

ANSWERS TO CHAPTER AND REVIEW QUESTIONS



CHP 1: CHEMICAL EQUILIBRIUM

Chapter Questions

1.1 Example 3 is likely to be slowest since many more bonds have to break.

1.2

- (a) 2 single + 1 double (4).
- (b) 4 (4 H–O bonds).

1.3 When a bond is broken or formed- energy greater than minimum required and orientation is appropriate.

1.4 As the reaction proceeds, H^+ ions are converted to H_2 molecules, hence there are less H^+ ions per unit volume to react with the Zn (concentration decreases). So collisions decrease.

1.5

- (a) 24 cm^2
- (b) 48 cm^2

(c) Surface area has doubled – chance of a successful collision increased.

1.6 To increase their surface area and so increase their rate of participation with more collisions.

1.7 A shift of 10°C will markedly increase the number of particles with a high energy ($E > E_a$). Hence collisions are more forceful and more frequent.

1.8

(a) Initially $[N_2]$ and $[H_2]$ are at their greatest and \therefore so is reaction rate, $[N_2]$ and $[H_2]$ will decrease rapidly causing decrease in reaction rate.

(b) H_2 is consumed at 3 times the rate of N_2 - refer to mole ratio in the equation.

1.9

$$(a) K = \frac{[NO_2]^2}{[N_2O_4]} \quad (b) K = \frac{[H_2][I_2]}{[HI]^2}$$

$$(c) K = [H^+][OH^-] \quad (d) K = [Ag^+][I^-]$$

$$(e) K = \frac{[SO_3]^2}{[SO_2]^2 \cdot [O_2]}$$

1.10

(a) $[PCl_3]$ and $[Cl_2]$ is not initially affected hence forward reaction rate is not affected.

(b) $[PCl_5]$ has been reduced, hence reverse reaction rate is lower.

NOTE: This means that the net effect is a shift in equilibrium to the left.

(b) System will partially compensate.

Suppose $[PCl_5]$ goes from $2.00 \rightarrow 2.10$
then $[PCl_3]$ goes from $0.585 \rightarrow 0.485$
 $[Cl_2]$ goes from $1.785 \rightarrow 1.685$
Hence ' K ' = 2.57 (a little high).

By trial and error, can show –

$$[PCl_5] = 2.06 \text{ mol L}^{-1}$$

$$[PCl_3] = 0.489 \text{ mol L}^{-1}$$

$$[Cl_2] = 1.689 \text{ mol L}^{-1}$$

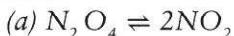
1.11

Initial change to → R/R	← R/R	Direction favoured
nil	inc	←
nil	inc	←
inc	nil	→
nil	dec	→
nil	nil	nil

1.12

Consequent pressure change	Direction favoured
decrease	nil
decrease	→
increase	←
decrease	←
increase	→

1.13



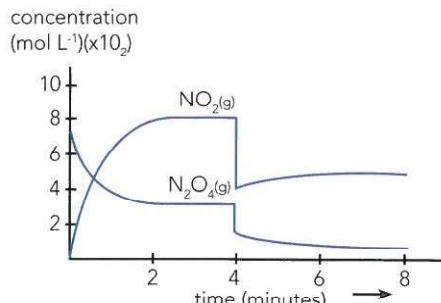
$$(b) K = \frac{[NO_2]^2}{[N_2O_4]}$$



(d) At $t = 2$ minutes.

(e) It was reduced; volume of system was increased.

(f)



1.14

Temperature change	Direction favoured
increase	→
decrease	←
increase	←
decrease	←

1.15

\rightarrow R/R	\leftarrow R/R	[NO]	[Br ₂]	[NOBr]	\rightarrow, \leftarrow or U
nil	dec	dec	dec	dec	\rightarrow
inc	inc	inc	inc	inc	\rightarrow

1.16

\rightarrow R/R	\leftarrow R/R	[H ₂ O]	[CO]	[H ₂]	\rightarrow, \leftarrow or U
nil	dec	nil	inc	dec	\rightarrow
inc	inc	nil	nil	nil	U
inc	inc	nil	inc	inc	\rightarrow
inc	inc	nil	inc	inc	\leftarrow

1. Review Questions

1.

- (a) Nature of reactants, concentration, state of subdivision, temperature and catalyst.
- (b) The minimum energy needed to reach an activated state.

2.

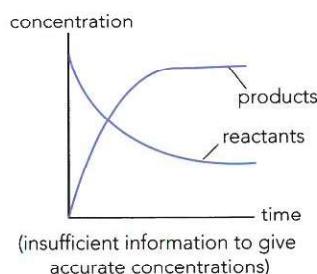
- (a) No change, concentration of NaOH is not being altered.
- (b) Rate increases, increased surface area of Al_(s) increasing the number of Al atoms being exposed to other reactants.
- (c) Rate decreases, temperature is decreased causing fewer collisions to have the activation energy.
- (d) Rate increases, [OH⁻] has increased.

3.

- (a) Higher temperature increases reaction rates; i.e. rate of activity of bacteria increases.
- (b) If sandwiches are to be pre-made, they will need to be kept in a refrigerated area to reduce the activity of the bacteria.

4.

- (a) Solution will lose its brown colour due to I_{2(aq)} and become colourless.
- (b) Reaction rate decreases because reactants become less concentrated.



5.

- (a) Catalysts do speed up chemical reactions (possibly involved in intermediate compounds between reactants and products) and they are re-usable. They DO react but are not permanently consumed.

(b) Providing an alternative reaction pathway with a lower activation energy.

6. (i) Constancy of macroscopic properties.
(ii) Rate of forward reaction equals the rate of the reverse reaction.

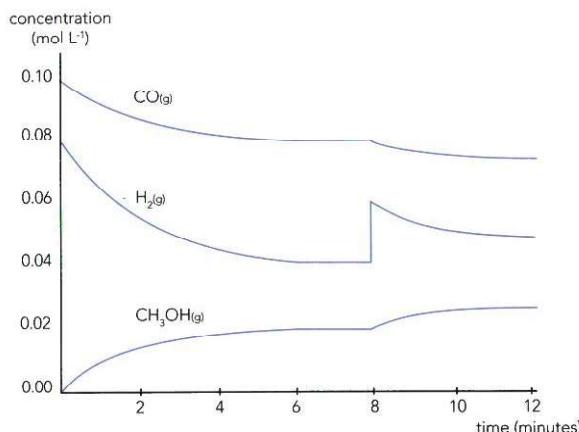
7.

- (a) CrO₄²⁻ : yellow ; Cr₂O₇²⁻ : orange ; H⁺ and H₂O: colourless.
- (b) Observe no changes in the system, especially changes in colour.
- (c) $K = \frac{[Cr_2O_7^{2-}]}{[Cr_2O_4^{2-}]^2 \cdot [H^+]^2}$

8. If a chemical system that is at equilibrium is subject to a change, the chemical system will adjust to re-establish equilibrium. The adjustments will be in such a way as to partially counteract the imposed change.

9.

- (a) CO(g) + 2H₂(g) ⇌ CH₃OH(g)
- (b) t = 6 min
- (c)



- (d) Experts only

Estimate by trial and error to find concentration values that give $K \approx 156$ e.g. if H₂(g) loses half of its extra concentration to achieve equilibrium then we would have:

$$[H_2] = 0.05 \text{ mol L}^{-1}$$

$$[CO] = 0.075 \text{ mol L}^{-1}$$

$$[CH_3OH] = 0.025 \text{ mol L}^{-1}$$

These give a $K \approx 133$ (too low)

A close estimate will be final $[CO] = 0.074 \text{ mol L}^{-1}$

10.

- (a) Forward reaction favoured, solution turns a deeper red.
 (b) Concentration of all species decreased, reaction favoured which increases concentration (by producing more particles) – solution loses red colour.
 (c) decreases because of production of precipitate. Reverse reaction favoured, solution loses red colour.

11.

- (a) No change in concentration of the solid, no effect on yield of CO_2 .
 (b) No change in concentration, no effect on yield of CO_2 .
 (c) No change in concentration of CaO , no effect on yield of CO_2 .
 (d) CO_2 is removed, forward reaction favoured, yield of CO_2 increases.

12.

- (a) No effect on the equilibrium yield.
 (b) To ensure an economic reaction rate – a high yield at a slow rate is not necessarily economical.

13.

Change made to equilibrium mixture	Effect on total gas pressure	Effect on $[\text{O}_2(\text{g})]$	Effect on equilibrium position	Effect on value of K
Temp reduced to 50°C	decrease	increase	←	lower
More O_2 gas at 100°C is added	increase	increase	→	none
Some Ar gas at 100°C is added	increase	none	none	none
Volume of reaction vessel is reduced to 1.5 L	increase	increase	→	none
Small pellets of a catalyst are added	none	none	none	none

14.

$$(a) K = \frac{[\text{H}_2]^4}{[\text{H}_2\text{O}]^4}$$

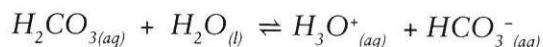
- (b) Constant removal of H_2 will favour the forward reaction ($\text{H}_2\text{O}_{(\text{g})}$ would be injected over the iron at the bottom of the reaction vessel).
 (c) Using the iron in mesh form will increase the reaction rate. It will not increase the equilibrium yield of H_2 but it will increase the rate of production.

15.

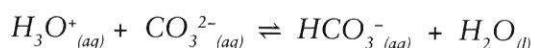
- (a) $\text{CO}_{2(\text{g})} + 394 \text{ kJ} \rightleftharpoons \text{C}_{(\text{s})} + \text{O}_{2(\text{g})}$
 (b) Equilibrium constant will not be affected.
 (c) Forward reaction is favoured so as to (partially) consume the added energy.

16.

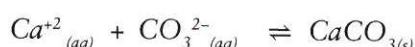
- (a) Carbon dioxide in water forms carbonic acid, $\text{H}_2\text{CO}_{3(\text{aq})}$. The carbonic acid, partially dissociates to form hydrogen ions ($\text{H}_3\text{O}_{(\text{aq})}^+$) which increase acidity. Equations are:



- (b) Any increase in concentration of $\text{CO}_{2(\text{g})}$ will, according to Le Châtelier's Principle, favour an increase in the concentration of $\text{CO}_{2(\text{aq})}$. Similarly this will lead to more $\text{H}_2\text{CO}_{3(\text{aq})}$ being formed and more $\text{H}_3\text{O}_{(\text{aq})}^+$. Hence acidity will increase.
 (c) An increase in the concentration of hydrogen ions in sea water will cause more of the carbonate ions in the water form bicarbonate ions to maintain the following equilibrium.



This makes calcification as indicated by the following equilibrium less favourable since there are less carbonate ions available.



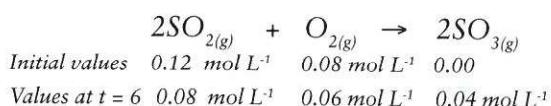
17.

- (a) $[\text{H}_3\text{O}^+]$ would increase
 (b) $[\text{H}_3\text{O}^+]$ would decrease, but the equilibrium would shift to increase it again.
 (c) $[\text{H}_3\text{O}^+]$ would decrease, but the equilibrium would shift to increase it again.

For the Experts

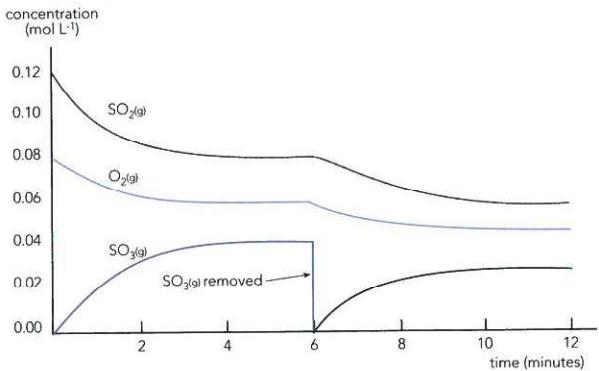
18.

- (a) $K = (\text{SO}_3)^2 / (\text{SO}_2)^2(\text{O}_2)$
 (b) The graph is horizontal between $t = 4$ and $t = 6$ indicating no change in concentration and that equilibrium has been reached.
 (c) The equation for the reaction and initial concentrations of the gases are shown below. Values for $t = 6$ are also shown, determined as discussed below.



From the graph we can see that the concentration of the $\text{SO}_{2(g)}$ has been reduced by 0.04 mol L^{-1} to 0.08 mol L^{-1} . Similarly, using the mole ratios from the equation we can see that the $\text{O}_{2(g)}$ concentration will be reduced by 0.02 mol L^{-1} to 0.06 mol L^{-1} . The concentration of the $\text{SO}_{3(g)}$ will increase from 0.0 to 0.04 mol L^{-1} .

(d) See graph below for $t = 0$ to $t = 6$



(e) With all $\text{SO}_{3(g)}$ removed a new equilibrium will re-establish and some $\text{SO}_{3(g)}$ will form.

CHP 2: ACIDS AND BASES Chapter Questions

$$2.1 \quad n(\text{Mg(OH)}_2) = \frac{m}{M} = \frac{0.0500}{58.326} = 8.57 \times 10^{-4}$$

$$c(\text{OH}^-) = \frac{2 \times 8.57 \times 10^{-4}}{1.00} = 1.71 \times 10^{-3} \text{ M}$$

$$c(\text{H}^+) = \frac{1 \times 10^{-14}}{1.71 \times 10^{-3}} = 5.83 \times 10^{-12} \text{ M}$$

$$\text{pH} = \log[\text{H}^+] = 11.2$$

2.2

$$(a) \quad \text{pH} = 3.60$$

$$\therefore [\text{H}^+] = 10^{-3.60}$$

$$\therefore [\text{H}^+] = 2.51 \times 10^{-4} \text{ mol L}^{-1}$$

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14}}{2.51 \times 10^{-4}} \\ = 3.98 \times 10^{-11} \text{ mol L}^{-1}$$

$$(b) \quad [\text{H}^+] = \frac{2.51 \times 10^{-4}}{2} \\ = 1.26 \times 10^{-4} \text{ mol L}^{-1}$$

$$[\text{OH}^+] = \frac{3.98 \times 10^{-11}}{2} \\ = 1.99 \times 10^{-11} \text{ mol L}^{-1}$$

$$2.3 \quad [\text{H}^+] = \sqrt{K_w} = 2.34 \times 10^{-7} \\ \text{pH} = 6.63$$

$$2.4 \quad \text{At } 50^\circ\text{C } K_w = 5.48 \times 10^{-14} \quad (\text{rather than } 1.00 \times 10^{-14})$$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]}$$

$$[\text{H}^+] = \text{inv log} (-2.50) \quad (\text{OR } 10^{-2.50}) \\ = 3.16 \times 10^{-3} \text{ M}$$

$$[\text{OH}^-] = \frac{5.48 \times 10^{-14}}{3.16 \times 10^{-3}} = 1.73 \times 10^{-11} \text{ mol L}^{-1}$$



$$n(\text{HNO}_3) = c \cdot V = 0.540 \times 0.0475$$

$$= 0.02565 \text{ mol}$$

$$n(\text{NaOH}) = c \cdot V = 0.444 \times 0.0555$$

$$= 0.02464 \text{ mol}$$

$n(\text{HNO}_3)$ not consumed

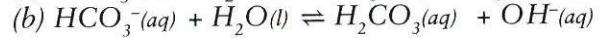
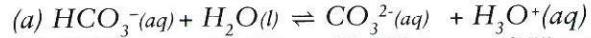
$$= 0.02565 - 0.02464 = 1.008 \times 10^{-3} \text{ mol}$$

$$[\text{H}^+] = n/V = 1.008 \times 10^{-3} / (0.0475 + 0.0555)$$

$$[\text{H}^+] = 9.79 \times 10^{-3} \text{ M}$$

$$\text{pH} = 2.01$$

2.6



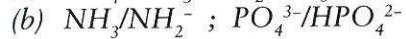
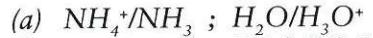
2.7 (a)

H_2SO_4	HSO_4^-
HF	F^-
H_2S	HS^-
HCO_3^-	CO_3^{2-}

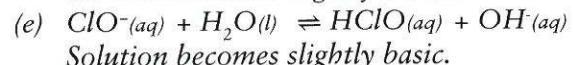
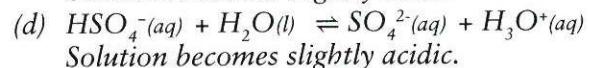
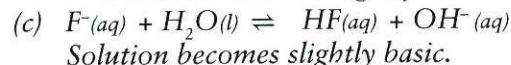
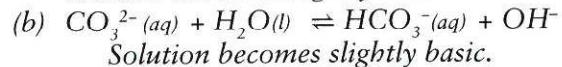
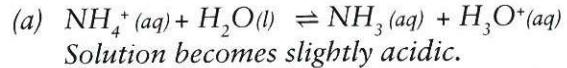
(b)

NH_3	NH_4^+
H_2PO_4^-	H_3PO_4
F^-	HF
HSO_4^-	H_2SO_4

2.8



2.9

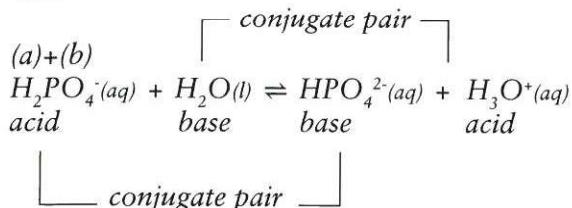


2.10

$\text{NaCl}_{(aq)}$	strong base/strong acid	neutral
$\text{Na}_2\text{CO}_{3(aq)}$	strong base/weak acid	basic
$\text{KH}_2\text{PO}_4_{(aq)}$	*strong base/weak acid	acidic
$\text{MgF}_{2(aq)}$	strong base/weak acid	basic
$\text{Ca(ClO)}_{2(aq)}$	strong base/weak acid	basic
$\text{K}_2\text{SO}_4_{(aq)}$	strong base/weak acid	basic

* H_2PO_4^- derived from polyprotic acid

2.11



(c) Addition of OH^- would reduce $[\text{H}_3\text{O}^+]$.

Forward reaction favoured to partially counteract this imposed change and pH of blood remains relatively constant.

2.12

WEAK ACID	CONJUGATE BASE	EQUATION
CH_3COOH	CH_3COO^-	$\text{CH}_3\text{COOH}_{(aq)} + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{COO}^{-(aq)} + \text{H}_3\text{O}^{+(aq)}$
H_3PO_4	H_2PO_4^-	$\text{H}_3\text{PO}_4^{-(aq)} + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{PO}_4^{2-}(aq) + \text{H}_3\text{O}^{+(aq)}$
NH_4^+	NH_3	$\text{NH}_4^+_{(aq)} + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_3^{(aq)} + \text{H}_3\text{O}^{+(aq)}$

2.13

(a) $V = 50,000 \text{ L}$, $\text{pH} = 7.6$, $[\text{H}^+] = 2.51 \times 10^{-8}$

$$n(\text{H}^+) = cV = 50,000 \times 2.51 \times 10^{-8} \\ = 1.26 \times 10^{-3}$$

$$\text{new } [\text{H}^+] \text{ added} = 0.1 \times 12.0 = 1.20$$

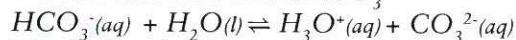
$$\text{new } [\text{H}^+] = n/V = (1.20 + 1.26 \times 10^{-3})/50,000$$

$$\text{new } [\text{H}^+] = 2.40 \times 10^{-5}$$

$$\text{new pH} = 4.62$$

(b) The pH did not change as predicted – the pool water must contain a buffer solution.

(c) A weak base such as NaHCO_3



The buffer should not be harmful to humans or damaging to the pool and its fittings.

2.14

(a) It is deliquescent.

(b) It is not pure – it results from dissolving an approximate amount of gas in water.

2.15

(a) No.

