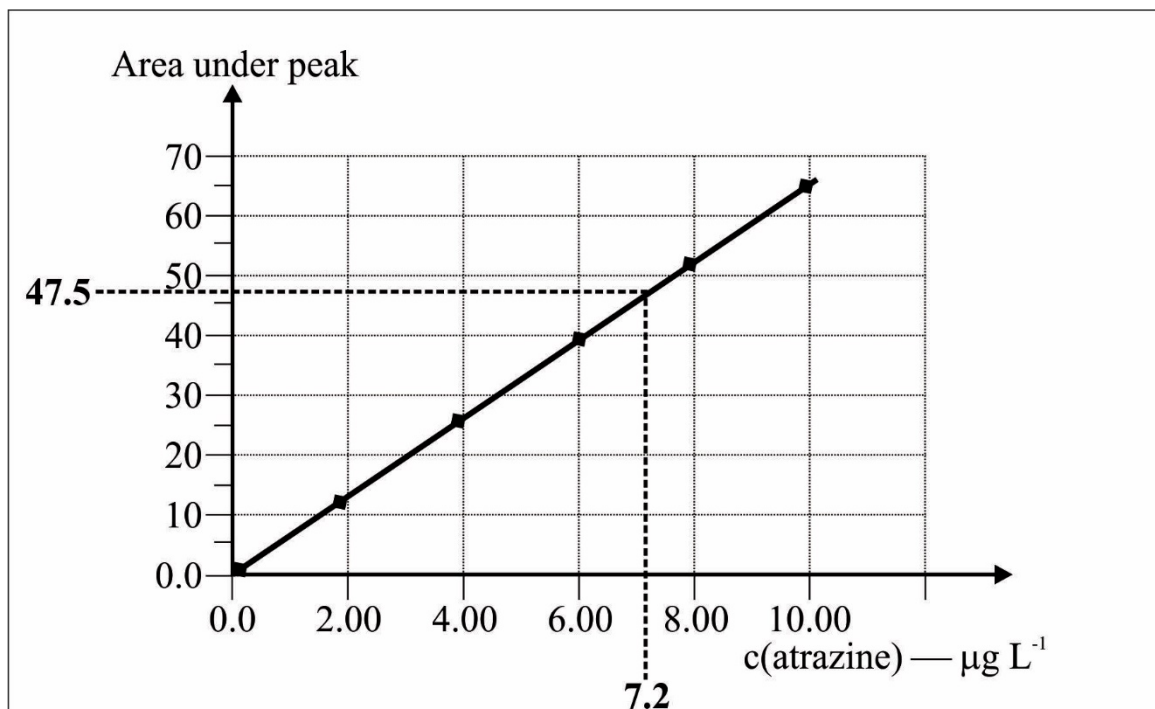
- B. Vitamin D<sub>3</sub> (refer to Table 10: VCE Chemistry Data Book) molecules have a lone -OH group but it is mainly a non-polar hydrocarbon with minimal attraction to water. Folic acid molecules have multiple polar functional groups which can form hydrogen bonds with water and so are soluble.  
C. (Refer to Table 17 VCE Chemistry Data Book).



The dipeptide and folic acid both have six carbon atoms in their molecules.

- D. The absorption band (refer to Table 14 VCE Chemistry Data Book)  $3200\text{-}3600\text{ cm}^{-1}$  is for -OH alcohol which is not present in folic acid molecules.

Q15. D



$$\begin{aligned}c(\text{atrazine}) \text{ in diluted sample of dam water} &= 7.2 \mu\text{g L}^{-1} \\ &= 0.0072 \text{ mg L}^{-1}\end{aligned}$$

Dam water was diluted by a factor of 50 for the analysis

$$\begin{aligned}c(\text{atrazine}) \text{ in dam water} &= 50 \times 0.0072 \text{ mg L}^{-1} \\ &= 0.36 \text{ mg L}^{-1}\end{aligned}$$

$$\begin{aligned}\text{Ratio } c(\text{atrazine}) \text{ in dam water} / \text{WHO drinking water limit} &= 0.36 \text{ mg L}^{-1} / 0.002 \text{ mg L}^{-1} \\ &= 180\end{aligned}$$

Hence the  $c(\text{atrazine})$  in dam water exceeds the WHO limit by a factor of **180**.

Q16. A The data show that

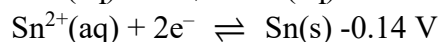
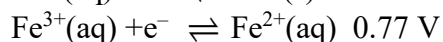
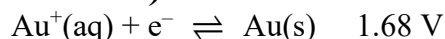
a) At constant temperature of  $400^{\circ}\text{C}$ , the yield of X increases as the pressure increases, as increasing the pressure on an equilibrium system forces the system to compensate and strive to decrease the pressure by favouring the side with fewer particles.

This indicates there are more particles on the reactant side than the product side.

b) At constant pressure of  $2.00 \times 10^5 \text{ kPa}$ , the yield of X decreases as the temperature increases. This indicates the reverse reaction is favoured at higher temperatures and is endothermic.

Hence the production of X is exothermic, i.e.  $\Delta H < 0$ .

**Q17. D** The relevant half-equations from the electrochemical series (*Table 2 VCE Chemistry Data Book*).

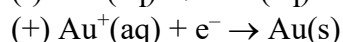
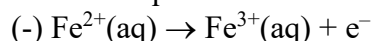


indicate that there are two cells that generate 0.91 V under standard conditions and involve  $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$ .

The fact that  $\text{K}^+(\text{aq})$  move towards Y indicate that Y is the cathode, the site of reduction.

In a galvanic cell, electrons flow from the (-) electrode to the (+) electrode, and the stronger oxidant is reduced at the (+) electrode, hence the half-cell  $\text{Y}^{n+}/\text{Y}$  must be  $\text{Au}^+/\text{Au}$ .

The half-equations for the reactions at the two electrodes are



The **electrode in the  $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$  half-cell must be inert**, i.e. C, It cannot be Fe(s) because Fe(s) is a stronger reductant than  $\text{Fe}^{2+}(\text{aq})$  and also would react with  $\text{Fe}^{3+}(\text{aq})$  in the half-cell.

The **electrode in the  $\text{Au}^+(\text{aq})/\text{Au}(\text{s})$  half-cell could be Au or C**, it is an electron collector and does not react in this cell.

**Q18. D**  $\text{RCOOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{RCOONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

$$\begin{aligned} n(\text{NaOH}) &= 0.120 \text{ mol L}^{-1} \times 17.2 \times 10^{-3} \text{ L} \\ &= 2.06 \times 10^{-3} \text{ mol} \end{aligned}$$

$$n(\text{RCOOH}) = 2.06 \times 10^{-3} \text{ mol}$$

Since  $n = m / M$  then  $M = m / n$

$$\begin{aligned} M(\text{RCOOH}) &= 0.182 \text{ g} / 2.06 \times 10^{-3} \text{ mol} \\ &= 88.2 \text{ g mol}^{-1} \end{aligned}$$