(b) Neutralisation reaction produces an acidic (and soluble) salt NH_4Cl . This salt will cause the solution to be acidic at the equivalence point.

Phenolphthalein is not suitable as its colour change is in the basic region (methyl orange would be suitable).

2.16

(a) Phenolphthalein.

(b) $\text{NaOH} + \text{CH}_3\text{COOH} \rightarrow \text{NaCH}_3\text{COO} + \text{H}_2\text{O}$

$$n(\text{NaOH}) = cV = 8.96 \times 10^{-4}$$

$$n(\text{CH}_3\text{COOH}) \text{ dilute} = 8.96 \times 10^{-4}$$

$$n(\text{CH}_3\text{COOH}) \text{ in } 250 \text{ mL} = 1.120 \times 10^{-2}$$

$$m(\text{CH}_3\text{COOH}) \text{ in } 250 \text{ mL} = nM$$

$$= 1.120 \times 10^{-2}$$

$$= 6.73 \times 10^{-1} \text{ g}$$

$$\% \text{ mass} = \frac{6.73 \times 10^{-1}}{15.50} \times \frac{100}{1}$$

$$= 4.34 \%$$

(c) $n(\text{CH}_3\text{COOH}) = n(\text{CH}_3\text{COOH})$
in 250 mL dilute in 15.50 mL commercial

$$= 1.120 \times 10^{-2}$$

$$c(\text{CH}_3\text{COOH}) = \frac{1.120 \times 10^{-2}}{0.01550}$$

$$(i) = 7.23 \times 10^{-1} \text{ mol L}^{-1} \quad (ii) = 43.4 \text{ g L}^{-1}$$

2.17

$$(a) M(H_2C_2O_4 \cdot 2H_2O) = 126 \text{ g mol}^{-1}$$

$$n(H_2C_2O_4 \cdot 2H_2O) = \frac{m}{M} = \frac{0.554}{126}$$

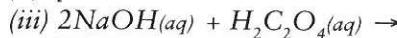
$$= 4.40 \times 10^{-3}$$

$$c(H_2C_2O_4(aq)) = \frac{n}{V} = \frac{4.40 \times 10^{-3}}{0.500}$$

$$= 8.79 \times 10^{-3} \text{ mol L}^{-1}$$

(b) (i) phenolphthalein

(ii) pink → colourless



$$2\text{H}_2\text{O}(l) + \text{Na}_2\text{C}_2\text{O}_4_{(aq)}$$

$$n(\text{oxalic acid}) = cV$$

$$= 8.79 \times 10^{-3} \times 0.01965$$

$$= 1.73 \times 10^{-4} \text{ mol L}^{-1}$$

$$n(\text{NaOH}) = 2n(\text{H}_2\text{C}_2\text{O}_4) = 3.45 \times 10^{-4}$$

$$c(\text{NaOH}) = \frac{n}{V} = \frac{3.45 \times 10^{-4}}{0.0200}$$

$$= 1.73 \times 10^{-2} \text{ mol L}^{-1}$$

(c) (i) phenolphthalein

(ii) pink → colourless

$$(iii) n(\text{NaOH}) = c \times V$$

$$= 1.73 \times 10^{-2} \times 0.0200$$

$$= 3.46 \times 10^{-4} \text{ mol}$$

$$c(\text{CH}_3\text{COOH}) = n(\text{NaOH})$$

$$= 3.46 \times 10^{-4} \text{ mol}$$

$$c(\text{CH}_3\text{COOH}) = \frac{n}{V} = \frac{3.46 \times 10^{-4}}{0.03250}$$

$$= 1.06 \times 10^{-2} \text{ mol L}^{-1}$$

2. Review Questions

1. Test the electrical conductivity of each solution. Comparatively, the strong electrolyte will be the best conductor, then the weak electrolyte and the non-electrolyte should not conduct.

2. STRONG WEAK NON
 Na_2CO_3 NH_3 $\text{CH}_3\text{CH}_2\text{OH}$
 HCl CH_3COOH $\text{C}_{12}\text{H}_{22}\text{O}_{11}$
 NaCl SO_2

3.

- (a) $[H^+] = 1.00 \times 10^{-4} \text{ mol L}^{-1}$
 $[OH^-] = 1.00 \times 10^{-10} \text{ mol L}^{-1}$
- (b) $[H^+] = 1.00 \times 10^{-10} \text{ mol L}^{-1}$
 $[OH^-] = 1.00 \times 10^{-4} \text{ mol L}^{-1}$
- (c) $[H^+] = 3.50 \times 10^{-6} \text{ mol L}^{-1}$
 $[OH^-] = 2.86 \times 10^{-9} \text{ mol L}^{-1}$
- (d) $[H^+] = 1.05 \times 10^{-13} \text{ mol L}^{-1}$
 $[OH^-] = 9.50 \times 10^{-2} \text{ mol L}^{-1}$

4. (a) 3 (b) 5 (c) 12.6 (d) 3.52 (e) 9.18

5.

Material	pH	$[H^+]$ (mol L ⁻¹)	$[OH^-]$ (mol L ⁻¹)
vinegar	3.00	1.00×10^{-3}	1.00×10^{-11}
toothpaste	6.80	1.58×10^{-7}	6.30×10^{-8}
oven cleaner	13.5	3.16×10^{-14}	0.316
window cleaner	9.75	1.79×10^{-10}	5.6×10^{-5}

6. $c(HCl) = 3.16 \times 10^{-5} \text{ mol L}^{-1}$
 $V(HCl) = 0.120 \text{ L}$
 $n(HCl) = 3.795 \times 10^{-6}$

$c(NaOH) = 1.58 \times 10^{-4} \text{ mol L}^{-1}$
 $V(NaOH) = 0.075 \text{ L}$
 $n(NaOH) = 1.189 \times 10^{-5}$

HCl completely consumed;
n(NaOH) remaining
 $= 1.18 \times 10^{-5} - 3.792 \times 10^{-6}$
 $= 8.092 \times 10^{-6} \text{ mol}$

i.e. $[OH^-] = \frac{8.092 \times 10^{-6}}{(0.120 + 0.075)} = 4.15 \times 10^{-5} \text{ mol L}^{-1}$

$[H^+] = \frac{1.00 \times 10^{-14}}{4.15 \times 10^{-5}} = 2.41 \times 10^{-10} \text{ mol L}^{-1}$
 $pH = 9.62$

7. CH_3COOH is a weak acid and will only partially ionise in solution (producing H_3O^+) and so will produce a solution with a higher pH than HNO_3 or HCl which are strong acids.

8.

- (a) It will be considered neutral if $[H^+] = [OH^-]$. In this example $[H^+] = [OH^-] \neq 1 \times 10^{-14}$ – a possible explanation is that the temperature of the solution was not at 25°C
- (b) The temperature would be less than 25°C
- (c) If neutral $K_w = [H^+]^2 = 2.86 \times 10^{-15}$
- (d) For solution temperatures greater than 25°C.

9.

(a) Original pH = 7.8, V = 45,000 L
 $[H^+] = 1.58 \times 10^{-8} \text{ mol L}^{-1}$
original $n(H^+) = c.V = 1.58 \times 10^{-8} \times 45,000 = 7.13 \times 10^{-4}$
 $m(HCl) \text{ added} = 0.900 \times 320 = 288 \text{ g}$
 $n(HCl) \text{ added} = m/M = 288/(1.008 + 35.45) = 7.90$
new conc = $\frac{n \text{ old} + n \text{ added}}{V \text{ old} + V \text{ added}} = 7.13 \times 10^{-4} + 7.90 = 45,000$
 $c(HCl) = 1.76 \times 10^{-14}$

(b) The pool contained a large amount of buffer solution compared to amount of HCl added.

10.

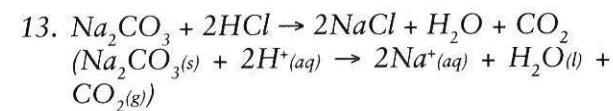
- (a) NH_4^+ and NH_3 OH and H_2O
(b) HPO_4^{2-} and $H_2PO_4^-$ H_2CO_3 and HCO_3^-
(c) HCO_3^- and H_2CO_3 H_3O^+ and H_2O
(d) CH_3COOH and CH_3COO^-
 NH_3 and NH_4^+

11.

Reactants	Salt Formed	Nature of the salt
$HCl + NH_3$	NH_4Cl	acidic
$H_2SO_4 + KOH$	K_2SO_4	slightly basic
$CH_3COOH + NaOH$	$NaCH_3COO$	basic
$HNO_3 + Mg(OH)_2$	$Mg(NO_3)_2$	neutral
$H_3PO_4 + NaOH$	Na_3PO_4	basic

12.

- (a) acidic: $NH_4^{+(aq)} + H_2O(l) \rightleftharpoons H_3O^{+(aq)} + NH_3(aq)$
- (b) neutral
- (c) basic: $S^{2-}(aq) + H_2O(l) \rightleftharpoons OH^{-(aq)} + HS^{-}(aq)$
- (d) basic: $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons OH^{-(aq)} + CH_3COOH(aq)$



The resulting solution is acidic because CO_2 dissolves in water to form solution of the weak acid H_2CO_3



14.

- (a) Add $H_2SO_4(aq)$ to both: the solution which produced a white precipitate would be the $Ba(OH)_2$.
- (b) Dissolve both in water and test pH (with an indicator or a meter), the neutral solution would be the $NaCl$; the slightly basic solution

would be the sodium ethanoate.

- (c) Add $\text{Ba}(\text{NO}_3)_2^{(aq)}$ to both: a white precipitate will form in the sulfuric acid.

15. HCl , NH_4Cl , NaCl , NaCH_3COO , NaOH .

16.

- (a) pH of solution A < 7; hydrolysis of $\text{NH}_4^+_{(aq)}$
 $\text{NH}_4^+_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{NH}_3^{(aq)} + \text{H}_3\text{O}^+_{(aq)}$
 pH of solution B > 7; NH_3 is a weak base
 $\text{NH}_3^{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{NH}_4^+_{(aq)} + \text{OH}^-_{(aq)}$
- (b) Not expected to separate $[\text{NH}_3]$ and $[\text{NH}_4^+]$; but their concentrations will be greatest and concentration of H_3O^+ and OH^- will be least.
- (c) $[\text{NH}_3] > [\text{OH}^-]$, therefore H^+ ions more likely to collide and react with NH_3 .
- (d) (i) H^+ ions would react with OH^- ions, forward reaction is favoured to partially counteract the reduced $[\text{OH}]$.
 (ii) The $[\text{OH}]$ will increase and the reverse reaction will be favoured to partially counteract this change.
 In both cases, the pH will remain very close to 9.
- (e) The buffer capacity could be exceeded by adding sufficiently large amounts of H^+ or OH^- ions that the buffer could not counteract.

17.

- (a) Primary Standard: substance that can be used to produce a pure solution of accurately known concentration.
- (b) Standardisation: when a solution of known concentration is used to accurately determine the concentration of another solution.
- (c) End Point: point at which the titration is stopped because the desired colour change is observed.
- (d) Equivalence Point: point at which stoichiometrically equivalent amounts of reactants have been added to the reaction vessel.
- (e) Indicator: substance which has a definite colour change when subject to different pH's.
- (f) Rough Titration: first titration that is done quickly to get an approximate quantity of reactant needed to reach the end point.

18.

- (a) Should be obtained in a very pure form.
- (b) Have a known formula.
- (c) Have a high molar mass.
- (d) Should not react with air or absorb moisture from the air.

19. It is difficult to obtain pure as it is deliquescent, i.e. it absorbs moisture from the air and can form a solution in this moisture.

20.

Reactant	Salt Produced	Nature of soln at equiv. point	Suitable indicator	Expected colour change
$\text{Na}_2\text{CO}_3 + \text{HCl}$	NaCl	acidic (due to CO_2)	methyl orange	yellow to red
$\text{NH}_3 + \text{HCl}$	NH_4Cl	acidic	methyl orange	yellow to red
$\text{NaOH} + \text{CH}_3\text{COOH}$	NaCH_3COO	basic	phenolphthalein	pink to colourless

21. Titration 1: should be a rough titration only.
 Titration 3: result is outside range of precision of $\pm 0.10 \text{ mL}$ titrations 2, 4 and 5.

22. $\text{HCl} + \text{NH}_3$: end point will be in acidic region. Methyl orange should be used as an indicator. If phenolphthalein is used then the volume of HCl added will be less as the phenolphthalein will change at a pH of approximately 8 rather than 4.

23. Graph indicates an equivalence point in the basic region, indicative of a titration involving a strong base and a weak acid.

24. No as it has not changed the number of moles of solution in the conical flask.

25. Indicator changes colour more slowly and larger volumes are used which give smaller percentage errors. Burette would not need to be continually refilled.

26.

$$(a) n(\text{conc. } \text{H}_2\text{SO}_4) = n(\text{dilute } \text{H}_2\text{SO}_4)$$

$$c_1 V_1 = c_2 V_2$$

$$V_1 = \frac{c_2 V_2}{c_1} = \frac{0.250 \times 2.00}{18.0} \\ = 0.0278 \text{ L}$$

$$V_1 (\text{conc. } \text{H}_2\text{SO}_4) = 27.8 \text{ mL}$$

$$(b) V(\text{conc. } \text{HNO}_3)$$

$$= \frac{c_2 V_2}{c_1} = \frac{0.500 \times 0.100}{14.0} = 0.00357 \text{ L}$$

$$V(\text{conc. } \text{HNO}_3) = 3.57 \text{ mL}$$

$$(c) V(\text{conc. HCl})$$

$$= \frac{c_2 V_2}{c_1} = \frac{0.750 \times 0.500}{12.0} = 0.0312 \text{ L}$$

$$V(\text{conc. HCl}) = 31.2 \text{ mL}$$

27.

$$(a) m(\text{battery acid}) = D \times V \\ = 1.224 \times 2.00 \times 10^3 = 2440 \text{ g} \\ m(H_2SO_4) = 35.0\% \text{ of } m(\text{battery acid}) \\ = 2440 \times \frac{35.0}{100} = 854 \text{ g}$$

$$n(H_2SO_4) = \frac{m}{M} = \frac{854}{98.086} = 8.71 \text{ mol} \\ n(H_2SO_4) \text{ per cell} = 8.71 \div 6 = 1.45 \text{ mol}$$

28.

$$(a) \text{min } [H^+] = \text{inv log } (-7.8) \\ = 1.58 \times 10^{-8} \text{ mol L}^{-1} \\ (b) \text{no. } H_3O^+ \text{ ions} = c \times V \times 6.022 \times 10^{23} \\ = 1.58 \times 10^{-8} \times 3.50 \times 10^4 \times 6.022 \times 10^{23} \\ = 3.34 \times 10^{20} \text{ ions} \\ (c) \text{If pH} = 7.2, [H^+] = \text{inv log } (-7.2) \\ = 6.31 \times 10^{-8} \text{ mol L}^{-1} \\ n(\text{acid}) \text{ in pool if pH} = 7.8 = cV \\ = 1.58 \times 10^{-8} \times 3.50 \times 10^4 = 5.53 \times 10^{-4} \text{ mol} \\ n(\text{acid}) \text{ in pool if pH} = 7.2 = cV \\ = 6.31 \times 10^{-8} \times 3.50 \times 10^4 = 2.21 \times 10^{-3} \text{ mol} \\ n(HCl) \text{ to be added} \\ = 2.21 \times 10^{-3} - 5.53 \times 10^{-4} \\ = 1.657 \times 10^{-3} \text{ mol} \\ (d) V(\text{conc. HCl}) = \frac{n}{c} = \frac{1.657 \times 10^{-3}}{12} \\ = 1.38 \times 10^{-4} \text{ L (0.138 mL)}$$

$$29. n(Mg(OH)_2) = \frac{m}{M} = \frac{30.0}{58.316} = 0.514; \text{ mol} \\ n(OH^-) = 2 \times 0.514 = 1.029$$

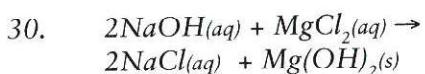
$$n(Al(OH)_3) = \frac{m}{M} = \frac{30.0}{78.004} = 0.385; \text{ mol}$$

$$n(OH^-) = 3 \times 0.385 = 1.154 \text{ mol} \\ n(OH^-) \text{ in 375 mL} = 1.029 + 1.154 = 2.18 \text{ mol}$$

$$n(OH^-) \text{ in 10.0 mL} = 2.18 \times \frac{10}{375} = 0.0582 \text{ mol}$$

$$\therefore n(HCl) \text{ neutralised} = n(OH^-) \text{ in 10.0 mL} \\ = 0.0582 \\ V(HCl) \text{ neutralised}$$

$$= \frac{n}{c} = \frac{0.0582}{\text{inv log } (-0.9)} = 0.462 \text{ L}$$



$$n(NaOH) = \frac{m}{M} = \frac{25.3}{39.998} = 0.633 \text{ mol}$$

$$n(MgCl_2) = \frac{m}{M} = \frac{9.60}{95.2} = 0.101 \text{ mol}$$

(Limiting Reagent)

$$n(OH^-) \text{ consumed} = 2n(MgCl_2) = 0.202 \text{ mol}$$

$$(a) n(OH^-) \text{ remaining in solution} \\ = 0.633 - 0.202 = 0.431 \text{ mol}$$

c(OH⁻) remaining in solution

$$= \frac{n}{V} = \frac{0.431}{8.45} = 0.0510 \text{ mol L}^{-1}$$

$$(b) c(H^+) = \frac{1.00 \times 10^{-14}}{c(OH^-)} = \frac{1.00 \times 10^{-14}}{0.0510} \\ = 1.96 \times 10^{-13} \text{ mol L}^{-1}$$

$$(c) pH = -\log [H^+] = 12.7$$

31.