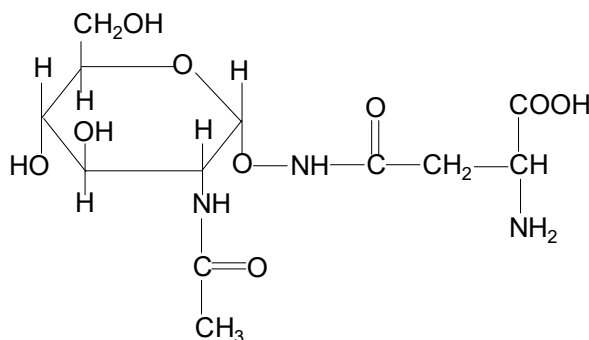
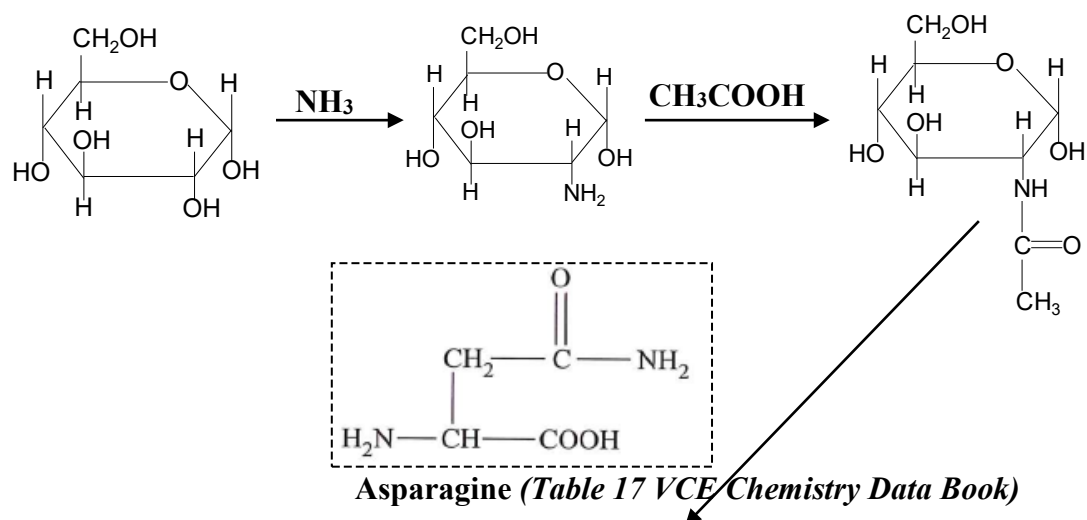
$$M(\text{C}_3\text{H}_7\text{COOH}) = 88.0 \text{ g mol}^{-1}$$

Carboxylic acid has molecules with 4 C atoms

Either butanoic acid  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  or **methylpropanoic acid**  $(\text{CH}_3)_2\text{CHCOOH}$ .



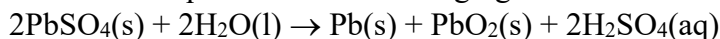
Q19. A



Q20. B Consider the alternatives

- A. Accurate: because since the *cetane number* measures how quickly a fuel starts to burn under diesel engine conditions, it reflects **how easily the fuel burns** and **vegetable sourced biodiesels have lower cetane numbers**.
- B. **Inaccurate:** the intermolecular bonds are weaker in the vegetable oil because the **molecules are generally unsaturated, and the kinks caused by the presence of C=C bonds impact in intermolecular attraction**.
- C. Accurate:  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_3)\text{CH}_2\text{NO}_3 \rightarrow \text{C}_8\text{H}_{17}\text{NO}_3$
- D. Accurate: the C=C double bonds in the biodiesel molecules are harder to break than the C-C bonds and vegetable oil sourced biodiesels are more unsaturated than animal fat sourced biodiesels.

Q21. B The overall equation for the recharging of a cell in the lead-acid battery is



Since recharging is electrolytic, electrons are transferred from the (+) electrode to the (-) electrode as electrical energy is converted to chemical energy.

(+) electrode, oxidation of  $\text{PbSO}_4$  to  $\text{PbO}_2$ , **oxidation number of Pb increases from +2 to +4**.

(-) electrode, reduction of  $\text{PbSO}_4$  to  $\text{Pb}$ , oxidation number of Pb decreases from +2 to 0.

So, the masses of both electrodes decrease.

Since  $\text{H}^+(\text{aq})$  ions (in  $\text{H}_2\text{SO}_4(\text{aq})$ ) are produced, the pH of the cell decreases.

Q22. C Calculating the heat of combustion from the information supplied

Mass of ethanol	Energy released	Heat of combustion
0.447 g	10.6 kJ	23.7 kJ g <sup>-1</sup>
1.034 g	24.5 kJ	23.7 kJ g <sup>-1</sup>
0.795 g	18.8 kJ	23.6 kJ g <sup>-1</sup>

Since essentially the same heat of combustion was obtained each time the experimental method was used, it was **reliable**.

According to *Table 11 in the VCE Chemistry Data Book*, the **heat of combustion of ethanol is 29.6 kJ g<sup>-1</sup>**. Hence the experimentally determined value was **not accurate**.

Q23. B Energy used by electrical vehicle = 400 km / 8.9 km kWh<sup>-1</sup>  
= 44.9 kWh  
= 44.9 × 3.60 MJ  
= 44.9 × 3.60 × 1000 kJ  
= 1.62 × 10<sup>5</sup> kJ

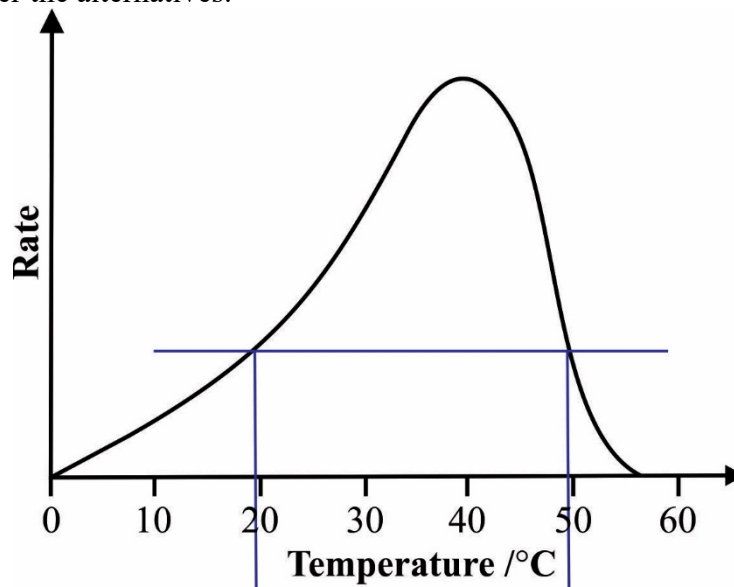
Since the petrol car is only 25 per cent efficient, 1.62 × 10<sup>4</sup> kJ is 25 per cent of energy content of petrol used.

Energy content of petrol used = 1.62 × 10<sup>4</sup> / 0.25  
= 6.47 × 10<sup>7</sup> kJ

$m(\text{octane})$  required = 6.47 × 10<sup>5</sup> kJ / 47.9 kJ g<sup>-1</sup>  
= 1.35 × 10<sup>4</sup> g

$V(\text{petrol}) = m / d = 1.35 \times 10^4 \text{ g} / 703 \text{ g L}^{-1}$   
= **19.2 L**

Q24. B Consider the alternatives.

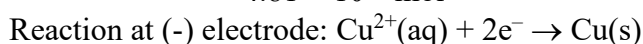


- A. Valid: the diagram shows that the rate of reaction at 50°C is approximately the same as the rate of reaction at 20°C.
- B. **Invalid:** colliding particles have **less energy** at 20°C than at 50°C because kinetic energy is proportional to temperature.
- C. Valid: the decrease in reaction rate after 40°C is due to a major enzyme structural change: the enzyme tertiary structure changes as it is denatured, and the active site is no longer available.
- D. Valid: the increase in rate up to 40°C is due to the increase in kinetic energy and so the reactant particles get to the active site faster as the temperature increases.

Q25. C Faraday's constant – the charge on 1 mol of electrons would be determined by

$$Q = It = 1.62 \times 581 = 941 \text{ C}$$

$$n(\text{Cu}) = m / M = 0.306 / 63.5 = 4.81 \times 10^{-3} \text{ mol}$$



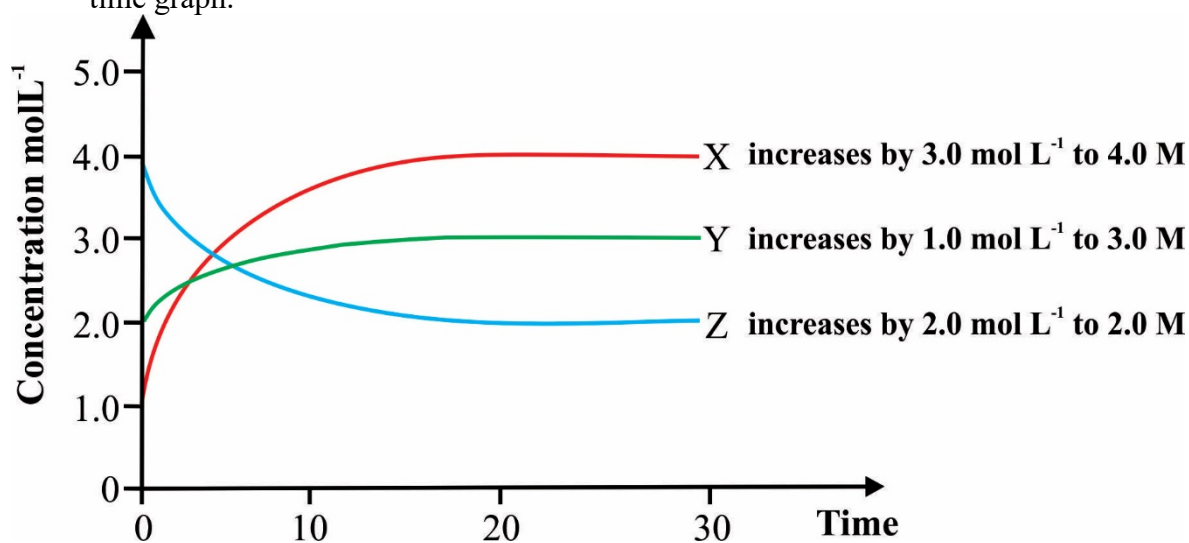
$$n(\text{e}^-) = 2 \times n(\text{Cu}) = 2 \times 4.81 \times 10^{-3} = 9.62 \times 10^{-3}$$

$$\text{Charge on 1 mol e}^- = 941 \text{ C} / 9.62 \times 10^{-3} \text{ mol} = \mathbf{97800 \text{ C mol}^{-1}}$$

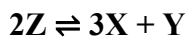
This is **higher** than the true value of 96500 C mol<sup>-1</sup> (*Table 4: VCE Chemistry Data Book*).

- A. Mass of Cu higher than the true value leads to higher  $n(\text{e}^-)$  and smaller Faraday's constant value.
- B. Lower than true current value gives a smaller value of  $Q$  and a smaller Faraday's constant.
- C. **Higher** than true **time** value gives a **larger** value of  $Q$  and a **larger Faraday's constant**.
- D. If  $n(\text{e}^-)$  is assumed to be the same as  $n(\text{Cu})$ , the Faraday's constant value would be doubled.

- Q26. D** The equilibrium equation can be deduced from the information on the concentration-time graph.



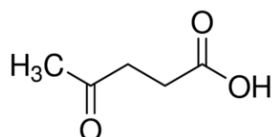
According to the changes in concentration in getting to equilibrium, the equation for the reaction described by the concentration changes is



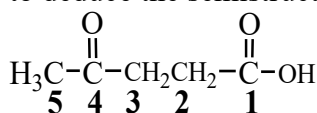
**Equilibrium concentrations** are:  $[X] = 4.0 \text{ M}$ ,  $[Y] = 3.0 \text{ M}$ ,  $[Z] = 2.0 \text{ M}$

$$\begin{aligned} K &= \frac{[X]^3[Y]}{[Z]^2} \\ &= \frac{4.0^3 \times 3.0}{2.0^2} \\ &= \frac{192}{4.0} \\ &= \mathbf{48 \text{ M}^{+2}} \end{aligned}$$

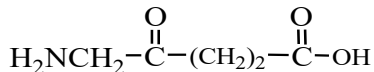
- Q27. C** Use the skeletal structure of levulinic acid



to deduce the semistructural formula and number the C atoms

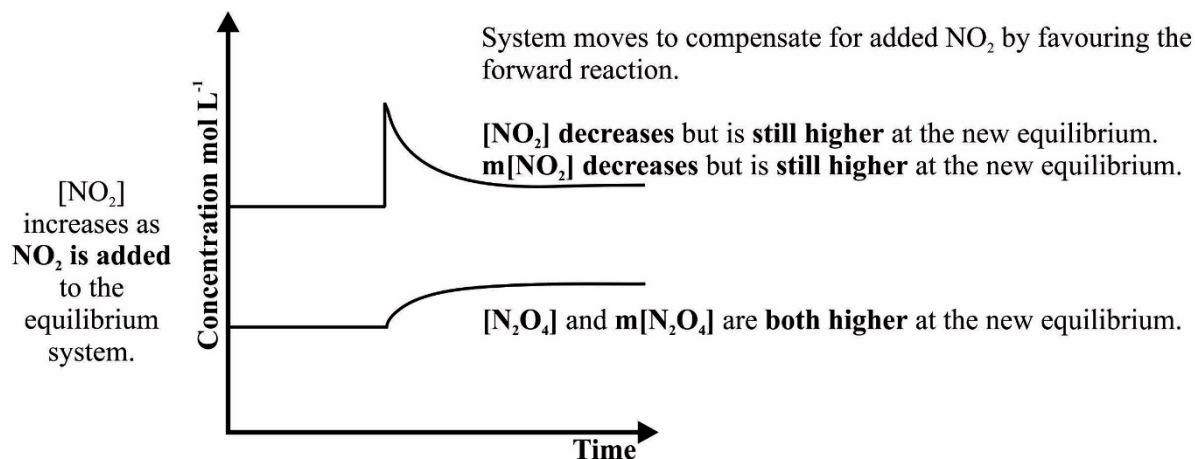
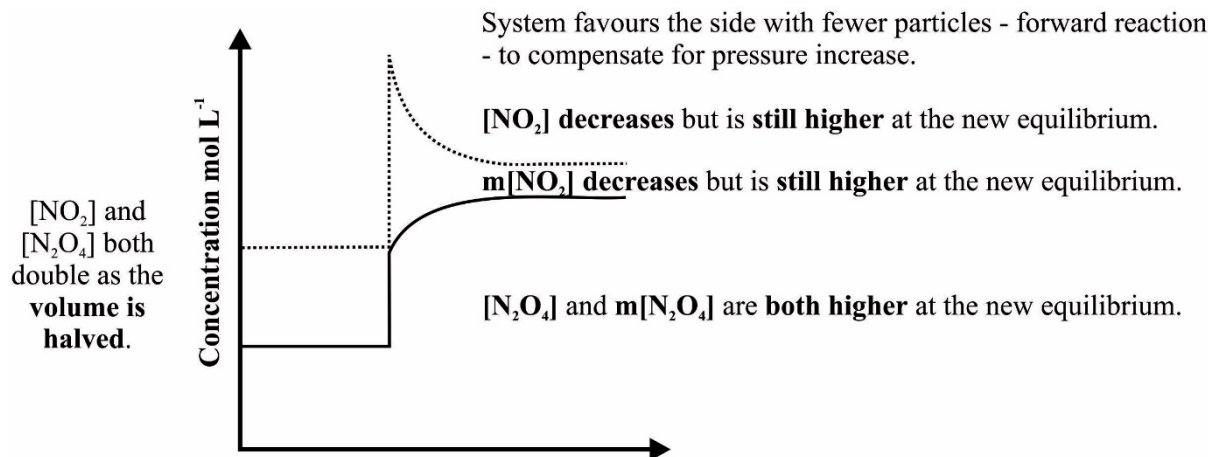


Hence the semi-structural formula for 5-aminolevulinic acid is



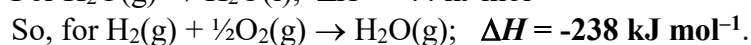
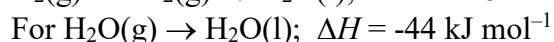
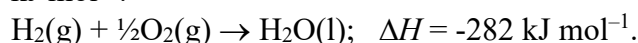
- Q28. C** For both imposed changes, the adjustment back to equilibrium after the imposed change shows the concentration of the species associated with the top graph changing twice as much as the concentration species associated with the bottom graph.