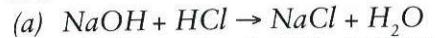


$$(b) n(Na_2CO_3) = cV = 0.997 \times 0.0200 \\ = 1.994 \times 10^{-3} \text{ mol}$$

$$(c) \text{average V(HCl)} = \\ (\text{titration 2} + \text{titration 3} + \text{titration 4}) \div 3 \\ = 41.4 \text{ mL}$$

$$(d) n(HCl) = 2n(Na_2CO_3) = 3.988 \times 10^{-3} \text{ mol} \\ c(HCl) = \frac{n}{V} = \frac{3.99 \times 10^{-3}}{0.0414} \\ = 0.0963 \text{ mol L}^{-1}$$

32.



$$n(HCl) = cV = 0.107 \times 0.0298$$

$$n(HCl) = 3.189 \times 10^{-3} \text{ mol}$$

$$n(NaOH) = n(HCl) = 3.189 \times 10^{-3} \text{ mol}$$

$$c(\text{dilute NaOH}) = \frac{n}{V} = \frac{3.189 \times 10^{-3}}{0.0200} \\ = 0.159 \text{ mol L}^{-1}$$

*(b) (Oven cleaner was diluted twice: in steps II and III)**n(NaOH) in 250 mL of dilute solution from step III*

$$= cV = 0.159 \times 0.250$$

n(NaOH) in 250 mL from step III

$$= 0.0399 \text{ mol}$$

∴ n(NaOH) in 24.0 mL from step II

$$= 0.0399 \text{ mol}$$

$$c(NaOH) \text{ from step II} = \frac{0.0399}{0.0240} \\ = 1.66 \text{ mol L}^{-1}$$

∴ n(NaOH) in all of solution in step II

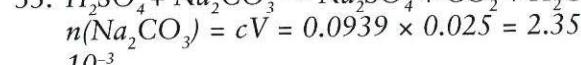
$$= cV = 1.66 \times 0.250 = 0.415 \text{ mol}$$

n(NaOH) in all of solution in step II

$$= nM = 0.415 \times 39.998 = 16.6 \text{ g}$$

% NaOH in drain cleaner

$$= \frac{16.6}{25.0} \times \frac{100}{1} = 66.4\% \text{ (w/w)}$$



$$n(Na_2CO_3) = cV = 0.0939 \times 0.025 = 2.35 \times 10^{-3}$$

$$\therefore n(\text{dilute } H_2SO_4) = n(Na_2CO_3) = 2.35 \times 10^{-3}$$

$$c(\text{dilute } H_2SO_4) = \frac{n}{V} = \frac{2.35 \times 10^{-3}}{0.0247} \\ = 0.0950 \text{ mol L}^{-1}$$

$n(\text{dilute } H_2SO_4) \text{ in } 1.00 \text{ L} = cV$

 $= 0.0950 \times 1.00 = 0.0950 \text{ mol}$

$\therefore n(\text{conc. } H_2SO_4) \text{ in } 20.0 \text{ mL}$

 $= n(\text{dilute } H_2SO_4) \text{ in } 1.00 \text{ L}$
 $= 0.0950 \text{ mol}$
 $c(\text{battery acid}) = \frac{n}{V} = \frac{0.0950}{0.0200}$
 $= 4.75 \text{ mol L}^{-1}$

34. At equivalence point the solution is neutral i.e. $[H^+] = 1.00 \times 10^{-7} \text{ mol L}^{-1}$
- $V(\text{solution}) = 0.0249 + 0.0200 = 0.0449 \text{ L}$
- $\therefore n(H^+) \text{ at equivalence point} = cV$
- $= 1.00 \times 10^{-7} \times 0.0449 = 4.49 \times 10^{-9} \text{ mol}$
- $n(H^+) \text{ in 1 drop} = cV = 0.100 \times 0.0001$
- $= 1.00 \times 10^{-5} \text{ mol}$
- $\therefore n(H^+) \text{ in solution after 1 drop added}$
- $= 4.49 \times 10^{-9} + 1.00 \times 10^{-5} = 1.00 \times 10^{-5} \text{ mol}$
- $c(H^+) = \frac{n}{V} = \frac{1.00 \times 10^{-5}}{0.0449}$
- $= 2.23 \times 10^{-4} \text{ mol L}^{-1}$
- new pH = $-\log(2.23 \times 10^{-4}) = 3.65$
- $\therefore \text{change in pH} = 7.00 - 3.65 = 3.35$

For the Experts

- 35.
- (a) $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
- (b) $n(HCl) = cV = 0.136 \times 0.0226$
- $= 3.07 \times 10^{-3} \text{ mol}$
- (c) $n(Na_2CO_3) \text{ in } 20 \text{ mL} = 1/2n(HCl)$
- $= 1.54 \times 10^{-3} \text{ mol}$
- (d) $n(Na_2CO_3) \text{ in } 500 \text{ mL of solution}$
- $= \frac{500}{20} \times 1.54 \times 10^{-3} = 3.84 \times 10^{-2} \text{ mol}$
- $m(Na_2CO_3) \text{ in } 500 \text{ mL of solution}$
- $= nM = 3.84 \times 10^{-2} \times 105.99$
- $= 4.07 \text{ g}$
- $\therefore m(H_2O) \text{ in } Na_2CO_3 \cdot xH_2O$
- $= m(Na_2CO_3 \cdot xH_2O) - m(Na_2CO_3)$
- $= 10.96 - 4.07 = 6.89 \text{ g}$
- (e) $n(H_2O) \text{ in } Na_2CO_3 \cdot xH_2O$
- $= \frac{6.89}{18.016} = 0.382 \rightarrow \frac{n(H_2O)}{n(Na_2CO_3)} = \frac{0.382}{3.84 \times 10^{-2}} \text{ mol}$
- i.e. $n(H_2O) = 10 \times n(Na_2CO_3)$
- $\therefore \text{correct formula} = Na_2CO_3 \cdot 10H_2O$

CHP 3: OXIDATION AND REDUCTION

Chapter Questions

3.1

- (a) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
- (b) Mg (c) Mg (d) Cl_2

3.2 True: oxidant removes electrons from reductant, e.g. $2Fe + O_2 \rightarrow 2FeO$
 O_2 removes electrons from Fe to form O^{2-} and Fe^{2+} .

3.3

- | | |
|----------|----------|
| (a) (+6) | (b) (+6) |
| (-2) | (-2) |
| (c) (+5) | (d) (-3) |
| (-2) | (+1) |
| | (-1) |
| (e) (+1) | (f) (+2) |
| (+4) | (+4) |
| (-2) | (-2) |

3.4

- | | |
|---------------|---------------|
| (a) Redox | (b) Not Redox |
| (c) Not Redox | (d) Redox |

3.5

- (a) oxidation: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
reduction: $2H^{+}(aq) + 2e^- \rightarrow H_2(g)$
- (b) oxidation: $Mg(s) \rightarrow Mg^{2+}(s) + 2e^-$
reduction: $S(s) + 2e^- \rightarrow S^{2-}(s)$

3.6

- (a) $MnO_4^-(aq) + 8H^{+}(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$
- (b) $H_2C_2O_4(aq) \rightarrow 2CO_2(g) + 2H^{+}(aq) + 2e^-$
- (c) $CH_3CH_2OH(l) \rightarrow CH_3CHO(l) + 2H^{+}(aq) + 2e^-$

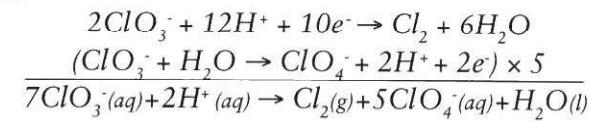
3.7

- (a) $(MnO_4^-(aq) + 8H^{+}(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)) \times 2$
 $(H_2S(g) \rightarrow S(s) + 2H^{+}(aq) + 2e^-) \times 5$
 $2MnO_4^-(aq) + 5H_2S(g) + 6H^{+}(aq) \rightarrow 2Mn^{2+}(aq) + 5S(s) + 8H_2O(l)$
- (b) $ClO^- + 2H^{+} + 2e^- \rightarrow Cl^- + H_2O$
 $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^{+} + 2e^-$
 $ClO^-(aq) + SO_2(g) + H_2O(l) \rightarrow Cl^-(aq) + SO_4^{2-}(aq) + 2H^{+}(aq)$

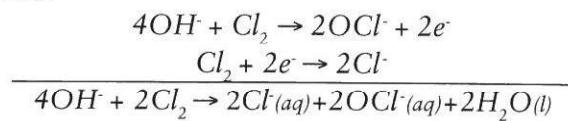
3.8

- (a) $5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^{+}(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$
- (b) $Sn^{2+}(aq) + 2H^{+}(aq) + OCl^-(aq) \rightarrow Cl^-(aq) + Sn^{4+}(aq) + H_2O(l)$

3.9



3.10



3.11	$(Cu \rightarrow Cu^{2+} + 2e^-) \times 3$	-0.34 V	(c) $Br_2 + 2e^- \rightarrow 2Br^{-}(aq)$	+1.08 V
	$(NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O) \times 2$	+0.96 V	$2Cl^- \rightarrow Cl_2 + 2e^-$	-1.36 V
	$2NO_3^- + 3Cu + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$	+0.62 V	<i>Reaction will not occur.</i>	-0.32 V
			(d) $Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36 V
			$H_2S \rightarrow S + 2H^+ + 2e^-$	-0.17 V
			<i>Reaction does occur.</i>	+1.25 V
3.12	$Fe \rightarrow Fe^{2+} + 2e^-$	$E^\circ = +0.44$ V	(e) $2I^- \rightarrow I_2 + 2e^-$	-0.54 V
	$Cu^{2+} + 2e^- \rightarrow Cu$	$E^\circ = +0.34$ V	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.51 V
	$Cu^{2+} + Fe \rightarrow Fe^{2+} + Cu$	$E^\circ_{TOT} = +0.78$ V	<i>Reaction does occur.</i>	+0.97 V
	<i>Not feasible → the steel tank will react.</i>			
	<i>Alloying alters likely reactions.</i>			
3.13			(f) $Ca \rightarrow Ca^{2+} + 2e^-$	+2.87 V
(a)	$Fe \rightarrow Fe^{2+} + 2e^-$	+0.44 V	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.83 V
	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76 V	<i>Reaction does occur.</i>	+2.04 V
	<i>No reaction</i>	-0.32 V		
(b)	$Cu \rightarrow Cu^{2+} + 2e^-$	+0.44 V	(g) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.51 V
	$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	+0.96 V	$Fe^{2+} \rightarrow Fe^{3+} + 2e^-$	-0.77 V
		+1.40 V	<i>Reaction does occur.</i>	+0.74 V
	<i>Reaction will occur.</i>			

3.14

Common Oxidising Agents	Name	Reduction Half Equation	E°
Cl_2	chlorine	$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36V
MnO_4^-	permanganate ion	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.51V
$Cr_2O_7^{2-}$	dichromate ion	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	+1.36V
ClO^-	hypochlorite ion	$ClO^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-$	+0.90V
H^+	hydrogen ion	$2H^+ + 2e^- \rightarrow H_2$	0.00V

3.15

Common Reducing Agents	Name	Reduction Half Equation	E°
Mg	magnesium	$Mg \rightarrow Mg^{2+} + 2e^-$	+2.36
Zn	zinc	$Zn \rightarrow Zn^{2+} + 2e^-$	+0.76V
$C_2O_4^{2-}$	oxalate ion	$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$	+0.43V
H_2	hydrogen gas	$H_2 \rightarrow 2H^+ + 2e^-$	0.00V
Fe^{2+}	iron (II) ion	$Fe^{2+} \rightarrow Fe^{3+} + e^-$	-0.77V

3.16

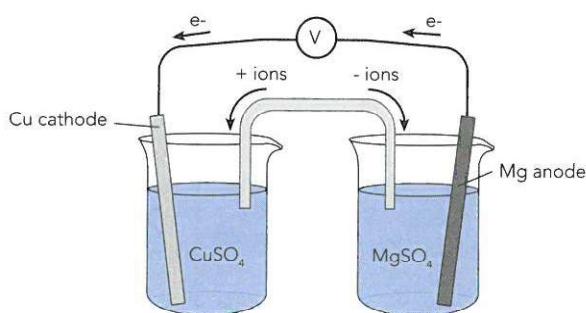
- (a) $Zn \rightarrow Zn^{2+} + 2e^-$
 (b) (i) Zn strip will be blackened, dull salmon pink solid growing on it.
 (ii) Solution loses blue colour.
 (c) (i) Cu^{2+}
 (ii) Zn

3.17

- (a) To allow a flow of ions to complete the circuit.
 (b) (i) Zn^{2+} , NH_4^+ ions move away from Zn/ Zn^{2+} half cell.
 (ii) SO_4^{2-} , NO_3^- ions move away from Cu/ Cu^{2+} half cell.
 (c) • slowly dissolves
 • slowly gains mass
 • no change
 • loses blue colour

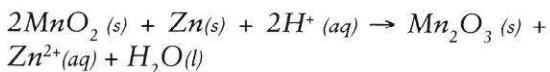
3.18

(a)



- (b) $Mg \rightarrow Mg^{2+} + 2e^-$
 $Cu^{2+} + 2e^- \rightarrow Cu$
 $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
 (c) 2.71 V
 (d) (i) Chemical equilibrium has been reached.
 (ii) Reactants are consumed.

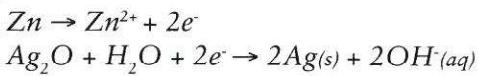
Dry Cell – Overall Reaction



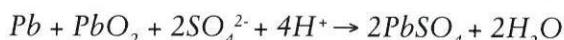
3.19

- (a) $NH_4^+(aq) \rightarrow NH_3(aq) + H^+(aq)$
 (b) Once it has been discharged it cannot be recharged.
 (c) Advantages: cheap, transportable.
 Disadvantages: relatively short life, cheap casing can dissolve, hence allowing leakage.

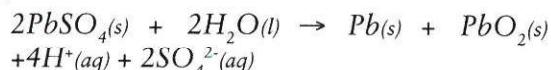
3.20



Lead-Acid Accumulator – Overall Reaction for Discharge



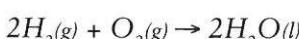
3.21



3.22

- (i) Electrodes are same substance – no reaction to produce transfer of e^- .
 (ii) Density of electrolyte decreases.

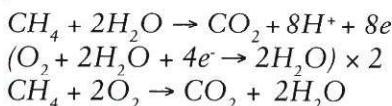
Fuel Cell – Overall Reaction



3.23

- (a) 1.23 V
 (b) $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$
 $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
 (c) $2H_2 + O_2 \rightarrow 2H_2O$
 (d) Same reaction but hydrogen combustion is explosive.

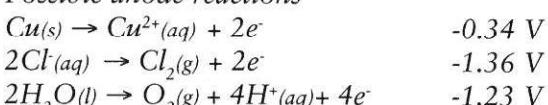
3.24



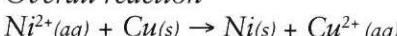
3.25

- (a) Possible cathode reactions
 $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ -0.26 V
 $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ -0.83 V

Possible anode reactions



Overall reaction



- (b) Concentration of Ni^{2+} ions in solution will decrease while that of Cu^{2+} ions will increase. As this occurs Cu^{2+} ions will be preferentially reduced at the cathode (more positive E° than Ni^{2+} or H_2O)

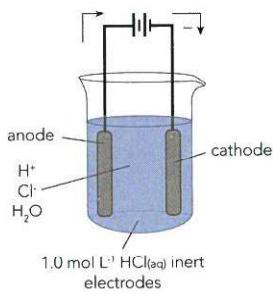
3.26

- (a) Aqueous NaCl (1.0 mol L⁻¹)
 anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
 cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
 Products are O_2 and H_2 .
 (b) Aqueous NaCl (concentrated)
 anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
 cathode: $H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Products are Cl_2 , H_2 and NaOH solution.

3.27

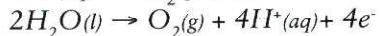
(a)



(b) anode:



-1.36 V



-1.23 V

cathode:

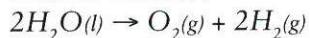


0.00 V



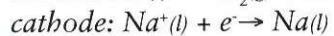
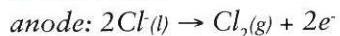
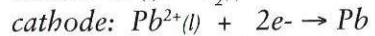
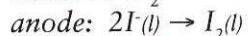
-0.83 V

Overall reaction

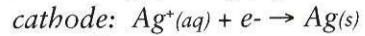
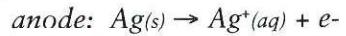


3.28

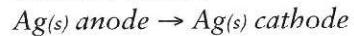
(a) Molten NaCl

Products are Cl₂ and Na.(a) Molten PbI₂Products are I₂ and Pb.

3.29



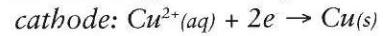
Overall reaction



3.30

The equilibrium reaction keeps the concentration of Ag⁺ ions in solution low but fairly constant. As Ag⁺ ions are deposited at the cathode more of the Ag(CN)₂⁻ dissociates to maintain equilibrium. This keeps the Ag⁺ ions in solution fairly constant.

3.31

(a) anode: Cu(s) → Cu²⁺(aq) + 2e⁻

Overall reaction

(b) (i) E° for their oxidation is much higher than Cu.

(ii) These valuable metals are recovered from the anode mud for profit.

(c) (i) Only a small voltage is used which is not high enough to reduce these ions.

(ii) The Pb²⁺ ions react with the sulphate ions and are recovered as lead sulphate residue. The electrolyte solution is periodically replaced as the Ni²⁺ ion concentration increases. The Ni²⁺ ions are removed as nickel sulphate solution.

3.32 Au, Ag, Cu, Pb, Fe, Al, Mg, Na

3. Review Questions

1. (a) +2 (b) +6 (c) -1 (d) +3
(e) +1 (f) +3 (g) +2
2. (a) H (b) Na (c) Cl
(d) nil (e) C
3. (a) O (b) N (c) O (d) nil

4.

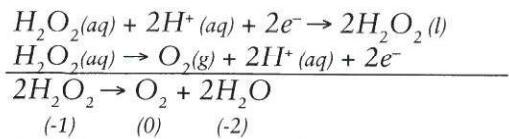
Oxidising Agents	Reducing Agents
oxygen gas, chlorine gas, acidified potassium permanganate, concentrated sulfuric acid, potassium dichromate (acidified), concentrated nitric acid, hydronium ion	zinc, hydrogen gas, carbon, iron (II) ions oxalic acid

5.

Equation	Colour of Reactants	Colour of Products
$\text{Br}_2(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow 2\text{Br}^-(\text{aq}) + \text{I}_2(\text{aq})$	straw brown	red brown
$2\text{Br}^-(\text{aq}) + \text{Cl}_2(\text{aq}) \rightarrow 2\text{Cl}^-(\text{aq}) + \text{Br}_2(\text{aq})$	colourless	straw brown
$\text{Cl}_2(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow 2\text{Cl}^-(\text{aq}) + \text{I}_2(\text{aq})$	colourless	red brown
$2\text{Ag}^+(\text{aq}) + \text{Cu}(\text{s}) \rightarrow 2\text{Ag}(\text{s}) + \text{Cu}^{2+}(\text{aq})$	colourless solution, reddish metal	light blue solution, silvery black crystals
$\text{Mg}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu}(\text{s})$	blue solution	soln loses colour, brown black crystals grow

6.

- (a) $2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^-(\text{aq})$
- (b) $2\text{Br}^-(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Br}_2(\text{l}) + \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- (c) $3\text{Ag}_2\text{S}(\text{s}) + 2\text{NO}_3^-(\text{aq}) + 8\text{H}^+(\text{aq}) \rightarrow 6\text{Ag}^+(\text{aq}) + 3\text{S}(\text{s}) + 2\text{NO}(\text{g}) + 4\text{H}_2\text{O}(\text{l})$
- (d) $2\text{CrO}_4^{2-}(\text{aq}) + 6\text{Cl}^-(\text{aq}) + 16\text{H}^+(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{Cl}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$
- (e) $\text{MnCl}_2(\text{s}) + \text{Br}_2(\text{aq}) + 4\text{OH}^-(\text{aq}) \rightarrow \text{MnO}_2(\text{s}) + 2\text{Br}^-(\text{aq}) + 2\text{Cl}^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
- (a) $\text{Ag}(\text{s}) + 2\text{H}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) \rightarrow \text{Ag}^+(\text{aq}) + \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- (b) $\text{S}(\text{s}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) \rightarrow \text{SO}_4^{2-}(\text{aq}) + \text{Cr}_2\text{O}_3(\text{s})$
- (c) $3\text{H}_2\text{S}(\text{s}) + 2\text{NO}_3^-(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow 3\text{S}(\text{s}) + 2\text{NO}(\text{g}) + 4\text{H}_2\text{O}(\text{l})$
- (d) $2\text{ClO}^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{Cl}^-(\text{aq}) \rightarrow 2\text{Cl}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- (e) $5\text{Fe}^{2+}(\text{aq}) + \text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) \rightarrow 5\text{Fe}^{3+}(\text{aq}) + \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$
- (f) $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{I}^-(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{I}_2(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$
- (g) $2\text{MnO}_4^-(\text{aq}) + 5\text{H}_2\text{O}_2(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 5\text{O}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$
8. When an element is simultaneously oxidised and reduced, disproportionation is said to occur, e.g.

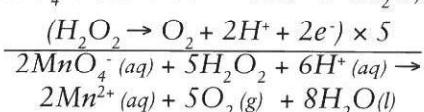


i.e. the oxygen in hydrogen peroxide has been oxidised to form O_2 and reduced in forming H_2O .

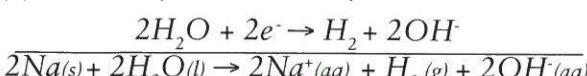
9. May be used as bleaches or for sterilising swimming pool water and drinking water
10. Chlorine, gold, silver, hydrogen, lead, calcium.
11. Br^- and I^- .
12. K^+ , Cr^{3+} , Br_2 , $\text{Cr}_2\text{O}_7^{2-}$, Au^{3+} , MnO_4^- , H_2O_2 .
13.
 - (a) All oxidising agents above $\text{Sn}^{4+} + 2e^- \rightarrow \text{Sn}^{2+}$ in a table of standard reduction potentials.
 - (b) All reducing agents below $\text{Fe}^{2+} + \text{Fe}^{3+} \rightarrow e^-$ in a table of standard reduction potentials.
 - (c) Acidified MnO_4^- (only just), HClO , H_2O_2 or F_2 (by use of a table of standard reduction potentials).
 - (d) Acidified NO_3^- , Hg^{2+} , Br_2 .
14. A galvanic cell may be established and the Al oxidises causing the rivets to break.