In both cases this is **consistent with the top graph representing  $\text{NO}_2$** .

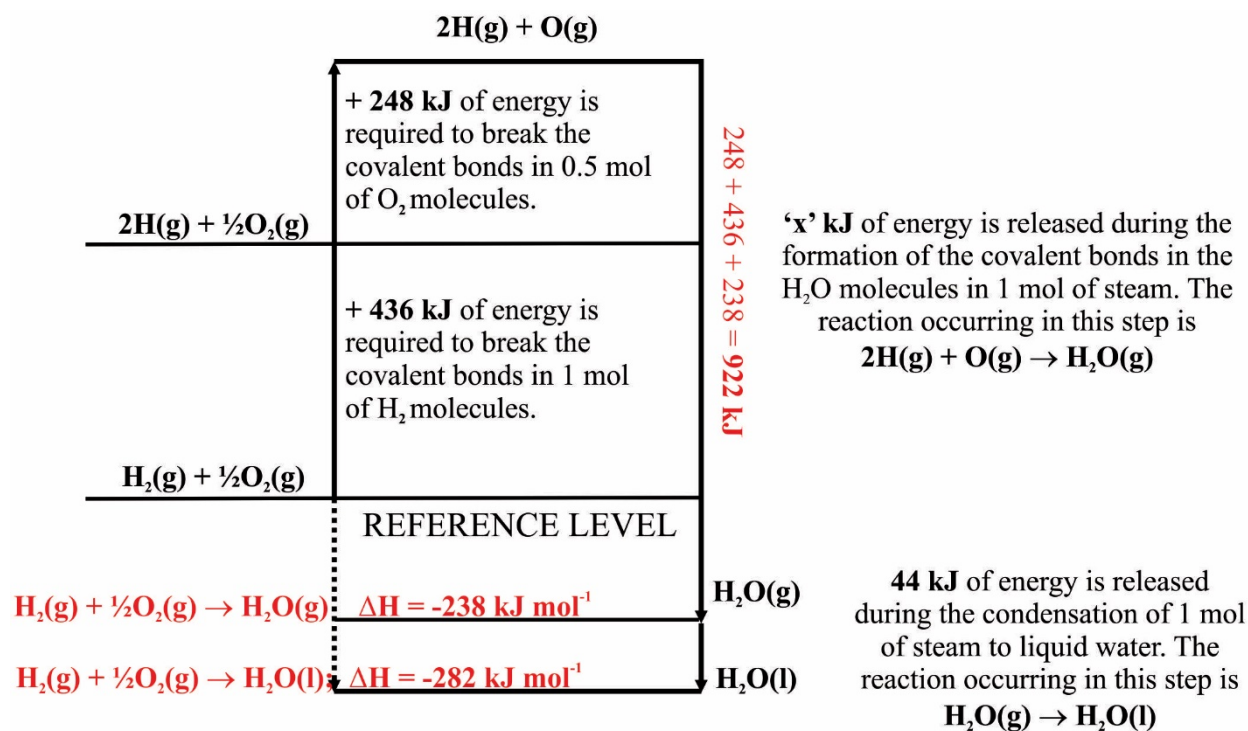


As a result of both imposed changes, the forward reaction was favoured so the **rate of the forward reaction** had to be **greater than the rate of the reverse reaction** as the systems returned to equilibrium.

- Q29. C** According to *Table 11 in the Data Book*, the heat of combustion of  $\text{H}_2$  at SLC is  $282 \text{ kJ mol}^{-1}$ .



The total energy released during the formation of bonds in 1 mol  $\text{H}_2\text{O}$  molecules is  $248 + 436 + 238 = 922 \text{ kJ}$



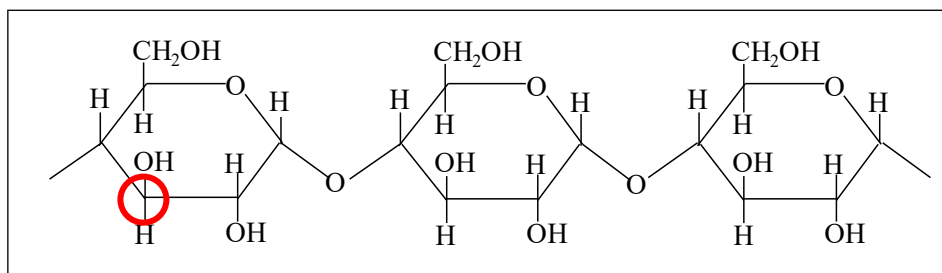
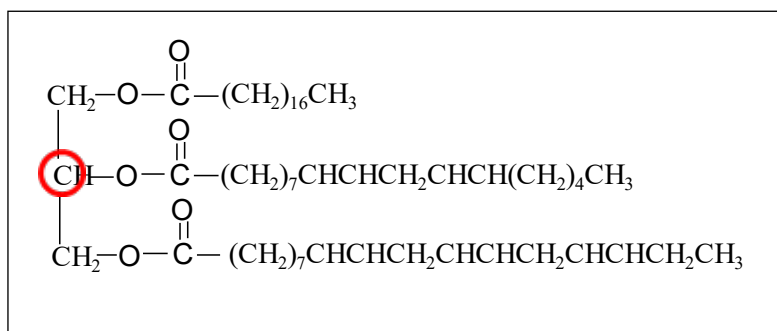
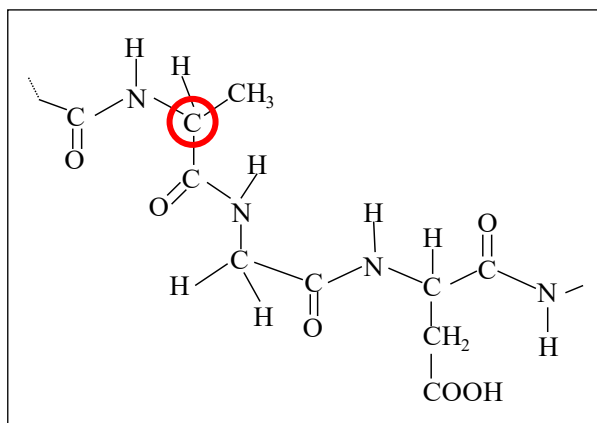
- Q30. A** Grass, a major component of a cow’s diet is difficult to digest. Ruminant animals such as cows have a rumen, or first (of four) stomachs which contains microbes called methanogens which produce methane in a fermentation of the carbohydrates in the diet.

## SECTION B – Short Answer (Answers)

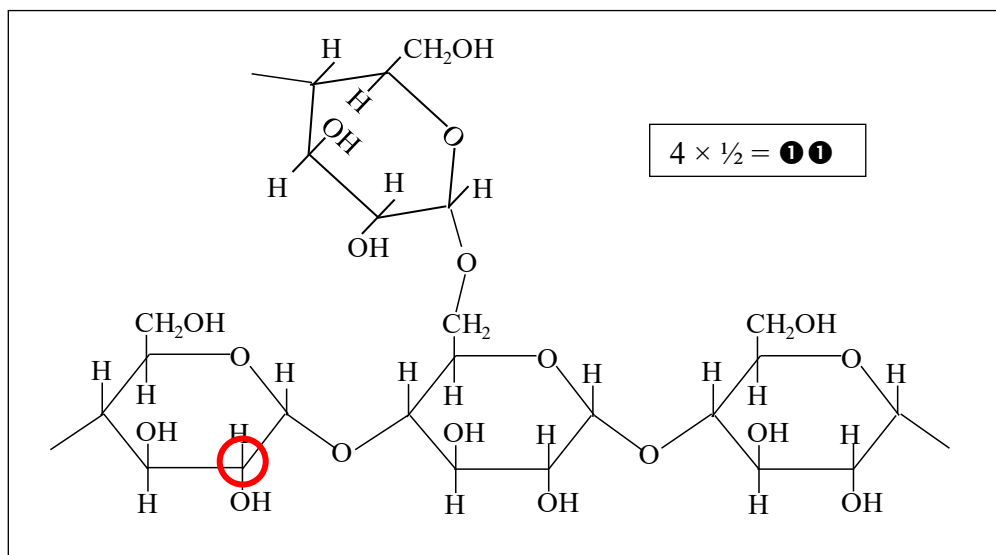
(95 marks)

Question 1 (15 marks)

a.



As long as the **carbon is bonded to four different atoms / groups of atoms** it is classified as **chiral!**



The peptide has two chiral carbons; the triglyceride has one chiral carbon; the polysaccharides have multiple chiral carbons.

- b. **Structure 1** represents a **section of a protein** formed from amino acids; **enzymes** which act as biological catalysts are **proteins**. ① All amino acids, except glycine, have **chiral carbons**.

Compounds with **chiral centres** (chiral carbons) have **optical isomers** which are molecules with same atoms and bonds but different spatial arrangements of the atoms.

Hence, they have **non-superimposable mirror images** called **enantiomers**. ①

**One enantiomer of an enzyme that acts as a catalyst allows contact between the active site and the substrate**, sometimes with the support of a **coenzyme**, but the **other enantiomer will not show catalytic action due to the different spatial arrangement of its atoms**. ①

- c. i. **Figure 16** shows a fat which will produce four different compounds which may be identified using **Tables 9 and 10 in the VCE Chemistry Data Book**.

**Glycerol** –  $\text{CH}_2\text{OHCHOHCH}_2\text{OH}$

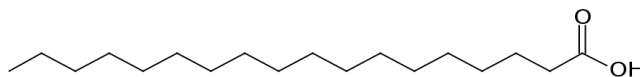
**Stearic acid** –  $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$

**Linoleic acid** –  $\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$

**Linolenic acid** –  $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2(\text{CH}_2)_7\text{COOH}$   $4 \times \frac{1}{2} = \text{①①}$

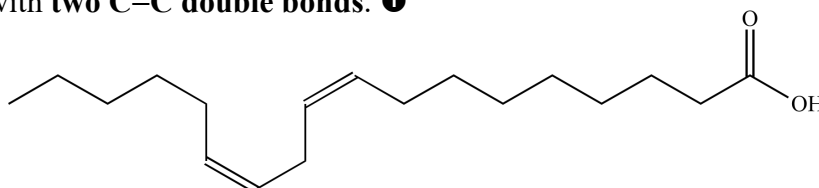
- ii. All three contain the carboxyl  $-\text{COOH}$  functional group and are **fatty acids**. ①

- iii. Stearic acid,  $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$ , is a **saturated fatty acid** because all **C-C bonds are single bonds**. ①

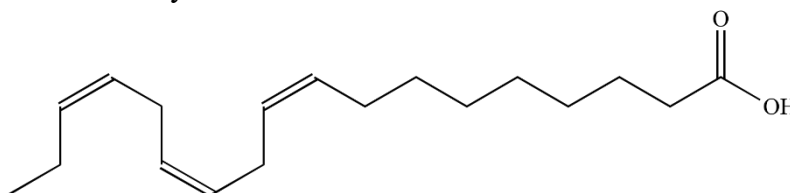


Fatty acids with **one or more C=C double bonds** are **unsaturated fatty acids**.

Linoleic acid,  $\text{CH}_3(\text{CH}_2)_4\text{CHCHCH}_2\text{CHCH}(\text{CH}_2)_7\text{COOH}$ , is a **polyunsaturated fatty acid** with **two C=C double bonds**. ①



Linolenic acid,  $\text{CH}_3\text{CH}_2\text{CHCHCH}_2\text{CHCHCH}_2\text{CHCHCH}_2(\text{CH}_2)_6\text{COOH}$ , is a **polyunsaturated fatty acid** with **three C=C double bonds**. ①



(Unsaturated fatty acids are also classified according to on which C atom C=C starts with respect to the hydrocarbon end of the molecule. **Linoleic acid** is **omega-6**, **linolenic acid** is **omega-3**.)

- iv. The **kinks**, caused by **C=C double bonds** in the hydrocarbon chains on linoleic and linolenic acid molecules **reduce intermolecular attraction**, compared to stearic acid molecules, since they **prevent the molecules packing together as effectively as stearic acid molecules**. ①

Hence **linoleic acid** ( $-5^\circ\text{C}$ ) and **linolenic acid** ( $-11^\circ\text{C}$ ) have significantly **lower melting temperatures than stearic acid** ( $69.6^\circ\text{C}$ ). The **extra C=C double bond in linolenic acid causes it to have a lower melting temperature than linoleic acid**. ①

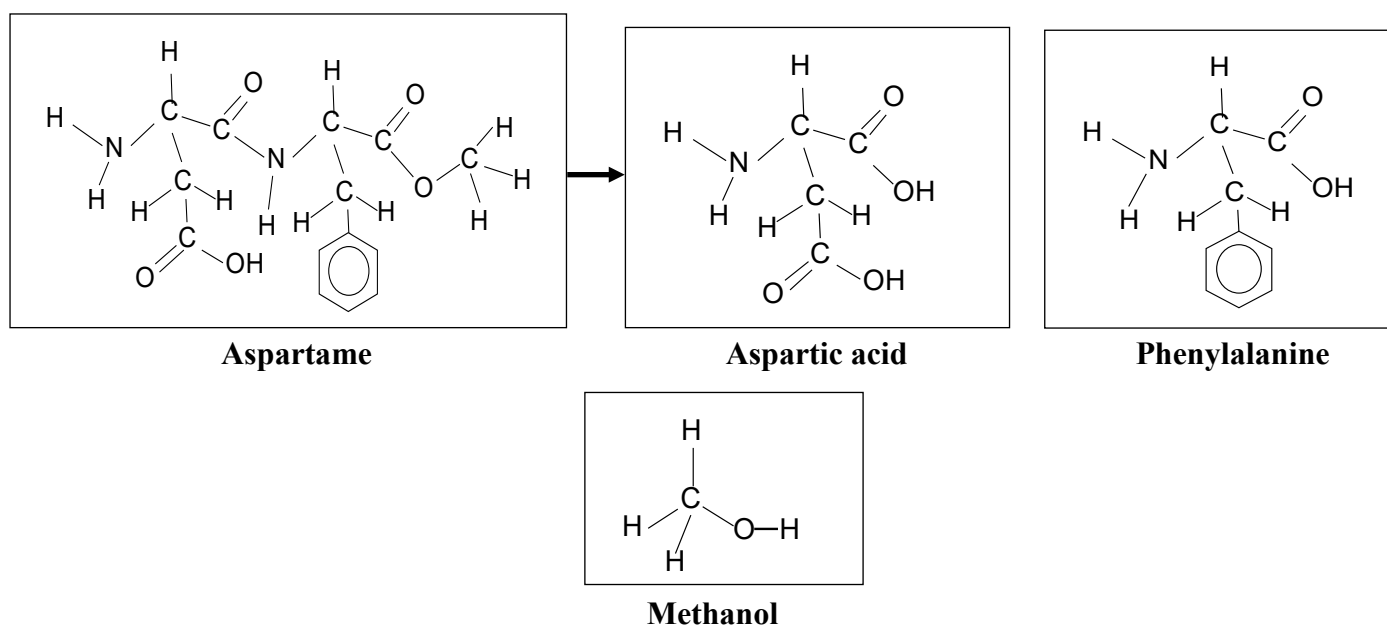


- d. The glycemic index ranks carbohydrates on a scale from 0 to 100 based on how quickly and how much they raise **blood sugar levels** after eating. Hence **GI depends on the rate at which blood sugar / glucose is released** into the blood. ❶  
**Figures 16 and 17** represent, respectively, **amylose** and **amylopectin** (*Table 10 VCE Chemistry Data Book*), two glucose sources in starch. Because **amylopectin has the more branched structure** it is **hydrolysed to glucose faster than amylose**. ❶ Hence the **higher the proportion of amylopectin present**, relative to amylose, the **faster glucose is released into the blood** and the **higher the GI**.