15.
 - (a) The standard electrode potential is the potential acquired if a chemical (e.g. $\text{Al}_{(s)}$) is immersed in a solution of its ions (e.g. Al^{3+} ions) of concentration 1.00 mol L^{-1} at 25°C . E° values are a comparison between the standard reduction potential of a substance and the H_2/H^+ reference cell.
 - (b) No – if reduction is occurring, oxidation must occur simultaneously.
 - (c) Mg, Na.

16.
 - (a) No reaction.
 - (b) $(\text{Cu}^+ \rightarrow \text{Cu}^{2+} + e^-) \times 2$
$$\frac{\text{I}_2 + 2e^- \rightarrow 2\text{I}^-}{2\text{Cu}^+(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow 2\text{Cu}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq})}$$
- (c) $(\text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}) \times 2$

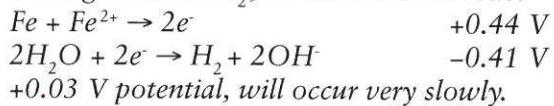


- (d) $\text{Cu} \rightarrow \text{Cu}^{2+} + 2e^-$
- $(\text{NO}_3^- + 2\text{H}^+ + e^- \rightarrow \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})) \times 2$
- $\text{Cu}_{(s)} + 2\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- (e) $(\text{Na} \rightarrow \text{Na}^+ + e^-) \times 2$



- (f) $(\text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}) \times 2$
- $(2\text{Cl}^- + \text{Cl}_2 + 2e^-) \times 5$
- $2\text{MnO}_4^-(\text{aq}) + 10\text{Cl}^-(\text{aq}) + 16\text{H}^+(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 5\text{Cl}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$

- (g) No reaction.
- (h) Boiling removes O_2 ; iron will not corrode.



17. They do initially – but once an oxide layer is formed it will protect the metal beneath from further oxidation. This oxide layer is a coherent coating.

18. (a) oxidation (b) reduction (c) negative (d) positive

19.
 - (a) From $\text{Mg} \rightarrow \text{Pb}$ (b) electrons
 - (c) ions (Mg^{2+} , Pb^{2+} , NO_3^-) (d) KNO_3
 - (e) $\text{Mg}_{(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2e^-$
 - (f) $\text{Pb}^{2+}(\text{aq}) + 2e^- \rightarrow \text{Pb}_{(s)}$ (g) $+2.24 \text{ V}$
 - (h) To complete the circuit by allowing the movement of ions.

20.
 - (a) Yes
 - (b) Yes, but no current would flow in the external circuit, reading on meter = 0.

21.
 - (a) Anode: $\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+} + 2e^-$ (0.76)
Cathode: $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}_{(s)}$ (0.34)
 $E^\circ = 1.10 \text{ V}$
 - (b) Anode: $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+} + 2e^-$ (0.44)
Cathode: $\text{Ag}^+ + e^- \rightarrow \text{Ag}_{(s)}$ (0.80)
 $E^\circ = 1.24 \text{ V}$
 - (c) Anode: $\text{Al}_{(s)} \rightarrow \text{Al}^{3+} + 3e^-$ (1.68)
Cathode: $\text{I}_2(\text{aq}) + 2e^- \rightarrow 2\text{I}^-$ (0.54)
 $E^\circ = 2.22 \text{ V}$
 - (d) Anode: $2\text{Br}^- \rightarrow \text{Br}_2 + 2e^-$ (-1.08)
Cathode: $\text{F}_2(\text{g}) + 2e^- \rightarrow 2\text{F}^-$ (2.89)
 $E^\circ = 1.81 \text{ V}$
 - (e) Anode: $\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^+ + 2e^-$ (-0.70)
Cathode: $\text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$ (1.51)
 $E^\circ = 0.81 \text{ V}$

Electrochemical Cells	Electrolytic Cells
Spontaneous chemical reaction	Forced chemical reaction
oxidation occurs at the anode	oxidation occurs at the anode
anode is negative	anode is positive
electrical energy is created by a chemical change	a chemical change is caused by electrical energy

23.

- (a) $\text{Na}^+(\text{l}) + e^- \rightarrow \text{Na}^+(\text{l})$
 $2\text{Cl}^-(\text{l}) \rightarrow \text{Cl}(\text{g}) + 2e^-$ min volts = 4.07 V
- (b) $\text{Zn}^{2+}(\text{l}) + 2e^- \rightarrow \text{Zn}(\text{l})$
 $2\text{Br}^-(\text{l}) \rightarrow \text{Br}_2(\text{g}) + 2e^-$ min volts = 1.84 V
- (c) $\text{Pb}^{2+}(\text{l}) + 2e^- \rightarrow \text{Zn}(\text{l})$
 $2\text{I}^-(\text{l}) \rightarrow \text{I}_2(\text{g}) + 2e^-$ min volts = 0.67 V



24.

- (a) Na^+, Cl^-, H_2O (b) Cl^- and H_2O
(c) H_2O
(d) Na^+ and H_2O ; H_2O most likely
(e) $(2H_2O) + 2e^- \rightarrow H_2 + 2OH^-$ $\times 2$
 $E^\circ = -0.083V$ (-0.41 V at pH=7)
 $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
 $E^\circ = -1.23V$ (-0.82 V at pH=7)
 $\frac{2H_2O(l)}{} \rightarrow O_2(g) + 2H_2(g)$

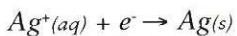
(f) 2.06 V minimum (-1.23 V at pH=7)

25. (c) H_2O is oxidised (d) H_2O is reduced

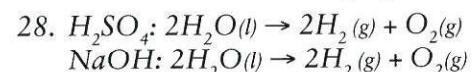
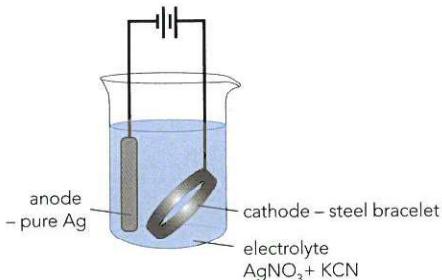
26.

- (a) oxidation: $2I(aq) \rightarrow I_{2(s)} + 2e^-$ $E^\circ = -0.54V$
reduction: $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $E^\circ = -0.26V$
 $2I(aq) + Ni^{2+}(aq) \rightarrow I_{2(s)} + Ni(s)$ $E^\circ = -0.80V$
(b) oxidation: $Pb(s) \rightarrow Pb^{2+} + 2e^-$ $E^\circ = +0.13V$
reduction: $Pb^{2+} + 2e^- \rightarrow Pb(s)$ $E^\circ = -0.13V$
 $Pb(s) \rightarrow Pb(s)$ $E^\circ = 0.0V$
Lead is effectively being transferred from the anode to the cathode. Very small positive voltage needed.
(c) oxidation:
 $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ $E^\circ = -1.23V$
 $(2H^+(aq) + 2e^- \rightarrow H_2) \times 2$ $E^\circ = 0.00V$
 $2H_2O(l) \rightarrow O_2(g) + 2H_2(g)$
- (d) anode:
 $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ $E^\circ = -0.34V$
 $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ $E^\circ = -0.83V$
 $Cu^{2+}(aq) + H_2(g) + 2OH^-(aq)$ $E^\circ = -1.17V$

27. Make the steel the cathode:



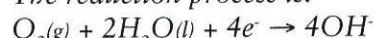
The steel will be coated with Ag.



29.

- reduced
- cathode, $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
- iron (II) hydroxide
- $Fe_2O_3 \cdot H_2O$ or $FeO(OH)$

30. The reduction process is:



By having an alkaline environment the reverse reaction is favoured and reduction process is less likely to occur.

31.

- (a) It coats the iron and stops contact with O_2 and H_2O , hence stopping the iron from corroding.
(b) $Fe \rightarrow Fe^{2+} + 2e^-$, $E^\circ = +0.44V$
 $Sn(s) \rightarrow Sn^{2+} + 2e^-$, $E^\circ = +0.14V$
 $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$, $E^\circ = +0.82V$
Once the Fe is exposed to O_2 and H_2O it will oxidise in preference to the Sn; i.e. the Fe will protect the Sn from oxidation.
(c) $Fe \rightarrow Fe^{2+} + 2e^-$, $E^\circ = +0.44V$
 $Zn \rightarrow Zn^{2+} + 2e^-$, $E^\circ = +0.76V$
The Zn will oxidise before the Fe, protecting the Fe.

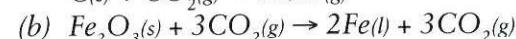
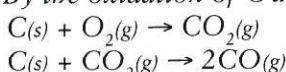
32. The Mg (or Zn) has a higher oxidation potential than the Fe and so will be oxidised before the Fe.

33. Add coating of oil: prevents O_2 and H_2O coming in contact with the Fe and so reduces the likelihood of corrosion.
Clean drain holes: stops H_2O build up which could promote rusting.

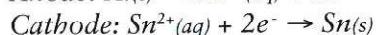
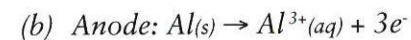
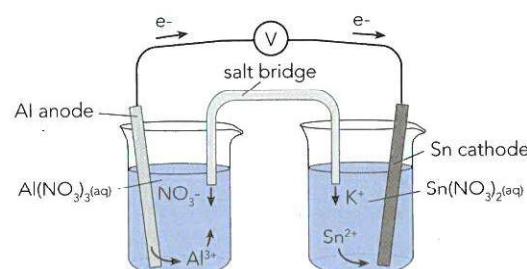
34.

- (a) Oxidation occurs at the anode; by making the pipe the cathode the likelihood of it corroding is reduced.
(b) The metals that are connected as the anode will oxidise and need replacement at some stage.

35. By the oxidation of C and CO_2 ,



36. (a), (d)



(c) $E^\circ = +1.54V$

(d) See diagram at (a).

(e)

- The concentration of the reactant ions in solution will have reduced.
- The electrode surfaces become pitted or coated and reduce reaction rate.
- (f) The Sn electrode would have gained mass as the Sn^{2+} ions form $Sn(s)$ on its surface.

CHP 4: ORGANIC CHEMISTRY

Chapter Questions

- 4.1 (a) alkene (=) (b) alkene (=)
 (c) -oic acid(-COOH) (d) halide (-Cl)
 (e) ester $\begin{array}{c} \text{O} \\ || \\ -\text{C}-\text{O}- \end{array}$ (f) ketone $\begin{array}{c} \text{O} \\ || \\ -\text{C}- \end{array}$
 (g) secondary alcohol (-OH)
 (h) amine (-NH₂)

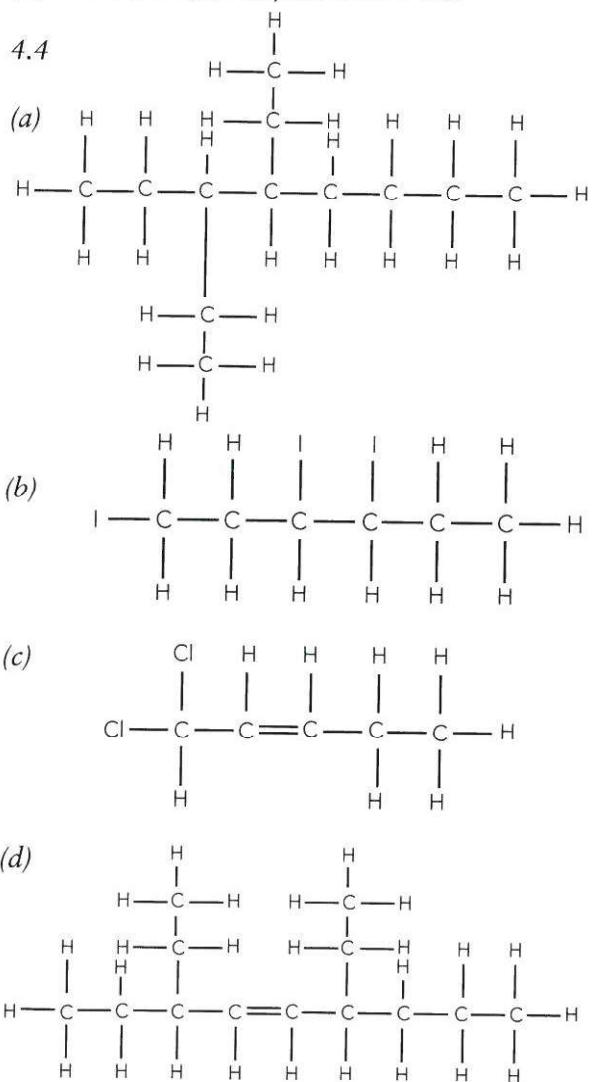
4.2

3	propene	propyl
4	1-butene	butyl
5	2-pentene	pentyl
6	1-hexene	hexyl
7	3-heptene	heptyl
8	3-octene	octyl

4.3

- (a) butane
 (b) but-1-ene
 (c) chloromethane
 (d) 3-methylbut-1-ene
 (e) 4-ethyl-2-methylheptane
 (f) 3-methylpentane
 (g) 1,2-difluoro-2-methylhex-3-ene
 (h) 4-chloro-1,3,4-trifluorobut-1-ene

4.4

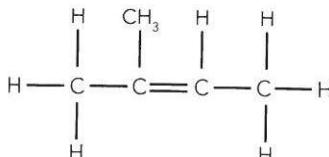


4.5

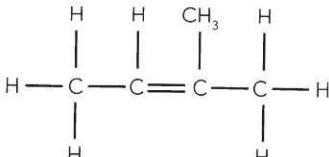
- (a) incorrect numbering – should be but-2-ene
 (b) longest chain is butane not propene
 (c) incorrect numbering – should be pent-1-ene
 (d) incorrect numbering – should be 2,3-dimethylpent-1-ene

4.6

(a)

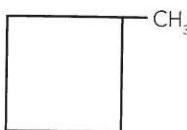


(b)

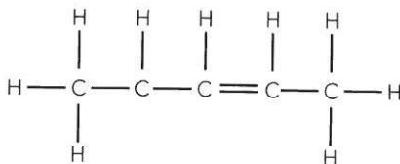


Not an isomer – incorrectly numbered – same as (a).

(c)



(d)



Wrong name - pent-2-ene - so same as Isomer 2.

4.7 (a) cis-3-chlorohex-3-ene

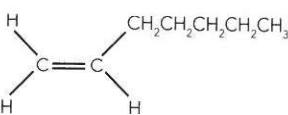
(b) cis-2,3-dichlorobut-2-ene

(c) trans-1,4-dichlorobut-2-ene

(d) cis-1,2-dibromobut-1-ene

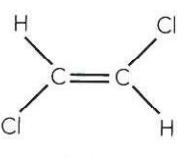
4.8

(a)

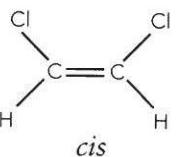


Not a geometric isomer.

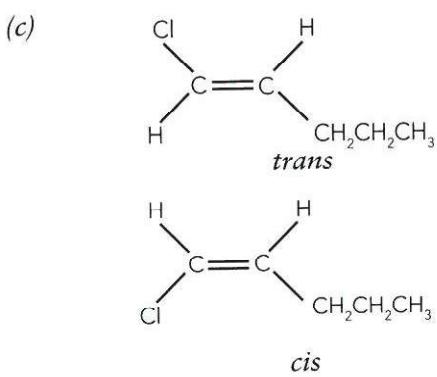
(b)



trans



cis



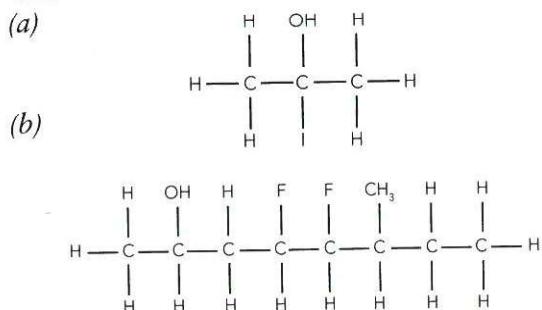
4.9

- (a) 3-methylpentan-1-ol
 (b) 5-bromo-1,1,1-trifluoro-3,4-dimethylpentan-2-ol

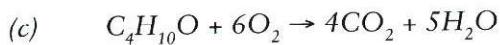
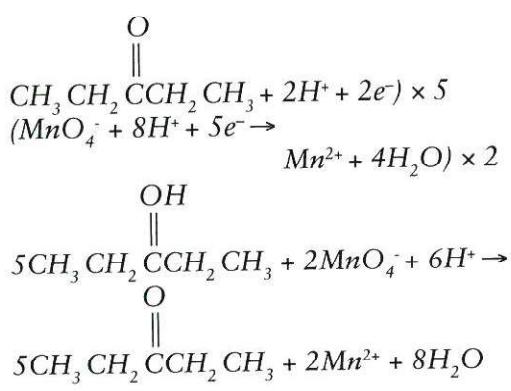
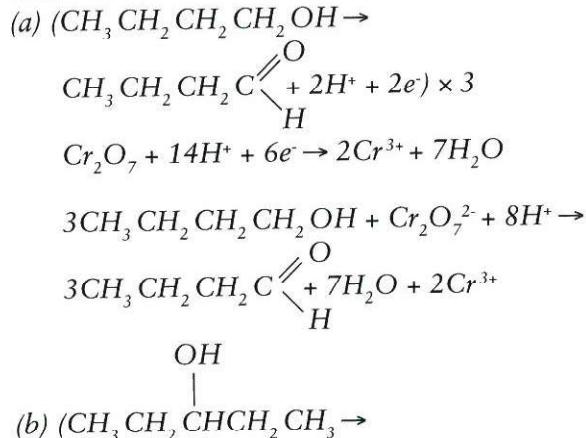
4.10

- (a) heptan-2-ol
 (b) 3-chloro-1,1-diiodopentan-2-ol
 (c) 5,5,5-trichloro-3-methylpentan-1-ol
 (d) 2-chloro-2,3-dimethylbutan-1-ol

4.11



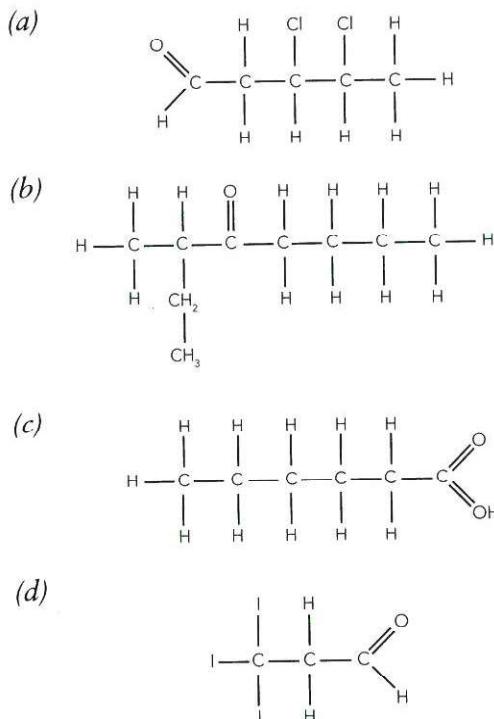
4.12



4.13

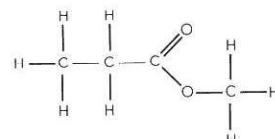
- (a) 3,5-dibromo-5-iodopentanal
 (b) 3,3-dimethylbutanone
 (c) 3,3,3-trichloropropanoic acid
 (d) 3-chloro-3-methylbutanal
 (e) 4,4,4-trifluoro-3,3-diiodobutanone
 (f) 3-methylheptanal