**Question 2** (9 marks)

a. **Methanol** ❶

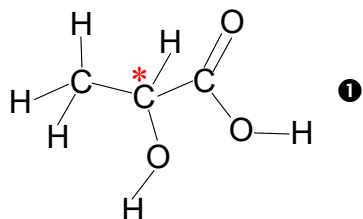
Aspartame → Aspartic acid + Phenylalanine + Methanol  
*(Refer Tables 10 and 17 in the VCE Chemistry Data Book).*



- b. i. *Spectrum 1:*  
**CH<sub>3</sub>OH** ❶ - clear *-OH (alcohol)* peak (3200-3600 cm<sup>-1</sup>) and *C-H* peak (2850-3090 cm<sup>-1</sup>)  
*Spectrum 2:*  
**HCOOH** ❶ - clear *O-H (acid)* peak (2500-3500 cm<sup>-1</sup>) . *C=O* peak (1680-1740 cm<sup>-1</sup>)
- ii. **Methanal** (HCHO) may also be produced by the **oxidation of methanol** (CH<sub>3</sub>OH) with **acidified dichromate** (Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>/H<sup>+</sup>)  
 Oxidation: **CH<sub>3</sub>OH(l) → HCHO(l) + 2H<sup>+</sup>(aq) + 2e<sup>-</sup>** ❶  
 Reduction: **Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>(aq) + 14H<sup>+</sup>(aq) + 6e<sup>-</sup> → 2Cr<sup>3+</sup>(aq) + 7H<sub>2</sub>O(l)** ❶
- iii. **One peak** since HCOOH molecules have **one carbon environment**. ❶
- c. Methanoic acid, HCOOH, reacts with ammonia, NH<sub>3</sub>, to produce **methanamide**, HCOONH<sub>2</sub>. The molecule ion peak at *m/z* = 45 is consistent with *M*(HCOONH<sub>2</sub>) = 45.0  
 The semi-structural formula of species producing the peaks are  
 45 – [HCOONH<sub>2</sub>]<sup>+</sup> ❶  
 43 – [HCOON]<sup>+</sup> ❶  
 29 – [HCO]<sup>+</sup> ❶

**Question 3** (15 marks)

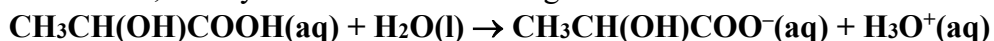
a.



The presence of a **chiral carbon**, indicated by (\*), means that lactic acid does have **optical isomers** (enantiomers).

b.  $C_6H_{12}O_6(aq) \rightarrow 2C_3H_6O_3(aq)$  ①

c. In aqueous solutions lactic acid molecules,  $CH_3CH(OH)COOH$ , ionise to produce lactate ions, and hydronium ions according to



**Increase in concentration of  $H_3O^+(aq)$  causes blood pH to fall.** ①

d. Applying Le Chatelier's principle,

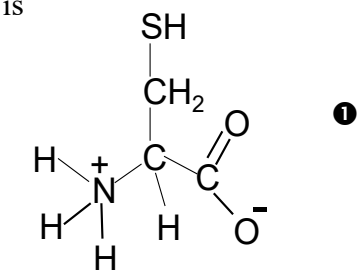
**an increase in  $c(H_3O^+)$  would shift the position of equilibrium 3. to the left.**

**This increases  $c(H_2CO_3)$  which impacts equilibrium 2. and shifts it to the left.** ①

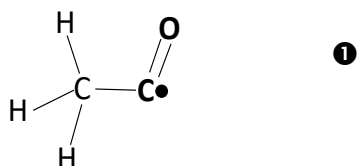
**This increases  $c[CO_2(aq)]$  which impacts equilibrium 1. and shifts it to the left, causing more  $CO_2(g)$  to be exhaled ① by faster breathing.**

e. i. The main structural difference between lactic acid and pyruvic acid molecules occurs at the middle C atom which is a secondary carbon atom. **Lactic acid has a hydroxyl, -OH, group at its middle C, whilst the middle carbon in pyruvic acid is part of a ketone -C=O, group.** ① This is consistent with **pyruvic acid** being an **oxidation product of lactic acid** (secondary alcohols are oxidised to ketones). Hence, **lactic acid may justifiably be described as a reduction product of pyruvic acid.** ①

ii. The thiol group is -SH, so when a carboxyl group, -COOH, reacts with a thiol group, -SH, the thioester group, -COS- is produced. The only amino acid containing the -SH group is cysteine (*Table 17 Data Book*), for which the zwitterion structure is



iii.  $CH_3CO\bullet$



f. i. **Propanone.** ①

ii. **3-hydroxybutanoic acid.** ①

g. i. Heats of combustion are related to the oxidation of the fuel. Since **glucose** releases  $2802 \text{ kJ mol}^{-1}$  when completely oxidised in combustion, it is **partially oxidised when converted to lactic acid or pyruvic acid.** ①

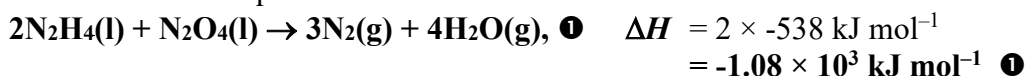
ii. **When converted to lactic or pyruvic acids, glucose is incompletely oxidised, but according to the heats of combustion - pyruvic acid ( $1165 \text{ kJ mol}^{-1}$ ), lactic acid ( $1362 \text{ kJ mol}^{-1}$ ) - glucose is more extensively oxidised when converted to pyruvic acid.** ①

This is consistent with the presence of the **ketone (carbonyl) group in pyruvic acid** compared to the **secondary hydroxyl group in lactic acid.** ①

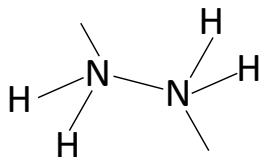
**Question 4** (14 marks)

- a. Chemical equation  $2\text{N}_2\text{H}_4(\text{l}) + \text{N}_2\text{O}_4(\text{l}) \rightarrow 3\text{N}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$   
Energy released per mol of  $\text{N}_2\text{O}_4 = 5.85 \text{ kJ g}^{-1} \times 92.0 \text{ g mol}^{-1}$   
 $= 538 \text{ kJ mol}^{-1}$

Thermochemical equation:



- b. The reaction generates thrust because
1. The reaction produces **7 mol of gaseous products from 3 mol of liquid reactants** 1
  2. The reaction is **exothermic**  
The combination of the production of large amounts of gas and greatly increased temperature **increases the pressure, and as the gas mixture seeks to expand, it pushes the rocket away.** 1
- c. Even though  $\text{N}_2\text{O}_4$  ( $M_r = 92.0$ ) molecules are heavier than  $\text{N}_2\text{H}_4$  ( $M_r = 32.0$ ) molecules, **the intermolecular bonding in hydrazine involves hydrogen bonding** 1 in addition to dipole-dipole bonding and dispersion forces. This is stronger than the intermolecular bonding between dinitrogen tetroxide molecules.
- d. At  $20^\circ\text{C}$ , or room temperature, both **hydrazine and dinitrogen tetroxide are liquids. Hydrogen, however, is a gas and must be stored under high pressure.** 1 However, both compounds are flammable so their storage must be carefully monitored.