4.14

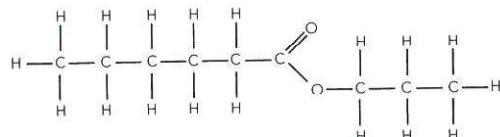


4.15

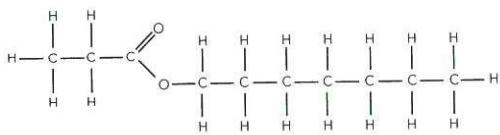
- (a) methyl propanoate



- (b) propyl hexanoate



- (c) heptyl ethanoate



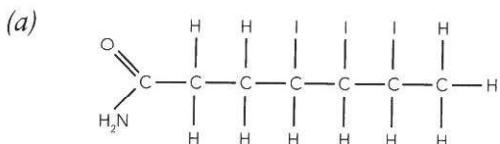
4.16

- (a) ethanol + propanoic acid
 (b) 1-octanol + butanoic acid
 (c) 1-propanol + methanoic acid

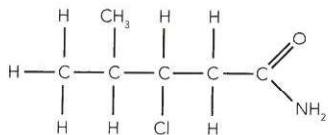
4.17

- (a) 7,7,7-trifluoro-3-methylheptanamide
 (b) 2,5-dibromohexanamide

4.18



(b)



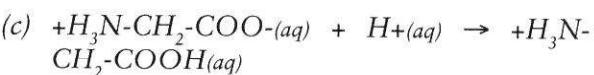
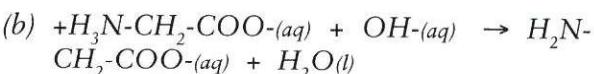
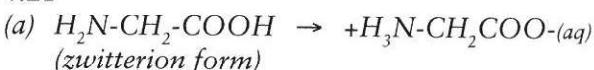
4.19

- (a) 2-methylpentan-1-amine
 (b) 2,5-dichloro-3,4-dimethylhexan-1-amine

4.20

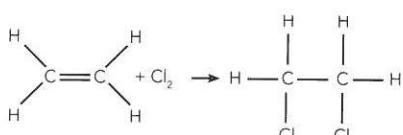
Attached chain is 'H' – non-polar and neutral

4.21

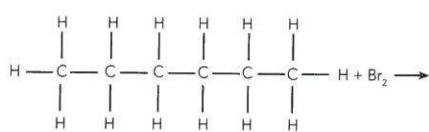


4.22

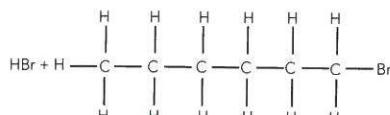
(a)



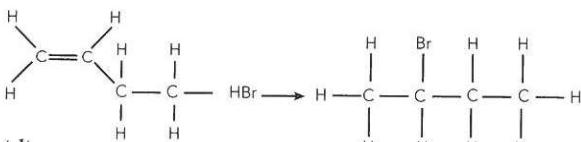
(b)



(c)

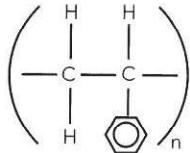


(d)



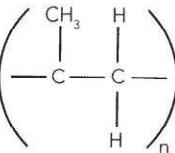
4.23

(a)



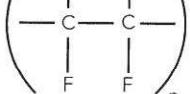
polymer = polystyrene

(c)



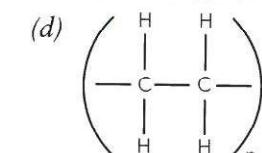
polymer = polypropene

(b)



polymer = polyethene or polythene

(d)



4.24 4 monomer units drawn.

4.25

Motor oil is non-polar - use a non-polar solvent, such as petrol, to dissolve it. Use a detergent to clean up residue.

4.26

Methylated spirits is polar and so will not be a very good solvent for non-polar materials. Tends not to leave streaks because it evaporates so quickly.

4.27

See next page.

4.28

Primary alcohol + $KMnO_4$	aldehyde or carboxylic acid	loss of purple colour, odour produced
Secondary alcohol + $K_2Cr_2O_7$	ketone	orange solution turns green, odour produced
Tertiary alcohol + $KMnO_4$	NR	NR
Alkane + Cl_2	chloroalkane	faint yellow/green colour disappears
Alkene + Cl_2	dichloroalkane	as above

4.29

COMBUSTION

Hydrocarbons

Alcohols

Aldehydes, ketones

Esters

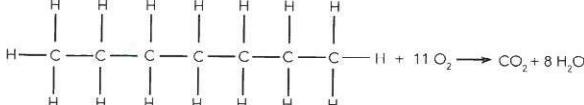
Carboxylic acids



SUBSTITUTION

Alkane + Halogen \rightarrow haloalkane + hydrogen halide

Alkene + Halogen \rightarrow dihaloalkane



4.27

Func. Group	Gen. Formula	Name ends in	Solubility	Produced by
-Cl -I -Br	R - X	has the prefix matching the alkene	usually low - increases as molecule becomes more polar	substitution $-C-C- + Br_2 \rightarrow$ $-C-C-Br + HBr$ addition $C=C + Br_2 \rightarrow -C-C-$
$\begin{array}{c} > C=C < \\ \text{(alkene)} \end{array}$	R ₁ -C=C-R ₂	-ene	not soluble	not applicable
-NH ₂ (primary amine)	R-C-NH ₂	-amine	soluble	not applicable
-OH (alcohols)	R-OH	-ol	soluble	hydration of an alkene
-CHO (aldehydes)	R-CHO	-al	soluble	oxidation of a primary alcohol
$\begin{array}{c} O \\ \\ -C- \\ O \end{array}$ (ketones)	R ₁ -C-R ₂	-one	soluble	oxidation of a secondary alcohol
-COOH (carboxylic acids)	R-C	-oic acid	soluble	oxidation of a primary alcohol or of an aldehyde
$\begin{array}{c} O \\ \\ -C-O- \\ O \end{array}$ (esters)	R-C	-oate	not soluble	alcohol and carboxylic acid

4.29 [continued]

OXIDATION OF ALCOHOLS

Oxidising agent

Primary Alcohol + $KMnO_4$ or $K_2Cr_2O_7 \rightarrow$
aldehyde \rightarrow carboxylic acid

Oxidising agent

Secondary Alcohols + $KMnO_4$ or $K_2Cr_2O_7 \rightarrow$
 \rightarrow ketone

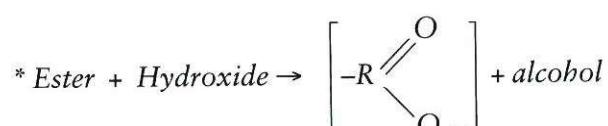
Oxidising agent

Tertiary Alcohols + $KMnO_4$ or $K_2Cr_2O_7 \rightarrow$
 \rightarrow no reaction

REACTIONS OF ESTERS

IN ACIDIC CONDITIONS:

Ester + Water \rightarrow carboxylic acid + alcohol



* Soap making is an example of the hydrolysis of an ester.

e.g. CH_2OOCR

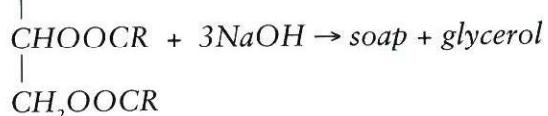


Table 4.3

glucose	$C_6H_{12}O_6$	$C_6H_{12}O_6$	CH_2O
ethyne	CHCH	C_2H_2	CH
benzene	C_6H_6	C_6H_6	CH

4.30

	C	H	O
mass	40.0	6.67	53.3
moles	$40.0/12.01 = 3.33$	$6.67/1.008 = 6.62$	$53.5/16.00 = 3.33$
mole ratio	1	2	1
simple ratio	1	2	1

Empirical formula = CH_2O

EF mass = 30

MF mass = 60

$$\therefore MF \text{ mass} = 2 \times EF \text{ mass}$$

$$\therefore MF = 2 \times EF = C_2H_4O_2$$

Worked Example 4.4

	C	H	O
mass	2.008	0.337	4.015
moles	2.008/12.01 = 0.167	0.337/1.008 = 0.334	4.015/16.00 = 0.251
mole ratio	1	1.9996	1.5009
simple ratio	2	4	3

$$EF = C_2H_4O_2$$

$$EF \text{ mass} = 76$$

$$MF \text{ mass} = 228$$

$$\therefore MF = 3 \times EF = C_6H_{12}O_9$$

Worked Example 4.5

$$(a) \text{ sample 1 } \text{ mass of H} = \\ = 0.05093 \text{ g}$$

$$\text{sample 2 } \text{ mass of S} = \\ = 0.2702 \text{ g}$$

$$\therefore \text{ mass of O} \\ = 0.6578 - 0.2023 - 0.05093 - 0.2702 \\ = 0.1344 \text{ g}$$

	C	H	S	O
mass	0.2023	0.05093	0.2702	0.1344
moles	0.01684	0.05052	0.00842	0.00840
mole ratio	2.005	6.014	1.003	1
simple ratio	2	6	1	1

$$\text{Hence } EF = C_2H_6SO$$

$$(b) \text{ molecular mass} = 78.21 \text{ g}$$

$$EF \text{ mass} = 78.14, MF \text{ mass} = EF \text{ mass}$$

$$MF = C_2H_6SO$$

Worked Example 4.6

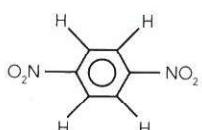
	C	H	N	O
moles	3.571	2.383	1.1906	2.377
mole ratio	3.000	2.001	1	1.996
simple ratio	3	2	1	2

$$(a) EF = C_3H_2NO_2$$

$$(b) EF \text{ mass} = 84$$

$$\therefore MF = 2 \times EF = C_6H_4N_2O_4$$

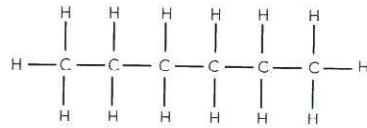
(c)



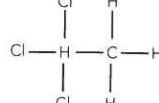
4. Review Questions

1. (a) pentane
- (b) 3-bromo-1,1,1-triiodopentane
- (c) but-1-ene
- (d) ethanamine
- (e) 4-ethylhept-1-ene
- (f) 3,6-dibromo-7,7,8-trifluorooct-2-ene
- (g) 3,3,4-trichlorobutan-1-amine
- (h) 1,4-dichlorobenzene
- (i) trans-1,2-difluoroethene
- (j) trans-hex-3-ene
- (k) propan-1-ol
- (l) 5,5-dichloro-3,3-dimethylheptanal
- (m) 4,4,4-triiodobutanone
- (n) propan-1-amine
- (o) 2,2,4-trichloropentanal
- (p) methanal
- (q) α -amino acid (glycine)
- (r) butanoic acid
- (s) 8,8,8-trichloro-6-ethyl-5-methyloct-2-ene
- (t) 3-fluorobutanal
- (u) 1-chlorobutanal
- (v) propyl propanoate
- (w) methyl butanoate
- (x) pentyl methanoate

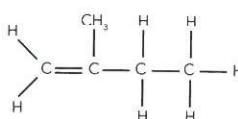
2. (a)



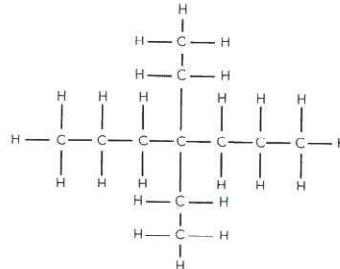
(b)



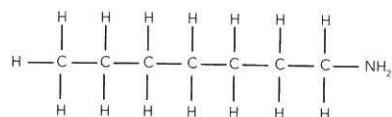
(c)



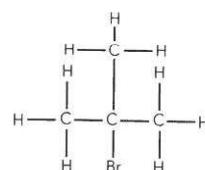
(d)

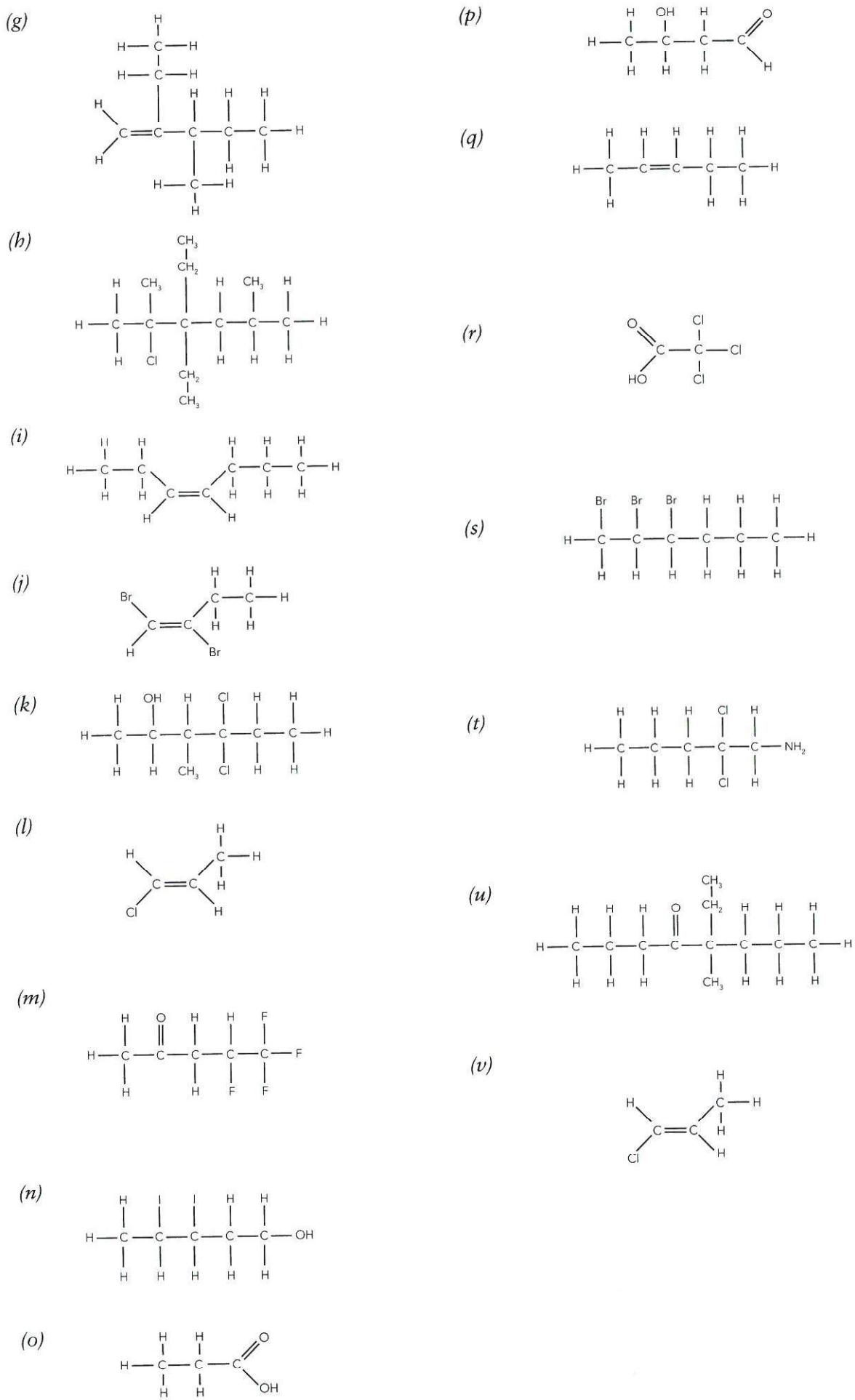


(e)



(f)





3.

- (a) Add several drops of acidified KMnO_4 solution to both. The butanal will decolourise the KMnO_4 while the butanone will not.
 - (b) Add several drops of acidified KMnO_4 solution to both. The butanal will decolourise the KMnO_4 while the hexane will not (or check solubility in water - butanal is more soluble than hexane).
 - (c) As (c) to (e) above - ethanol decolourises KMnO_4 while propanone does not.
 - (d) Add a small piece of sodium to both. The sodium reacts more vigorously with 1-butanol than it does with 2-methylpropan-2-ol.
 - (f) Check solubilities, methanol is much more soluble in water than 1-pentanol. (Check boiling points - methanol has a lower boiling point than 1-pentanol.)

4.

- (a) (i) oxidation
 $(CH_3CH_2OH \rightarrow CH_3CHO + 2H^+ + 2e^-) \times 3$
reduction
 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

(ii) nett
 $3CH_3CH_2OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3CHO + 2Cr^{3+} + 7H_2O$

(iii) orange solution turns green when mixed with colourless solution

- (b) (i) oxidation

$$(H_2O + CH_3OH \rightarrow HCOOH + 4H^+ + 4e^-) \times 5$$

reduction

$$(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 4$$

(ii) nett

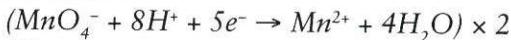
$$5CH_3OH + 4MnO_4^- + 12H^+ \rightarrow 5HCOOH + 4Mn^{2+} + 11H_2O$$

(iii) purple solution becomes colourless on mixing with colourless liquid

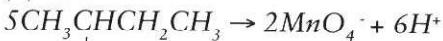
(a) (i) oxidation

- $$(c) \text{ (i) oxidation} \\ (\text{CH}_3\text{CHCH}_2\text{CH}_3 \xrightarrow{\quad} \text{CH}_3\overset{\text{O}}{\underset{\text{||}}{\text{C}}} \text{CH}_2\text{CH}_3 + 2\text{H}^+ + 2e) \times 5$$

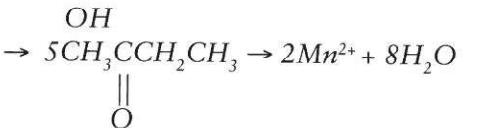
reduction



(ii) nett



1

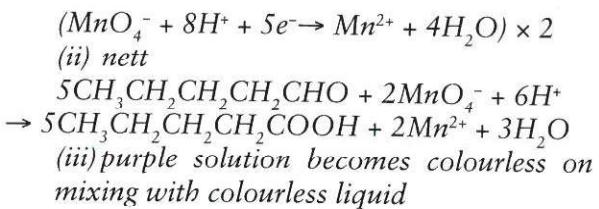


(iii) purple solution becomes colourless on mixing with colourless liquid

- $$(d) \text{ (i) oxidation}$$

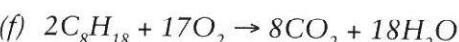
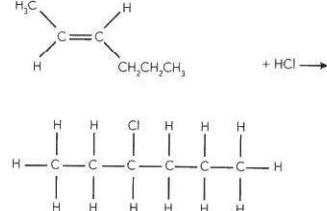
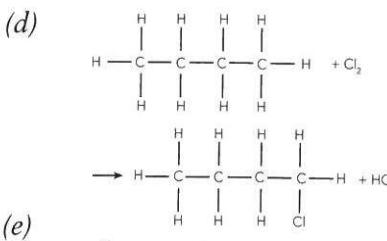
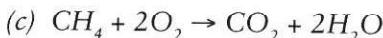
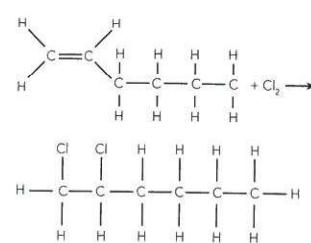
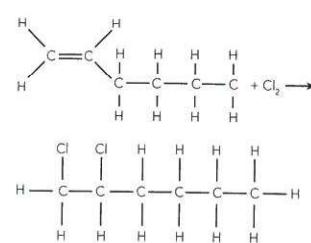
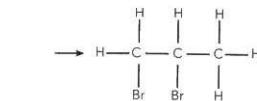
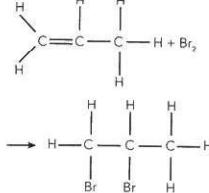
$$\begin{aligned} & (\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO} + \text{H}_2\text{O}) \\ & \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} + 2\text{H}^+ + 2e^- \times 5 \end{aligned}$$

reduction



5. (a) cis-but-2-ene
(b) trans-1-chlorohex-1-ene
(c) cis-1,2-dibromobut-1-ene
(d) 1,1-dibromobut-1-ene

6. (a) $\pi \pi \pi$



7. (a) ester

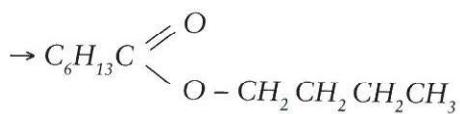
- (b) carboxylic acids

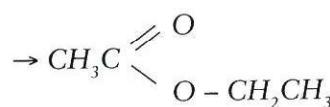
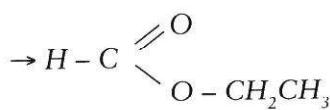
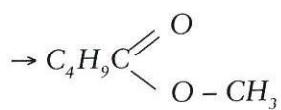
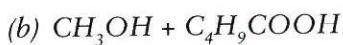
- (c) alcohol

- (d) alkene

8. (a) methyl methanoate
(b) butyl ethanoate
(c) hexyl heptanoate
(d) ethyl pentanoate

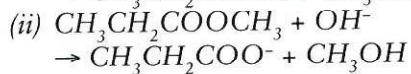
9. (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{C}_6\text{H}_{12}\text{COOH}$





10.