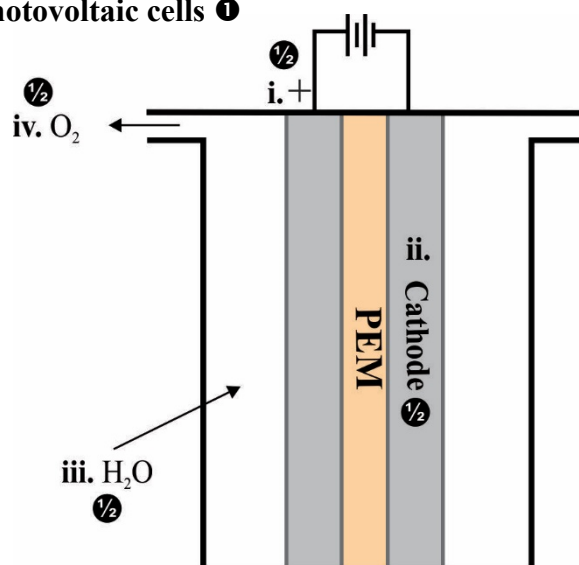


- e. **Electrode X. The anode is the site of oxidation and the fuel,  $\text{N}_2\text{H}_4$ , is oxidised.** 1
- f. **Negative (-). Electrons flow spontaneously from the site of oxidation of the fuel to the site of reduction.** 1
- g.  $\text{N}_2\text{H}_4(\text{l}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$  1
- h.  $\text{H}_2\text{O}_2(\text{l}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$  1
- i.  **$\text{Na}^+$  ions move toward the cathode.** 1
- j. **Heat energy would be released via the neutralisation reaction** 1  
 $2\text{NaOH}(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
- k.  $n(\text{N}_2)$  produced  $= pV / RT$   
 $= 110 \times 4.50 / [8.31 \times (28 + 273)]$   
 $= 0.195 \text{ mol}$  1
- $n(\text{N}_2)$  available from  $\text{N}_2\text{H}_4 = n(\text{N}_2\text{H}_4)$   
 $= 6.47 / 32.0$   
 $= 0.202 \text{ mol}$
- % yield**  $= (n(\text{N}_2) \text{ produced} / n(\text{N}_2) \text{ available}) \times 100$   
 $= (0.195 / 0.202) \times 100$   
 $= 96.6 \%$  1

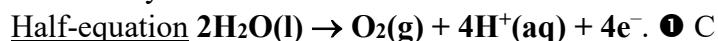
Question 5 (14 marks)

a. Solar energy / photovoltaic cells ①

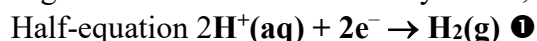
b.



c. Oxygen is produced by the oxidation of water at the anode, the positive electrode in an electrolytic cell



The  $\text{H}^+(\text{aq})$  ions transfer from the anode through the PEM to the cathode ①, the negative electrode in an electrolytic cell, where they are reduced.



d.  $4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$  ①

e. For the equilibrium  $\text{CO}_2(\text{g}) + 4\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + 2\text{H}_2\text{O}(\text{l})$   $\Delta H = -182 \text{ kJ mol}^{-1}$  the  $\Delta H$  value indicates that the forward reaction is exothermic, which means the yield of products is favoured by low temperatures. However, at lower temperatures, the rate of production decreases. ① The temperature selected,  $400^\circ\text{C}$ , is a compromise position which provides good yield at a good rate of reaction. ①

f. In the Sabatier equilibrium 5 mol of reactants produce 3 mol of products which means the pressure decreases as the reaction proceeds. ①

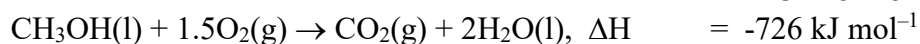
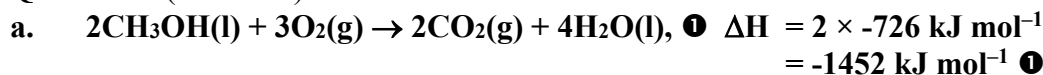
Higher pressure will, according to Le Chatelier's principle, favour the forward reaction, increasing the extent of reaction and product yield as the system partially compensates for the pressure increase. ①

g. Collect water and  $\text{CO}_2$  from the planet. ①

Use a PEM electrolysis cell to produce  $\text{H}_2(\text{g})$  and  $\text{O}_2(\text{g})$  by electrolysis of water. ①

React the  $\text{H}_2$  produced in electrolysis with  $\text{CO}_2$  in a Sabatier system to produce methane and water. ①

**Question 6** (11 marks)



Molar heats of combustion are provided in **Table 11 of the VCE Chemistry Data Book**.



c.  $n(\text{e}^-) = 6 \text{ mol}$ ,

$F = 96500 \text{ C mol}^{-1}$ ,

$E_{\text{cell}} = 0.657 \text{ V}$ ,

N.B. Electrical Energy =  $QV = n(\text{e}^-) \times F \times E_{\text{cell}}$

Electrical energy =  $6 \times 96500 \times 0.657$

$= 3.80 \times 10^5 \text{ J}$

$= 380 \text{ kJ}$  ①

$\Delta H = -726 \text{ kJ mol}^{-1}$

Therefore for each mole of methanol the thermal energy available will be

Efficiency =  $-380 / -726$

$= 0.523$

$= 52.3 \%$  ①

- d. Both coal-fired power stations and fuel cells **convert chemical energy into electrical energy**. However, where that is a **direct conversion in a fuel cell**, it is a **multistage conversion** (chemical  $\rightarrow$  thermal  $\rightarrow$  mechanical  $\rightarrow$  electrical) **in a coal-fired power station**. **Fuel cells are more efficient** because **less thermal energy is 'lost' in the conversion to electrical energy**. ①

- e. According to **Table 2 in the VCE Chemistry Data Book**,

$E^0(\text{O}_2(\text{g}), \text{H}^+(\text{aq})/\text{H}_2\text{O}(\text{l})) = 1.23 \text{ V}$

Theoretical  $E_{\text{cell}} = E^0(\text{oxidant}) - E^0(\text{reductant})$

$= E^0(\text{O}_2(\text{g}), \text{H}^+(\text{aq})/\text{H}_2\text{O}(\text{l})) - E^0(\text{CO}_2(\text{g}), \text{H}^+(\text{aq})/\text{CH}_3\text{OH}(\text{l}), \text{H}_2\text{O}(\text{l}))$

$= 1.23 - (-0.38) \text{ V}$

$= 1.61 \text{ V}$  ①

The actual cell voltage (0.657 V) was significantly lower than the value predicted under standard conditions. Possible reasons could be

- the **cell was not operating at standard conditions (25°, 101.3 kPa, 1 M)**. ①
- the cell had been working for an extended period of time and electrodes were starting to degrade.
- catalyst quality.
- internal electrical resistance.

- f. Octane energy –  $47.9 \text{ kJ g}^{-1}$  (**VCE Chemistry Data Book**),

Methanol energy –  $22.7 \text{ kJ g}^{-1}$  (**VCE Chemistry Data Book**)

$m(\text{C}_8\text{H}_{18})$  in 50.0 L =  $d \times V = 703 \text{ g L}^{-1} \times 50.0 \text{ L}$

$= 3.52 \times 10^4 \text{ g}$

Energy in 50.0 L  $\text{C}_8\text{H}_{18} = 3.52 \times 10^4 \text{ g} \times 47.9 \text{ kJ g}^{-1}$

$= 1.68 \times 10^6 \text{ kJ}$  ①

$m(\text{CH}_3\text{OH})$  required =  $1.68 \times 10^6 \text{ kJ} / 22.7 \text{ kJ g}^{-1}$

$= 7.42 \times 10^4 \text{ g}$  ①

**Question 7** (17 marks)

- a.  $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$  ①  
 b. Students A and C each showed only three sets of titration data that contain concordant titre volumes, whereas **Student B's first set of titration data is significantly higher than the other three sets of data which are concordant.** ①

c.