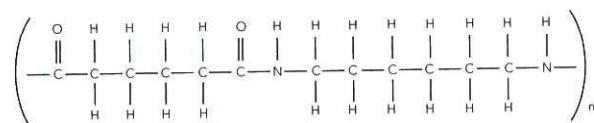
(a)



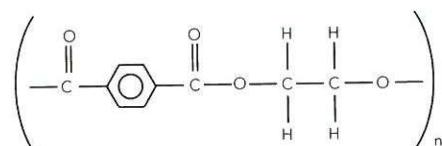
(b) Soap.

11.

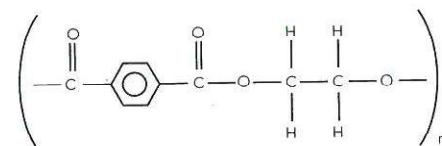
(a) Nylon "6,6"



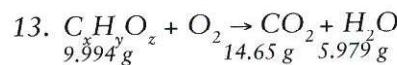
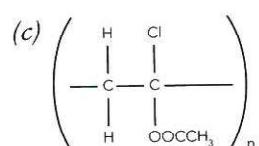
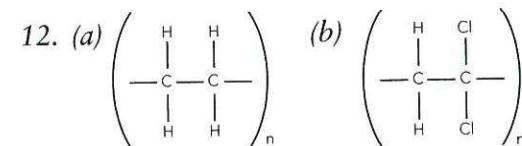
(b) Terylene



(c) Dacron



(d) H_2O



$$(a) n(\text{C}) = n(\text{CO}_2) = \frac{14.65}{44.01} = 0.3329 \text{ mol}$$

$$m(\text{C}) = 0.3329 \times 12.01 = 3.998 \text{ g}$$

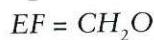
$$n(\text{H}) = 2n(\text{H}_2\text{O}) = \frac{2 \times 5.997}{18.016} = 0.6657 \text{ mol}$$

$$m(\text{H}) = 0.6657 \times 1.008 = 0.6711 \text{ g}$$

$$m(\text{O}) = m(\text{sample}) - [m(\text{C}) + m(\text{H})] = 9.994 - [3.998 + 0.6711] = 5.325 \text{ g}$$

$$n(\text{O}) = \frac{m}{M} = 0.3329$$

$$\begin{array}{ccc} \text{C} & \text{H} & \text{O} \\ 0.3329 & 0.6657 & 0.3329 \\ 1 & 2 & 1 \end{array}$$



$$n(\text{NaOH}) = cV = 0.986 \times 0.0375 = 0.0370$$

$$\therefore n(\text{H}^+) = 0.0370$$

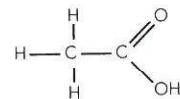
If monoprotic then $n(\text{compound}) = n(\text{H}^+) = 0.0370$

$$M(\text{compound}) = \frac{m}{M} = \frac{2.22}{0.0370}$$

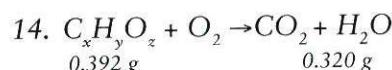
$$= 60.04 \text{ g mol}^{-1}$$

mass of EF = 30, MF = $2 \times EF$

Molecular formula = $\text{C}_2\text{H}_4\text{O}_2$



(ethanoic acid)



$$(a) n(\text{C}) = n(\text{CO}_2) = \frac{PV}{RT} = \frac{101.3 \times 0.547}{8.315 \times 373.1}$$

$$= 1.79 \times 10^{-2} \text{ mol}$$

$$m(\text{C}) = 1.79 \times 10^{-2} \times 12.01 = 0.215 \text{ g}$$

$$n(\text{H}) = 2n(\text{H}_2\text{O}) = \frac{2 \times m}{M} = \frac{2 \times 0.320}{18.016}$$

$$= 3.55 \times 10^{-2}$$

$$m(\text{H}) = 3.58 \times 10^{-2} \text{ g mol}$$

$$m(\text{O}) = m(\text{sample}) - [m(\text{C}) + m(\text{H})]$$

$$= 0.392 - [0.215 + 0.0358] = 0.141 \text{ g}$$

$$n(\text{O}) = \frac{m}{M} = 8.84 \times 10^{-3}$$

$$\begin{array}{ccc} \text{C} & \text{H} & \text{O} \\ 0.0179 & 0.0355 & 0.00884 \\ 0.00884 & 0.00884 & 0.00884 \\ 2.02 & 4.02 & 1 \end{array}$$

$$\therefore EF = \text{C}_2\text{H}_4\text{O}$$

$$(b) n = \frac{PV}{RT} = \frac{194 \times 0.100}{8.315 \times 523.1} = 4.46 \times 10^{-3} \text{ mol}$$

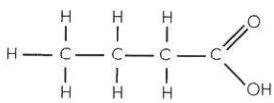
$$M = \frac{m}{n} = \frac{0.392}{4.46 \times 10^{-3}} = 87.9 \text{ g mol}^{-1}$$

mass of EF = 44,

mass of MF = 2 × mass of EF

∴ Molecular formula = $C_4H_8O_2$

(c) (i)



(ii) methyl butanoate

15. (a)

	Cu	S	O	H
mass	$5.945 \times$	$5.945 \times$	$5.945 \times$	$5.945 \times$
	25.45%	12.84%	57.67%	4.04%
moles	<u>1.513 g</u>	<u>0.7633 g</u>	<u>3.428 g</u>	<u>0.240 g</u>
	63.55	32.07	16.00	1.008
	<u>0.02381</u>	<u>0.02380</u>	<u>0.2142</u>	<u>0.2383</u>
	0.02380	0.02380	0.02380	0.02380
	1	1	9	10

$$EF = CuSO_4H_{10}$$

$$(b) m(H_2O) \text{ lost} = 2.145 \text{ g}$$

$$n(H_2O) \text{ lost} = 0.1191 \text{ mol}$$

$$\text{mole ratio of } H_2O \text{ lost} = 5.00$$

$$MF = CuSO_4 \cdot 5H_2O$$

16.

(a) $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$

$$11.61 \text{ g} \quad 26.41 \text{ g} \quad 10.81 \text{ g}$$

$$n(C) = \frac{26.41}{44.01} = 0.6001 \text{ mol}$$

$$m(C) = 0.6001 \times 12.01 = 7.207 \text{ g}$$

$$n(H) = \frac{2 \times 10.81}{18.016} = 1.200 \text{ mol}$$

$$m(H) = 1.200 \times 1.008 = 1.2096 \text{ g}$$

$$m(O) = 11.61 - (7.207 + 1.2096) \\ = 3.193 \text{ g}$$

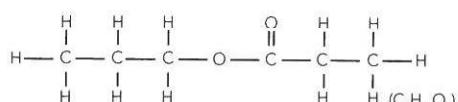
$$n(O) = \frac{3.193}{16.00} = 0.1996 \text{ mol}$$

C	H	O
0.6001	1.200	0.1996
0.1996	0.1996	0.1996
3.006	6.01	1

$$EF = C_3H_6O$$

(b) Information suggests Z is an ester made from an alcohol and carboxylic acid of equal length and less than 5 carbons each.

i.e.



17.

(a) $C_xH_yN_z + O_2 \rightarrow CO_2 + H_2O + NO_2$

$$3.990 \text{ g} \quad 8.927 \text{ g} \quad 5.478 \text{ g} \quad 3.111 \text{ g}$$

$$n(C) = \frac{8.927}{44.01} = 0.2028 \text{ mol}$$

$$n(H) = \frac{2 \times 5.478}{18.016} = 0.6081 \text{ mol}$$

$$n(N) = \frac{3.111}{46.01} = 0.0676 \text{ mol}$$

$$\frac{C}{0.2028} \quad \frac{H}{0.6081} \quad \frac{N}{0.0676}$$

$$2.999 \quad 8.993 \quad 1$$

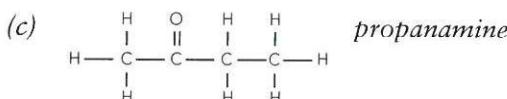
$$EF = C_3H_9N$$

$$(b) n = \frac{PV}{RT} = \frac{101.3 \times 2.680}{8.315 \times 483.1} = 0.0676$$

$$M = \frac{m}{n} = \frac{3.990}{0.0676} = 58.99$$

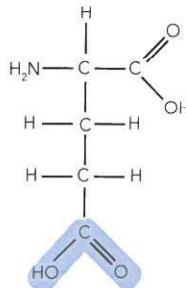
molar mass of EF = 59 = molar mass of MF

∴ Molecular formula = C_3H_9N



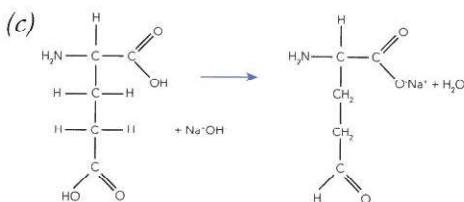
18. FOR THE EXPERTS

(a)

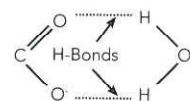


(b) acidic COOH group, polar.

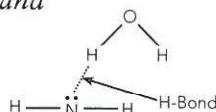
(c)



(d) Soluble in H_2O owing to

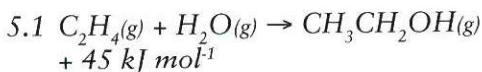


and



CHP 5: CHEMICAL SYNTHESIS

Chapter Questions



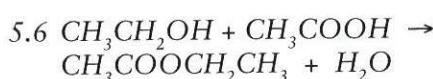
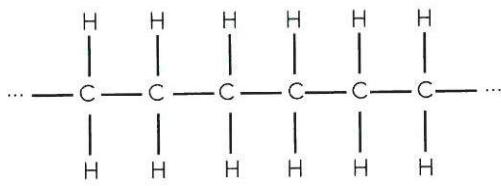
5.2 **Temperature:** As the forward reaction is exothermic, a low temperature favours the formation of the products and consequently a high yield of ethanol.

Pressure: A high pressure would favour a high yield of ethanol as a high pressure favours the forward reaction as it produces fewer particles which helps reduced the imposed increase in pressure.

5.3 Increasing the concentration of the reactants would favour the forward reaction as an increase in the rate of the forward reaction would partially counteract the imposed change by reducing the concentration of the reactants.

5.4 The yield of ethanol is favoured by a low temperature, however to have an economical rate of production of ethanol a compromise between rate and yield requires the moderately high temperature of 300 °C to be used.

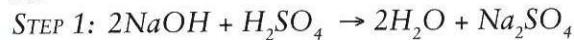
5.5



5.7 The statement is not valid, a catalyst will not alter the relative proportion of product as compared to reactant as it favours both forward and reverse reactions equally. A catalyst is used because it gives a greater reaction rate.

5.8 As the reaction $2 SO_2 + O_2 \rightarrow 2 SO_3$ is exothermic, the equilibrium yield of SO_3 is favoured by a low temperature but the low temperature gives an uneconomical rate of production of SO_3 . A compromise between yield and rate leads to the choice of reaction vessel temperatures of 400°C to 450°C. Increasing the pressure, effectively increases the concentration of all gaseous molecules present. The forward reaction is favoured in this case as it partially opposes this increase pressure by reducing the pressure because less particles are being formed.

5.9



$$3.200 \text{ g} \quad 1.125 \text{ g} \quad x \text{ g}$$

$$\text{STEP 2: } n(NaOH) = \frac{3.200}{40.0} = 0.080$$

$$n(H_2SO_4) = \frac{1.125}{98.08} = 0.0115$$

$$\text{Stoic. ratio of } \frac{NaOH}{H_2SO_4} = \frac{2}{1} = 2$$

$$\text{Actual ratio} = \frac{0.0800}{0.0115} = 6.98$$

∴ H_2SO_4 is the limiting reagent.

$$\text{STEP 3: } n(Na_2SO_4) = n(H_2SO_4) = 0.0115 \text{ mol}$$

$$m(Na_2SO_4) = nM = 0.0115 \times 142.05$$

$$m(Na_2SO_4) = 1.63 \text{ g}$$

STEP 4: $n(NaOH)$ remaining

$$= n(NaOH) - 2n(H_2SO_4)$$

$$= 0.0800 - 0.0229 = 0.0571$$

$$m(NaOH) \text{ remaining} = nM$$

$$= 0.0571 \times 40.0 = 2.28 \text{ g}$$

5.10

$$(a) n(NaOH) = cV = 0.0200 \times 0.450 = 9.00 \times 10^{-3}$$

$$n(MgCl_2) = 0.030 \times 0.540 = 0.0162$$

NaOH is the limiting reagent.

$$n(Mg(OH)_2) = \frac{1}{2} n(NaOH) = 4.50 \times 10^{-3} \text{ mol}$$

$$m(Mg(OH)_2) = nM = (4.50 \times 10^{-3}) \times 58.316 = 0.262 \text{ g}$$

$$(b) c(Na^+) \text{ ions} = \frac{n}{V} = \frac{9.00 \times 10^{-3}}{0.0500} = 0.180 \text{ mol L}^{-1}$$

$$c(Cl^-) \text{ ions} = \frac{n}{V} = \frac{2 \times 0.0162}{0.0500} = 0.648 \text{ mol L}^{-1}$$

$$c(Mg^{2+}) \text{ ions} = \frac{n}{V} = \frac{(0.0162 - 0.00450)}{0.0500} = 0.234 \text{ mol L}^{-1}$$

5.11

$$n(Cu) = \frac{m}{M} = \frac{12.25}{63.55} = 0.193 \text{ mol}$$

$$n(Cu_2S) \text{ in ore} = \frac{1}{2} n(Cu) = 0.193 \times \frac{1}{2} = 0.0964$$

$$m(Cu_2S) \text{ in ore} = nM = 0.0964 \times 159.17 = 15.3 \text{ g}$$

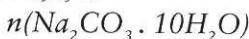
$$\therefore \% Cu_2S \text{ in ore} = \frac{15.3}{154.5} \times \frac{100}{1} = 9.93\%$$

STEP 1: $2\text{NH}_3 \rightarrow 2\text{NH}_4^+\text{HCO}_3^- \rightarrow 2\text{NaHCO}_3^-$
 $\rightarrow \text{Na}_2\text{CO}_3^- \rightarrow \text{Na}_2\text{CO}_3^- \cdot 10\text{H}_2\text{O}$
 $m(\text{Na}_2\text{CO}_3^- \cdot 10\text{H}_2\text{O})$

$$= 1000 \times \frac{100}{90} = 1111 \text{ kg}$$

(allowing for 90% efficiency)

STEPS 2,3,4:



$$= \frac{m}{M} = \frac{1111000}{286.15} = 3883 \text{ moles}$$

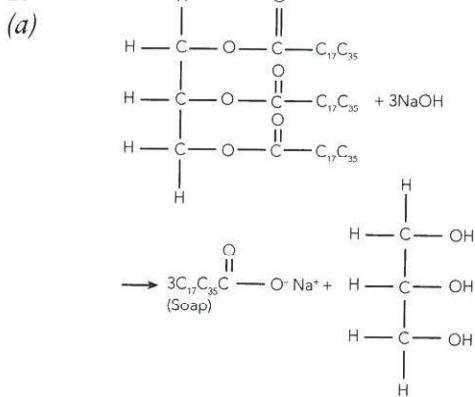
$$n(\text{NH}_3) = 2n(\text{Na}_2\text{CO}_3^- \cdot 10\text{H}_2\text{O}) \\ = 2 \times 3883 = 7766$$

$$m(\text{NH}_3) \text{ required} = nM = 7766 \times 17.034 \\ = 1.32 \times 10^5 \text{ g} = 132 \text{ kg}$$

$$n(\text{NaCl}) = 2n(\text{Na}_2\text{CO}_3^- \cdot 10\text{H}_2\text{O}) = 7766 \text{ mol} \\ m(\text{NaCl}) = nM = 7766 \times 58.44 \\ = 4.54 \times 10^5 \text{ g} = 454 \text{ kg}$$

5. Review Questions

1.

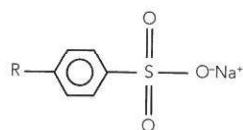


- (b) The soap is able to dissolve in water because the Na^+ ions dissociate from the soap leaving a negative region around the O. The interactions between the highly polar water molecules and this region of the soap molecules allows the soap to dissolve.
(c) The long hydrocarbon chain end is responsible for the soap being able to dissolve in or attract to non-polar fat and oil stains.

2.

- (a) Ca^{2+} and Mg^{2+} ions
(b) Because they combine with the soap to form insoluble substances, i.e. $\text{Mg}(\text{C}_{17}\text{H}_{35}\text{COO})_2$ and $\text{Ca}(\text{C}_{17}\text{H}_{35}\text{COO})_2$. These precipitate out and remove soap from the solution. A 'scum' forms.
(c) Smaller amounts of detergents are required to clean the same amount of dirty materials plus they do not form insoluble substances when used in water containing Ca^{2+} or Mg^{2+} ions.

(d)



where R is a hydrocarbon chain of at least 10 carbons in length.

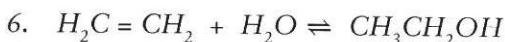
3.

- (a) A zwitterion is a neutral ion that has both a negative and a positive charge.
(b) A surfactant, such as a soap or detergent, lowers the surface tension of liquids and allows for greater interaction or mixing between the liquids.
(c) (i) is the zwitterion, with the positive region being one of the CH_3 groups joined to the N and the negative regions is O atom that is joined to the C with a single bond.
(d) The section labeled R is a non-polar hydrocarbon region of the zwitterion. This non-polar section is attracted to the oils on the skin. It helps break the oil down into small globules or micelles that are suspended in the water.

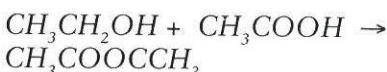
4.

- (a) propan-1-ol and propan-2-ol
(b) $\text{CH}_3\text{CH}=\text{CH}_2(g) + \text{H}_2\text{O}(g) \rightarrow \text{CH}_3\text{CHOHCH}_3(g)$
(c) High pressure as the forward reaction would be favoured as it would produce less particles, decreasing the pressure and partially counteract the imposed change.
(d) This would indicate that at low temperatures the reaction rate would be too slow to be economically viable. A compromise is found between yield of product, favoured by low temperatures and rate of production as favoured by high temperatures.

5. The production of ethanol by the acid catalysed hydrolysis of ethene requires temperatures in the region of 300°C . The fermentation of alcohol is best at temperatures of about 25°C . The lower temperature in part is due to the reactions involved being catalysed by enzymes.



(Ethanol can be oxidised to ethanoic acid by O_2 as per the equation:



7. These conditions would be based on ensuring that the rate of production of the ethanoic

acid was at high as possible within the economic constraints of building reaction vessels and ongoing energy consumption to produce and maintain these pressure and temperature conditions. 20 °C and 1 atm would be far cheaper to build and run but the rate of production of the CH₃COOH would be too slow to be economically viable.

$$8. n(\text{CH}_3\text{OH}) = \frac{m}{M} = \frac{9.44 \times 10^6}{32.042} = 295\,000$$

$$n(\text{CO}) = \frac{n}{M} = \frac{6.38 \times 10^6}{28.01} = 228\,000$$

CO is the limiting reagent

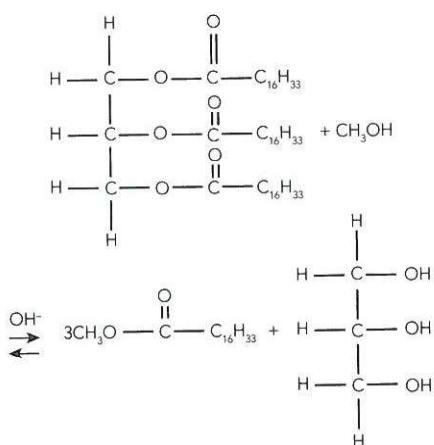
$$n(\text{CH}_3\text{COOH}) = n(\text{CO})$$

$$m(\text{CH}_3\text{COOH}) = n \cdot M = 228\,000 \times (24.02 + 32.00 + 4.032)$$

$$m(\text{CH}_3\text{COOH}) = 1.37 \times 10^7 \text{ g}$$

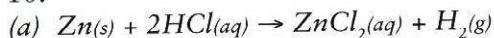
9.

(a)



(b) The use of a biological enzyme may allow the production of the biodiesel to occur at temperatures and pressures much closer to standard conditions. This will reduce costs to build the plant and also the ongoing run costs to maintain the higher temperatures and pressures as required by the base catalysed process.

10.



$$(b) n(\text{Zn}) = \frac{m}{M} = \frac{7.34}{65.38} = 0.112 \text{ mol}$$

$$n(\text{HCl}) = cV = (1.50)(0.120) = 0.180 \text{ mol}$$

To find L.R. consider Zn. 0.112 mol of Zn would require (2)(0.112) = 0.224 mol of HCl (from equation).

There is only 0.18 mol of HCl available ∴ HCl is LR.

$$(c) n(\text{H}_2) \text{ collected} = (\frac{1}{2})(0.18) = 0.090 \text{ mol}$$

$$V(\text{H}_2) = \frac{nRT}{P} = \frac{(0.090)(8.315)(291.1)}{105}$$

$$= 2.07 \text{ L}$$

(d) To find excess zinc, first determine mass of zinc consumed.

$$n(\text{Zn}) \text{ that react} = (\frac{1}{2})(0.18)$$

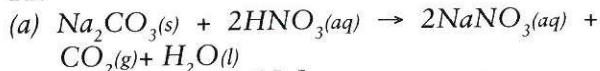
$$\therefore m(\text{Zn}) \text{ that react} = (0.090)(65.38)$$

$$= 5.88 \text{ g}$$

$$\therefore m(\text{Zn}) \text{ remaining} = 7.34 - 5.88$$

$$= 1.46 \text{ g}$$

11.



$$(b) n(\text{Na}_2\text{CO}_3) = \frac{15.5}{106} = 0.146 \text{ mol}$$

$$n(\text{HNO}_3) = cV = (2.42)(0.100) = 0.242 \text{ mol}$$

To determine LR, consider Na₂CO₃. 0.146 mol of HNO₃ would require (2)(0.146) = 0.292 mol of HNO₃ (from equation). There is only 0.242 mol of HNO₃ available ∴ HNO₃ is LR.

$$(i) n(\text{CO}_2) \text{ produced} = (\frac{1}{2})(0.242) = 0.121 \text{ mol}$$

$$\therefore V(\text{CO}_2) \text{ STP} = (n)(22.41) = 2.71 \text{ L}$$

(ii) All ions are still in solution except those that reacted to form CO₂ and H₂O

$$c(\text{Na}^+) = \frac{n}{V} = \frac{(0.146)(2)}{0.100} = 2.92 \text{ mol L}^{-1}$$

$$c(\text{NO}_3^-) = \frac{n}{V} = \frac{(0.242)}{0.100} = 2.42 \text{ mol L}^{-1}$$

For CO₃⁻² determine how many reacted

$$n(\text{CO}_3^{2-}) \text{ reacted} = (\frac{1}{2})(0.242) = 0.121 \text{ mol}$$

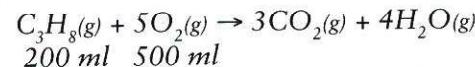
$$n(\text{CO}_3^{2-}) \text{ left over} = 0.146 - 0.121 = 0.0250 \text{ mol}$$

$$c(\text{CO}_3^{2-}) = \frac{n}{V} = \frac{0.025}{0.100} = 0.250 \text{ mol L}^{-1}$$

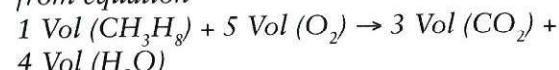
For H⁺ they are all consumed

∴ c(H⁺) = 0 [Note for a neutral solution the [H⁺] would still be 1 × 10⁻⁷ mol L⁻¹]

12.



All gas volumes at same condition hence from equation



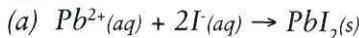
To find Limiting Reagent, consider C₃H₈. 200 mL C₃H₈ would require (5)(200) = 1000 mL of O₂.

Since there is only 500 mL of O₂, it is the LR. Hence final volumes of gases remaining

• Vol of O₂ = 0 all O₂ consumed

- Vol of $C_3H_8 = 100 \text{ mL}$ ($1/5$ (500) consumed)
- Vol of $CO_2 = 300 \text{ mL}$ ($3/5$ (500) produced)
- Vol of $H_2O = 400 \text{ mL}$ ($4/5$ (500) produced)

13.



$$(b) n(NaI) available = cV$$

$$= (1.15)(0.050)$$

$$= 5.75 \times 10^{-2} \text{ mol}$$

$$n(KI) available = cV$$

$$= (0.50)(0.100)$$

$$= 5.00 \times 10^{-2} \text{ mol}$$

$$n(I) total available = 10.75 \times 10^{-2} \text{ mol}$$

$$n(Pb(NO_3)^2) added = 20.0 = 6.04 \times 10^{-2} \text{ mol}$$

331.22

$6.04 \times 10^{-2} \text{ mol of } Pb(NO_3)^2$ would require

$$2(6.04 \times 10^{-2}) \text{ mol of } I$$

$$\text{i.e. } 12.08 \times 10^{-2} \text{ mol } I$$

But we have only $10.75 \times 10^{-2} \text{ mol } I$

Hence I is the limiting reagent.

$$n(PbI_2) formed = \frac{1}{2} \times n(I)$$

$$= (\frac{1}{2})(10.75 \times 10^{-2})$$

$$= 5.375 \times 10^{-2}$$

$$\therefore m(PbI_2) = (5.375 \times 10^{-2})(461) = 24.8 \text{ g}$$

(c) $I(aq)$ is all consumed

$$\text{i.e. } c(I) = 0$$

$Pb^{2+}(aq)$ is in excess

$$n(Pb^{2+}(aq)) \text{ in excess} = 6.04 \times 10^{-2} - \frac{1}{2}(10.75 \times 10^{-2})$$

$$= 6.65 \times 10^{-3}$$

$$c(Pb^{2+}(aq)) = \frac{6.65 \times 10^{-3}}{0.150}$$

$$c(Pb^{2+}(aq)) = 4.43 \times 10^{-2} \text{ mol L}^{-1}$$

$$c(Na^+(aq)) = \frac{5.75 \times 10^{-2}}{0.150}$$

$$= 3.83 \times 10^{-1} \text{ mol L}^{-1}$$

$$c(K^+) = \frac{5.00 \times 10^{-2}}{0.150}$$

$$= 3.33 \times 10^{-1} \text{ mol L}^{-1}$$

$$c(NO_3^-) = \frac{2(6.04 \times 10^{-2})}{0.150}$$

$$= 0.805 \text{ mol L}^{-1}$$

14. From the equations for the reactions, 1 mol $S(s)$ produces 1 mol H_2SO_4

$$n(S) = \frac{m}{M} = \frac{3.25 \times 10^6}{32.06} = 101372$$

$$n(H_2SO_4) = n(S) = 101372$$

$$m(H_2SO_4) \text{ pure} = n.M = 101372 \times 98.076 = 9.94 \times 10^6 \text{ g}$$

$$m(\text{acid}) = \frac{9.94 \times 10^6 \times 100}{98.5}$$

$$= 1.10 \times 10^7 \text{ g} = 11.0 \text{ tonnes}$$

15. From the equations, 1 mol of P_4 will produce 4 mol of H_3PO_4

$m(H_3PO_4)$ in final acid solution

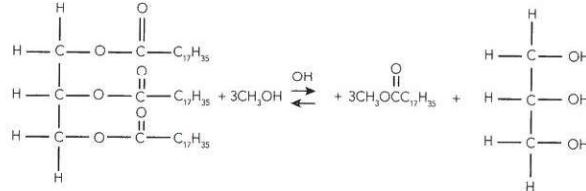
$$= \frac{1500000 \times 85.0}{100} = 1.275 \times 10^6 \text{ g}$$

$$n(H_3PO_4) \frac{m}{M} = \frac{1.275 \times 10^6}{97.994} = 13011$$

$$n(P_4) = \frac{n(H_3PO_4)}{4} = \frac{13011}{4} = 3253$$

$$m(P_4) = n.M = 3253 \times (30.97 \times 4) = 4.03 \times 10^5 \text{ g or } 403 \text{ kg.}$$

16.



molecular formula of palm oil - $C_{57}O_6H_{110}$

$$n(\text{palm oil}) = \frac{m}{M} = \frac{1000}{((57 \times 12.01) + (6 \times 16.00) + (110 \times 1.008))} = 1.12$$

$$n(\text{biodiesel}) = 3 \times n(\text{palm oil}) = 3.37$$

molecular formula for biodiesel ester = $C_{19}O_2H_{38}$

$$m(\text{biodiesel}) = n.M = 3.37 \times ((19 \times 12.01) + 32.00) = (38 \times 1.008) = 1.00 \text{ kg}$$

Process is 85% efficient, therefore the mass of biodiesel = 850 g/kg of triglyceride.

$$17. m(\text{iron ore}) = m(Fe_2O_3) = \frac{33.3}{100 \times 1.40 \times 10^9} = 4.66 \times 10^8 \text{ tonnes}$$

$$Assumption \text{ from question: Steel is 99\% Fe and 1\% C}$$

$$n(Fe_2O_3) = \frac{m}{M} = \frac{4.66 \times 10^{14}}{((2 \times 55.85) + 3 \times 16.00))}$$

$$= 2.92 \times 10^{12}$$

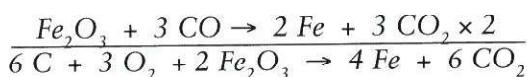
$$n(Fe) = 2 \times n(Fe_2O_3) = 5.84 \times 10^{12}$$

$$m(Fe) = n.M = 5.84 \times 10^{12} \times 55.85$$

$$= 3.26 \times 10^{14} \text{ g}$$

$$m(\text{plain steel}) m(\text{Fe}) \times \frac{100}{99} = 3.29 \times 10^{14} \text{ g}$$

$$m(\text{plain steel}) = 3.29 \times 10^8 \text{ tonnes}$$



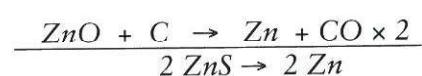
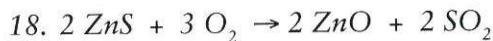
$$n(\text{Fe}_2\text{O}_3) = \frac{m}{M} = 1.40 \times \frac{1015}{159.7}$$

$$= 8.77 \times 10^{12}$$

$$n(\text{CO}_2) = 3 \times n(\text{Fe}_2\text{O}_3) = 2.63 \times 10^{13}$$

$$m(\text{CO}_2) = n.M = 2.63 \times 10^{13} \times (12.01 + 32.00) = 1.16 \times 10^{15} \text{ g}$$

$m(\text{CO}_2) = 1.16$ billion tonnes of CO_2 produced



$$m(\text{ZnS}) = 235000 \times \frac{65.0}{100} = 1.53 \times 10^5 \text{ g}$$

$$n(\text{ZnS}) = \frac{m}{M} = \frac{1.53 \times 10^5}{(65.38 + 32.06)} = 1568$$

$$n(\text{Zn}) = n(\text{ZnS}) = 1568$$

$$m(\text{Zn}) = n.M = 1568 \times 65.38 = 1.02 \times 10^5 \text{ g}$$

$$m(\text{Zn}) = 10^2 \text{ kg}$$

$$19. n(\text{Al}) = \frac{m}{M} = \frac{3500000}{26.98} = 1.297 \times 10^5$$

$$n(\text{Al}_2\text{O}_3) = \frac{n(\text{Al})}{2} = 6.49 \times 10^4$$

$$m(\text{Al}_2\text{O}_3) = n.M = 6.94 \times 10^4 \times ((2 \times 26.98) + (3 \times 16.00))$$

$$m(\text{Al}_2\text{O}_3) = 6.61 \times 10^6 \text{ g}$$

$$m(\text{Bauxite}) = m(\text{Al}_2\text{O}_3) \times \frac{100}{60.0} = 1.10 \times 10^7 \text{ g}$$

$$m(\text{Bauxite}) = 11.0 \text{ tonnes}$$

FOR THE EXPERTS

20.

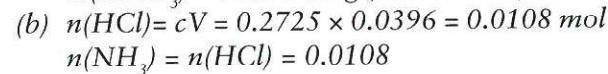


$$n(\text{NH}_3) = \frac{m}{M} = \frac{1.50 \times 10^6}{17.034} = 8.81 \times 10^4 \text{ mol}$$

$$n(\text{HNO}_3) = n(\text{NH}_3) = 8.81 \times 10^4 \text{ mol}$$

$$m(\text{HNO}_3) = nM = 8.81 \times 10^4 \times (1.008 + 14.01 + 48.00)$$

$$m(\text{HNO}_3) = 5.55 \times 10^6 \text{ g (5.55 tonnes)}$$



$$n(\text{NH}_3) = n(\text{HCl}) = 0.0108$$

$$\frac{n(\text{NO}_3^-) \text{ in } 25 \text{ ml aliquot}}{mol} = n(\text{NH}_3) = 0.0108$$

$$n(\text{NO}_3^-) \text{ in } 500 \text{ ml} = 0.0108 \times \frac{500}{25} = 0.2158$$

$$\therefore n(\text{HNO}_3) \text{ in original } 20.0 \text{ g} = 0.2158 \text{ mol}$$

$$m(\text{HNO}_3) \text{ in original } 20.0 \text{ g} = nM$$

$$= 0.2158 \times (1.008 + 14.01 + 48.00) = 13.6 \text{ g}$$

$$\% \text{ mass HNO}_3 = \frac{13.6}{20.0} \times \frac{100}{1} = 68.0\%$$

$$(c) \text{ density} = 1.41 \text{ g cm}^{-3} \quad V = \frac{\text{mass}}{\text{density}} = \frac{20.0}{1.41} = 14.2 \text{ mL}$$

$$\text{mass} = 20.0 \text{ g}$$

$$c(\text{HNO}_3) = \frac{n}{V} = \frac{0.2158}{0.0142} = 15.2 \text{ mol L}^{-1}$$

ANSWERS TO TRIAL TESTS



TRIAL TEST 1: Reaction Rates and Equilibrium

Section 1

- | | |
|------|-------|
| 1. d | 6. d |
| 2. c | 7. b |
| 3. a | 8. c |
| 4. a | 9. d |
| 5. b | 10. b |

[20]

Section 2

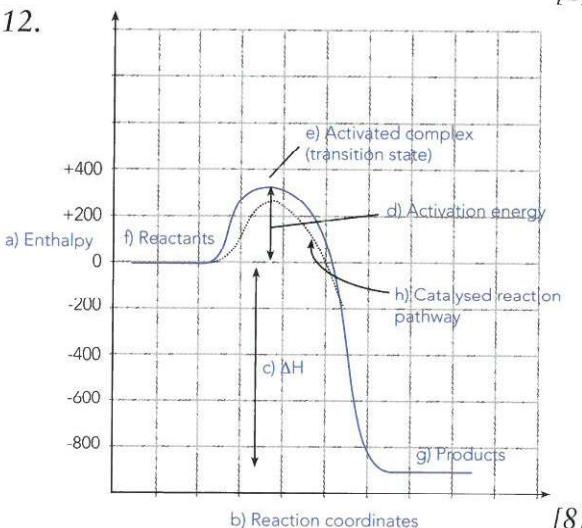
11.

- (a) Increase pressure - concentration of the O_2 is increased, this will increase the likelihood of a successful collision between reactant particles as there are more O_2 particles per unit volume.
- (b) Increase the surface area of the C_8H_{18} - make it into a fine spray. Reactions occur on the surface of solids and liquids - by increasing the surface area the chance of a successful collision is increased.
- (c) Increase the temperature - reactant particles will be moving more rapidly - collisions will be more frequent and more energetic. The number of successful collisions occurring will increase.
or/and:

Add a Catalyst: an alternative reaction pathway exists that requires less energy – hence more of the collisions will now have an energy greater than the activation energy.

[6]

12.



[8]

13.

- (a) Line B is H_2 while line C is NH_3

$$(b) N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(c) At $t = 2$ the forward reaction rate is greater than the reverse reaction rate.
At $t = 10$ the forward and reverse reaction rates are equal.
(d) (i) Forward RR no change since no change to concentrations of the reactants.
(ii) Reverse RR will initially be lower as the concentration of the products is lower.

[8]

14.

- (a) (i) increase, since extra pressure favours the side with less gaseous molecules (there are 3 on the left and only 1 on the right)
(ii) decrease, the equilibrium position shifts to the left to partially counteract the imposed change
(iii) decrease, the equilibrium position shifts to the left to partially counteract the imposed change

$$(b) K = \frac{[HNO_3]^2[NO]}{[NO_2]^3}$$

[8]

15.

- (a) No change – the concentration of the H_2SO_4 has not been changed.
(b) No change – the concentration of the $CaCO_3$ is not altered.
(c) Reverse reaction favoured – concentrations decreased equally – reverse reaction favoured to partially counteract this.

[6]

16.

- (a) (i) Unchanged – white powder will settle on the bottom.
(ii) To the left – white precipitate dissolves.
(iii) To the right – more white precipitate produced.
(b) Exothermic – on warming the reaction is favoured that tries to oppose this warming, ie. reaction that consumes energy is favoured which is the reverse reaction.

[8]

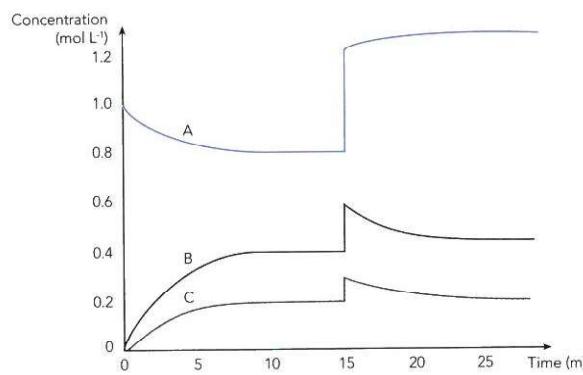
17.

- (a) Equilibrium was reached.
(b) A is CH_3OH , B is H_2 , C is CO

$$(c) K = \frac{[CH_3OH]}{[CO][H_2]^2} = \frac{(0.8)}{(0.2)(0.4)^2} = 2.5$$

(d) Pressure was increased by reducing volume of the containing vessel.