**Student B**

Volume of vinegar aliquot	Initial burette reading	Endpoint burette reading	Average titre
20.0 mL	2.50 mL	26.80 mL	<del>24.30 mL</del>
20.0 mL	26.80 mL	46.73 mL	19.93 mL
20.0 mL	0.65 mL	20.61 mL	19.96 mL
20.0 mL	20.61 mL	40.64 mL	20.03 mL
			<b>19.97 mL</b> ①

- d. Students B and C may have used the same vinegar. **Concordant titres for Student B are double those for Student C. This is consistent with Student B using 20 mL aliquots but Student C using 10 mL aliquots.** ① Since the average titres are in the same ratio as the aliquot sizes, both vinegars should have the same  $c(\text{CH}_3\text{COOH})$ . ①

- e.  $V(\text{NaOH})$  used = 19.97 mL  
 $n(\text{NaOH}) = 0.982 \text{ mol L}^{-1} \times 19.97 \times 10^{-3} \text{ L}$   
 $= 1.96 \times 10^{-2} \text{ mol}$   
 $n(\text{CH}_3\text{COOH})$  in 20.00 mL aliquot =  $1.96 \times 10^{-2} \text{ mol}$  ①  
 $m(\text{CH}_3\text{COOH})$  in 20 mL vinegar =  $1.96 \times 10^{-2} \text{ mol} \times 60.0 \text{ g mol}^{-1}$   
 $= 1.18 \text{ g in 20 mL}$   
 $m(\text{CH}_3\text{COOH})$  in 100 mL vinegar =  $(1.18 / 20) \times 100$   
 $= 5.88 \text{ g in 100 mL}$   
 $c(\text{CH}_3\text{COOH})$  in vinegar = **5.88 % (m/V)** ①

*Alternatively for second mark:*

$$n(\text{CH}_3\text{COOH}) \text{ in 100 mL vinegar} = 5 \times 1.96 \times 10^{-2} \text{ mol}$$

$$= 9.81 \times 10^{-2} \text{ mol}$$

$$m(\text{CH}_3\text{COOH}) \text{ in 100 mL vinegar} = 9.81 \times 10^{-2} \text{ mol} \times 60.0 \text{ g mol}^{-1}$$

$$= 5.88 \text{ g in 100 mL}$$

$$c(\text{CH}_3\text{COOH}) \text{ in vinegar} = \mathbf{5.88 \% (m/V)}$$
 ①

- f. The vinegars used by Students B and C both have  $c(\text{CH}_3\text{COOH})$  of 5.88 % (m/V). Since Students A and C both use 10.0 mL aliquots of vinegar, the  $c(\text{CH}_3\text{COOH})$  in these vinegars will be in the same ratio as their average titre volumes.

$$c(\text{CH}_3\text{COOH}) \text{ for A} / c(\text{CH}_3\text{COOH}) \text{ for C} = V(\text{NaOH}) \text{ for A} / V(\text{NaOH}) \text{ for C}$$

$$c(\text{CH}_3\text{COOH}) \text{ for A} / 5.88 = 7.95 / 9.88$$

$$c(\text{CH}_3\text{COOH}) \text{ for A} = (7.95 / 9.88) \times 5.88$$

$$= \mathbf{4.73 \% (m/V)}$$
 ①

Vinegar A **does meet the requirement of  $c(\text{CH}_3\text{COOH}) > 4 \% \text{ (m/V)}$**  ①

- g. Independent variable – **brand of vinegar used** ①

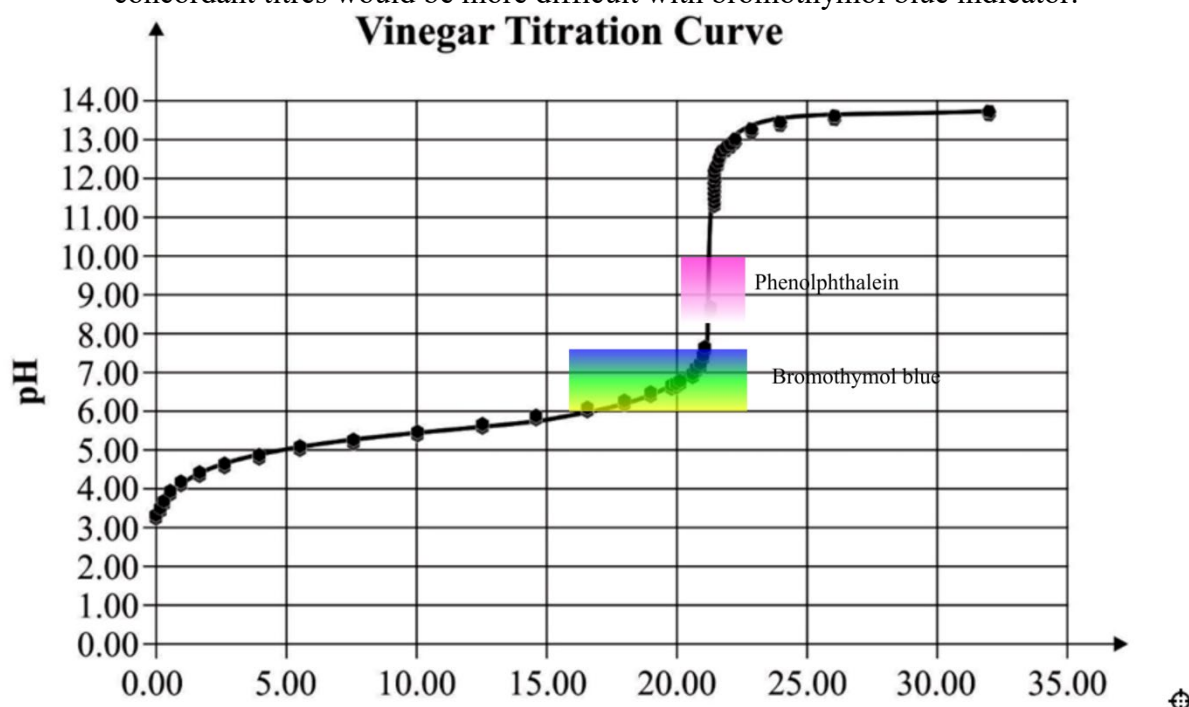
Dependent variable – **titre volume** ①

Controlled variable –  **$c(\text{NaOH})$ , aliquot volume, temperature, amount of indicator** ①

- h. The (i) **accuracy of the data cannot be determined because the actual concentration of the vinegar used was not known.** The fact that each analysis obtained three concordant titres suggests that the **exercise was accurately executed but true accuracy can only be assessed by comparing the  $c(\text{CH}_3\text{COOH})$  calculated from this data with the true or stated  $c(\text{CH}_3\text{COOH})$ .** ①

The fact that concordant titres were obtained by each student shows that **data collected were reproducible and hence reliable (ii).** This is **evident in the data collected by Students B and C, where the relative titres volume are in the same ratio as the relative aliquot sizes.** ①

- i. i. The **endpoint colour change – large increase in pH for minimal addition of NaOH occurs across the colour change range of phenolphthalein (8.3-10).** ①
- ii. The **volume of NaOH at which the sharp pH change occurs (ca 21 mL), the endpoint volume, is larger** according to the titration curve than the endpoint titre volume for Student B's vinegar. So, the **concentration of ethanoic acid would be higher.** ①
- iii. If bromothymol blue had been used as the indicator, the **colour change would occur in the pH range 6.0-7.6, i.e. when less NaOH(aq) had been added.** Hence the recorded titre volume and **calculated  $c(\text{CH}_3\text{COOH})$  would be lower.** ①
- Also, the colour changes with bromothymol blue would not be as sharp, so getting concordant titres would be more difficult with bromothymol blue indicator.



**End of Suggested Answers**