(e)



(f) The equilibrium will shift so as to compensate for the greater imposed pressure. Moves right as there are less molecules. Concentration of the H₂ affected most as there are two molecules of it. The other reactants affected equally (one molecule of each) but in opposite directions.

[16]

TRIAL TEST 2: Acids and Bases

Section 1

- | | |
|------|-------|
| 1. d | 6. d |
| 2. b | 7. a |
| 3. a | 8. b |
| 4. c | 9. b |
| 5. c | 10. d |

[20]

Section 2

11.

(a) Test: Add Ba(NO₃)_{2(aq)} to both solutions
Observation: white precipitate forms in the H₂SO₄, no change in the HNO₃

(b) Test: Add powders to HCl solutions
Observation: MgCO₃ will fizz as bubbles of gas are produced, Mg(OH)₂ will simply dissolve

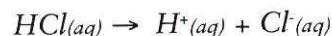
(c) Test: Add universal indicator to both
Observation: KCl solution will turn green, KCH₃COO will form orange/yellow.

[12]

- 12.
- Ba^{2+(aq)} + 2OH^{-(aq)} + 2H^{+(aq)} + SO₄^{2-(aq)} → BaSO_{4(s)} + 2H₂O(l)
 - 3OH^{-(aq)} + H₃PO_{4(aq)} → PO₄^{3-(aq)} + 3H₂O(l)
 - CaCO_{3(s)} + 2H^{+(aq)} → Ca^{2+(aq)} + CO_{2(g)} + H₂O(l)

[6]

13. HCl is a strong acid and is completely ionized when in solution



For HCl, the [H⁺] = [HCl]

CH₃COOH is a weak acid and so only a small percentage of molecules ionise
CH₃COOH_(aq) ⇌ H^{+(aq)} + CH₃COO⁻_(aq)

For CH₃COOH, the [H⁺] < [CH₃COOH]
Therefore, [H⁺] in HCl is > [H⁺] in CH₃COOH and pH of 0.01 mol L⁻¹ HCl is less

[4]

14. (a) H₂CO_{3(aq)} ⇌ H^{+(aq)} + HCO₃⁻_(aq)
(b) H₃PO_{4(aq)} ⇌ H^{+(aq)} + H₂PO₄⁻_(aq)
(c) H₂SO_{4(aq)} ⇌ H^{+(aq)} + HSO₄⁻_(aq)

[6]

15.

(a) Hydrolysis is the reaction between a salt and water to produce either H₃O⁺ ions or OH⁻ ions.

(b)

- CO₃^{2-(aq)} + H₂O(l) ⇌ HCO₃⁻_(aq) + OH⁻_(aq); basic
- CH₃COO⁻_(aq) + H₂O(l) ⇌ CH₃COOH_(aq) + OH⁻_(aq); basic
- NH₄⁺_(aq) + H₂O(l) ⇌ NH_{3(aq)} + H₃O⁺_(aq); acidic

[8]

16.

(a) be obtained pure; have a known formula; not react with surroundings; have a high molar mass

(b) deliquescent: absorbs water from the atmosphere and dissolves in the water

(c) end point: the point at which the titration is stopped because the desired colour change is observed

equivalence point: reactants have been mixed in stoichiometrically equivalent amounts

[8]

17.

(a) H₂PO₄⁻_(aq) + H₂O(l) ⇌ HPO₄^{2-(aq)} + H₃O⁺_(aq)

(b) The OH⁻ ions will reduce the concentration of the H₃O⁺ ions. The forward reaction would be favoured to partially counteract this change and the pH would remain reasonably constant.

(c) The buffer capacity of the solution would be exceeded and the pH would drop considerably.

[6]



$$\begin{array}{rcl} 2\text{ mol} & 1\text{ mol} & \\ M(Na_2CO_3) & & = 45.98 + 12.01 + \\ 48.00 & & 105.99 \end{array}$$

$$n(\text{Na}_2\text{CO}_3) \text{ in } 500 \text{ mL} = \frac{m}{M} = \frac{2.23}{105.99} = 0.0210 \text{ mol}$$

$$c(\text{Na}_2\text{CO}_3) = \frac{n}{V} = 0.0421 \text{ mol L}^{-1}$$

$$n(\text{Na}_2\text{CO}_3) \text{ used in titration} = cV$$

$$= 0.0421 \times 0.0200 = 8.42 \times 10^{-4} \text{ mol}$$

$$n(\text{HCl}) = 2n(\text{Na}_2\text{CO}_3)$$

$$= 2 \times 8.42 \times 10^{-4} = 1.68 \times 10^{-3}$$

$$c(\text{HCl}) = \frac{n}{V} = \frac{1.68 \times 10^{-3}}{0.0413}$$

$$= 4.08 \times 10^{-2} \text{ mol L}^{-1}$$

TRIAL TEST 3: Oxidation and Reduction

Section 1

- | | |
|------|-------|
| 1. d | 6. d |
| 2. c | 7. a |
| 3. d | 8. a |
| 4. a | 9. b |
| 5. c | 10. a |

Section 2

11.

- (a) Equation: $\text{Br}_{2(aq)} + 2\text{I}_{(aq)} \rightarrow 2\text{Br}_{(aq)} + \text{I}_{2(aq)}$
 Observation: straw yellow solution turns a red/brown colour
- (b) Equation: $\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \rightarrow \text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)}$
 Observation: metal turns black and then black coloured crystals grow on it.
 Solution loses blue colour
- (c) Equation: $2\text{Na}_{(s)} + 2\text{H}_2\text{O}_{(l)} \rightarrow 2\text{Na}^{+}_{(aq)} + 2\text{OH}^{-}_{(aq)} + \text{H}_2(g)$
 Observation: silver coloured metal fizzes around on top of water, colourless, colourless gas produced
- (d) Equation: $2\text{MnO}_4^-_{(aq)} + 5\text{H}_2\text{O}_2_{(aq)} + 6\text{H}^+_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 5\text{O}_2(g) + 8\text{H}_2\text{O}_{(l)}$
 Observation: purple solution goes colourless and bubbles of colourless odourless gas produced

[20]

14.

- (a) Anode: $\text{Mg} \rightarrow \text{Mg}^{2+} + 2e^-$
 Cathode: $\text{Sn}^{2+} + 2e^- \rightarrow \text{Sn}$

[12]

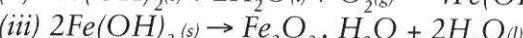
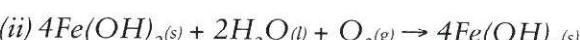
- (b) (i) Coat the windmill with a paint to stop the oxygen and water coming in contact with the iron. This will prevent the cathodic reaction.

- (ii) Connect another metal of higher oxidation potential to the windmill so that the iron acts as a cathode and the other metal an anode. For example if the other metal is zinc it will oxidise instead of the iron.

[12]

15.

- (a)
- $$\begin{array}{rcl} (i) (\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+}_{(aq)} + 2e^-) \times 2 & & \text{anodic reaction} \\ \text{O}_2(g) + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4\text{OH}^-_{(aq)} & & \text{cathodic reaction} \\ \hline 2\text{Fe}_{(s)} + \text{O}_2(g) + 2\text{H}_2\text{O}_{(l)} \rightarrow 2\text{Fe}(\text{OH})_2(s) & & \end{array}$$



(b) Any two of the following:

- Painting or plating the iron. This excludes air and/or water hence reaction prevented.
- Using a sacrificial anode such as galvanising

13.

2.23 V

$\text{KNO}_3(aq)$

e-

-ve ions

e-

Mg²⁺

Mg(NO₃)_{2(aq)}

Sn²⁺

Sn(NO₃)_{2(aq)}

iron with zinc. The more reactive zinc will corrode in preference to the iron.

- Using cathodic prevention by applying a low voltage to, say, a steel jetty. The power source provides a source of electrons in preference to the iron.

[14]

TRIAL TEST 4:
Organic Chemistry

Section 1

- | | |
|------|-------|
| 1. a | 6. a |
| 2. d | 7. c |
| 3. c | 8. d |
| 4. b | 9. c |
| 5. d | 10. d |

[20]

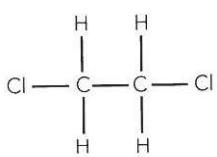
Section 2

11.

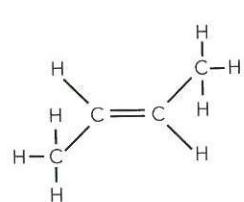
- cis-but-2-ene
- cis-2,2-dibromo-5-methylhept-3-ene
- pentan-2-one
- propanoic acid
- 6,7,7-tribromo-3,4-dichloroheptan-1-amine
- propylethanoate

12.

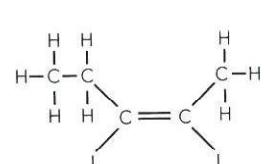
(a)



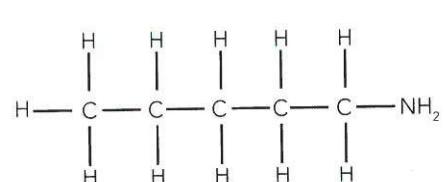
(b)



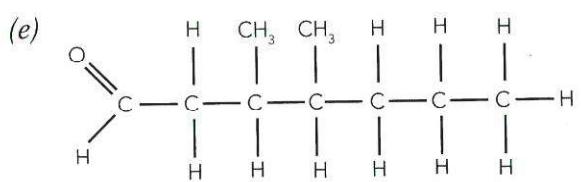
(c)



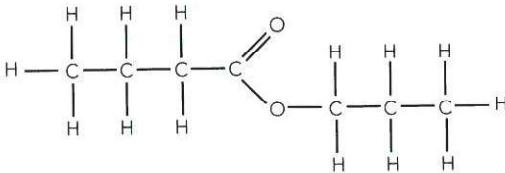
(d)



(e)

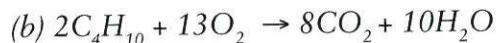
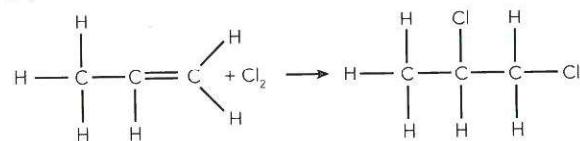


(f)

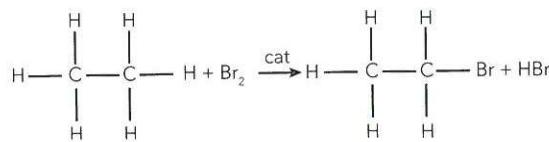


13.

(a)



(c)

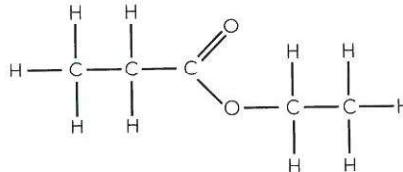


14.

- Oxidation: $CH_3CH_2CHO + H_2O \rightarrow CH_3CH_2COOH + 2H^+ + 2e^-$
Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
Redox: $3CH_3CH_2HO + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow 3CH_3CH_2COOH(aq) + 2Cr^{3+}(aq) + 4H_2O(l)$
Name: propanoic acid
- Oxidation: $CH_3CHOHCH_2CH_3 \rightarrow CH_3COCH_2CH_3 + 2H^+ + 2e^-$
Reduction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
Redox: $5CH_3CHOHCH_2CH_3 + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 5CH_3COCH_2CH_3 + 2Mn^{2+}(aq) + 8H_2O(l)$
Name: butanone

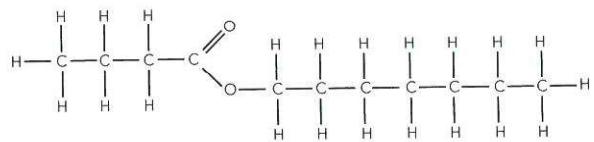
15.

(a)



ethyl propanoate

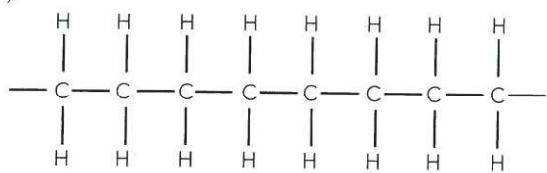
(b)



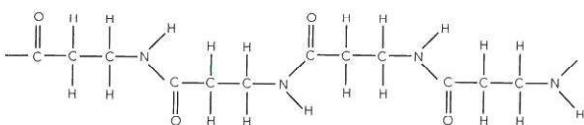
heptyl butanoate

16.

(a)

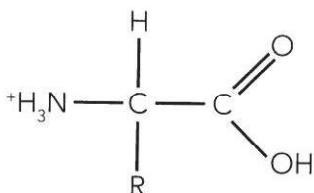


(b)

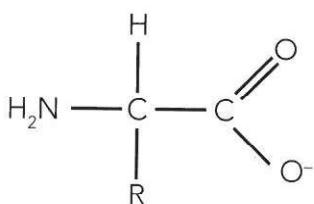


17.

(a)



(b)

18. $\text{nicotine} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + ?$ $0.467 \text{ g} \quad 1.266 \text{ g} \quad 0.3589 \text{ g}$

$$n(\text{C}) = n(\text{CO}_2) = \frac{1.266}{44.01} = 0.02877 \text{ mol}$$

$$m(\text{C}) = 0.02877 \times 12.01 = 0.34548 \text{ g}$$

$$n(\text{H}) = 2n(\text{H}_2\text{O}) = \frac{2 \times 0.3589}{18.016} = 0.03984 \text{ mol}$$

$$m(\text{H}) = 0.03984 \times 1.008 = 0.04016 \text{ g}$$

*2nd sample is different size to first sample
but must contain the same proportion of N.
i.e. proportion N in first sample*

$$= 0.467 \times \frac{0.06263}{0.362}$$

$$= 0.0808 \text{ g}$$

$$n(\text{N}) \text{ in first sample} = \frac{0.0808}{14.01} \times 10^{-3} \text{ mol} = 5.767$$

$$m(\text{O}) \text{ in nicotine} = 0.467 - (0.3455 + 0.04016 + 0.0808) = 0.0 \text{ g}$$

Nicotine contains C, H + N only

C	H	N
0.02877	0.03984	0.005767
0.005767	0.005767	0.005767
4.98	6.91	1

EF of Nicotine = $\text{C}_5\text{H}_7\text{N}$

Sample 3

$$m = 0.964 \text{ g}$$

$$n = \frac{PV}{RT} = \frac{544 \times 0.0500}{8.315 \times 550} = 5.948 \times 10^{-3} \text{ mol}$$

$$M = \frac{m}{n} = \frac{0.964}{5.948 \times 10^{-3}} = 162.08 \text{ g mol}^{-1}$$

$$\text{mass of EF} = 81.116$$

$$\text{mass of molecular formula} = 2 \times \text{mass of EF}$$

$$\therefore \text{molecular formula} = 2 \times \text{EF} \\ = \text{C}_{10}\text{H}_{14}\text{N}_2$$

TRIAL TEST 5:
Chemical Synthesis

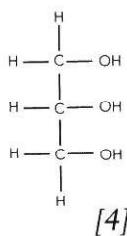
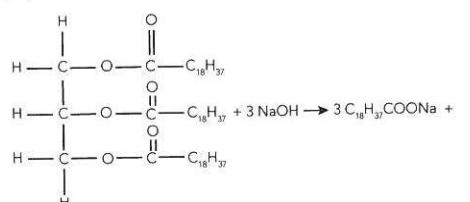
Section 1

- | | |
|------|-------|
| 1. d | 6. c |
| 2. d | 7. a |
| 3. c | 8. b |
| 4. c | 9. c |
| 5. b | 10. d |

Section 2

11.

(a)

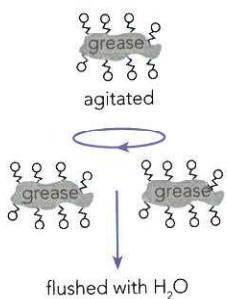


[4]

σ = hydrophilic end

δ = hydrophobic (non-polar) end

(b)

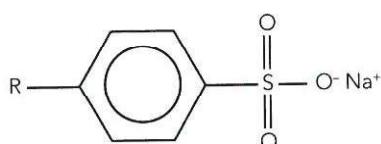


[4]

(c) Water is classified as hard if soap will not lather in it. This is caused by the water containing Mg^{2+} and Ca^{2+} ions that form insoluble salts with soap anions.

[2]

(d)



12.



(b)



[3]

[3]

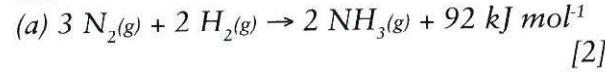
(c) The most common source of ethene and diesel is from crude oil. [2]

(d) Standard fuels are fossil fuels and so are not renewable. Biofuels are from renewable sources and the use of them will prolong the life of the fossil fuels. [2]

(e) lipase and bases (such as sodium hydroxide). [2]

[20]

13.



(b) At high pressure the concentration of all gaseous species is increased. The forward reaction is favoured as it reduces the number of particles and consequently partially counteracts the imposed pressure increase. The forward reaction being favoured leads to a higher yield of NH_3 . [2]

(c) As the forward reaction is exothermic, an increase in temperature will lead to the reverse reaction being favoured to partially counteract the imposed change. This would lead to a lower yield of ammonia. [2]

(d) The Haber process is carried out at approximately 500°C . This high temperature is required to ensure that the reaction rate is sufficiently high to produce ammonia at a rate that is economically viable. [3]

(e) An iron/iron oxide catalyst is used to increase the rate of production of ammonia. As it effects the forward and reverse reactions equally, a catalyst has no effect on the equilibrium yield of ammonia. [3]

[2]

14.

$$(a) m(\text{methane}) = 850\,000 \text{ g}$$

$$n(\text{CH}_4) = \frac{n}{M} = \frac{850000}{16.042} = 5.299 \times 10^4$$

$$n(\text{H}_2) = 3.n(\text{CH}_4) = 1.59 \times 10^5$$

$$m(\text{H}_2) = n.M = 1.59 \times 10^5 \times 2.016 = 3.20 \times 10^5 \text{ g}$$

$$m(\text{H}_2) = 320 \text{ kg}$$

[4]

$$(b) n(\text{CH}_3\text{OH}) = n(\text{CH}_4) = 5.299 \times 10^4$$

$$m(\text{CH}_3\text{OH}) \text{ if } 100\% \text{ efficient} = n.M$$

$$m(\text{CH}_3\text{OH}) = 5.299 \times 10^4 \times (12.01 + 3.024 + 16.00 + 1.008)$$

$$m(\text{CH}_3\text{OH}) = 1.698 \times 10^6 \text{ g}$$

$m(CH_3OH)$ at 92.5% efficiency

$$= 1.698 \times 10^6 \times \frac{92.5}{100}$$

$$m(CH_3OH) = 1.57 \times 10^6 \text{ g} \quad (1.57 \text{ tonne})$$

[6]

15.

(a) By examining the reaction pathways, 1 mole of $Ca(OH)_2$ will lead to 1 mole of Cl_2 being produced.

$$n(Ca(OH)_2) = \frac{m}{M} = \frac{1480000}{(40.08 + 32.00 + 2.016)} \\ = 19974$$

$$n(Cl_2) = \frac{m}{M} = \frac{1120000}{70.90} = 15796$$

If 100% efficient. 19974 mol of $Ca(OH)_2$ should produce 19974 mol of Cl_2 .

Efficiency of process

$$= \frac{(n(Cl_2))}{n(Ca(OH)_2) \times \frac{100}{1}} \\ = \left(\frac{15796}{19974} \right) \times \frac{100}{1} \\ = 79.1\%$$

(b) If 100% efficient, 1kg of sea water would produce 0.0013 kg of Mg

$$i.e. \frac{1}{0.0013} = \frac{x}{1}$$

$x = 7692 \text{ kg}$ (7962 kg of sea water required to produce 1 kg of Mg)

However process is on 79.1% efficient, therefore

$$m(sea \text{ water}) = 7692 \times \frac{79.1}{100}$$

$$m(sea \text{ water}) = 9725 \text{ kg}$$

[12]