EXPLORING

CHEMISTRY

YEAR 12 - EXPERIMENTS, INVESTIGATIONS & PROBLEMS

Worked Solutions

The STAWA *Worked Solutions* have been developed through the collaboration of teachers working in Department of Education, Catholic Education WA and Association of Independent Schools of WA. Funding assistance was provided by the Department of Education.

The *Worked Solutions* are intended to support the Chemical understanding and problem solving section of the STAWA ATAR Exploring Chemistry Year 12: experiments, investigations and problems.

In an endeavour to provide the highest quality publication, the STAWA *Worked Solutions* were written and checked by different teachers. This does not guarantee that all answers are correct. Teachers are advised to work through disputed solutions with their students. If they are sure there is an error then they are asked to forward corrections to STAWA by email: admin@stawa.net

The STAWA *Worked Solutions* are a great example of teachers helping teachers for the benefit of all students.

STAWA
SCIENCE TEACHERS' ASSOCIATION OF WESTERN AUSTRALIA

YEAR 12 ATAR

Answers

Measurement in Chemistry

Set 1: Significant figures and unit conversion

1. (a) 3 (b) 3 (c) 3 (d) 3 (e) 3
   (f) 4 (g) 6 (h) 3

2. (a) 6.409×10^3 (b) 3.2×10^{-2} (c) 8.91×10^5
   (d) 5.38×10^1 (e) 6.1×10^{-6}

3. (a) $8 \times 10^{-4} (\times 10^3) = 0.8$ mm (d) $7.03 \times 10^5 (\div 10^3) = 703$ L
   (b) $4.5 \times 10^3 (\div 10^{-3}) = 4.5$ kg (e) $0.05 \times 10^4 (\times 10^3) = 5 \times 10^5$ mL
   (c) $9.0 \times 10^{-2} (\times 10^3) = 90$ g (f) $2.59 (\div 10^9) = 2.59 \times 10^{-9}$ m

4. In addition or subtraction calculations the answer can have no more digits to the right of the decimal point than are contained in the measurement with the least number of digits to the right of the decimal point.
   3.104
   0.72
   16.2
   +0.002
   20.026 g = 20.0 to the first decimal place Answer: 2.00×10^1

5. 20 kg = 20 x 10^3 g: Number of atoms = total mass ÷ mass per atom
   $= (20 \times 10^3) \div (3.819 \times 10^{-23})$
   $= (20 / 3.819) \times (10^{3+23})$
   $= 5 \times 10^{-23}$ atoms

6.

	Pressure - mmHg	Pressure - atm	Pressure - Pa
(a)	760	1.00	1.01×10^5
(b)	750	9.87×10^{-1}	9.97×10^{-1}
(c)	1.56×10^3	2.05	2.07×10^5
(d)	100	1×10^{-1}	1×10^5
(e)	4.83×10^3	6.36×10^0	7.31×10^3

7. In addition or subtraction calculations the answer can have no more digits to the right of the decimal point than are contained in the measurement with the least number of digits to the right of the decimal point (see qn 4)
   0.103 + **11.45** + **0.01** + 0.001 + 68.53 = 80.094 = 80.09 g (to 2nd decimal place) Answer: 8.009×10^1

Set 2: Errors

1. (a) first weighing = ±2 mg ∴ 0.002/12.363 × 100 = 0.02%; final weighing ± 2 mg ∴ 0.002/0.834 × 100 = 0.2%
   (b) Total error ±4 mg = ±4 mg = 0.004/0.834 × 100 = 0.5 %

2. 153/36671 × 100 = 0.417 %

3. (a) 1 part in 3000 so 3000 × 0.2 = 600 mg
   (b) Min Mass = (0.2 × 100) / 0.01 = 2000 mg or 2 g

4. (a) Smallest mass: 80.1 – 40.2 = 39.9 g (b) (80.3 – 40.0) ± (0.2 + 0.2) = 40.3 ± 0.4 g

5. 6.8245 ÷ 1.13 = 6.03938 (the answer is expressed to the least number of significant figures, which is 3) = **6.04**

6. 0.0229 or 2.29×10^{-2} (the answers is expressed to the least number of significant figures, which is 3)

7. (a) 1.67×10^2 °C or 167 °C (b) -2×10^1 °C or -20 °C

8. (a) 13.6 × 96.485 = 1.31×10^3 kJ mol^{-1} (b) 24.6 × 96.485 = 2.37×10^3 kJ mol^{-1}
   (c) 9.32 × 96.485 = 8.99×10^2 kJ mol^{-1}

9. 350 / 1920 × 100 = 18%

10. 0.24 or 2.4×10^{-1} (the answers is expressed to the least number of significant figures, which is 2)

Answers

Set 3: Random and systematic and errors

1. Random Error: b and d   Systematic Error: a and c

2. No one was right. The instrument can only be read to half a graduation. The bottom of the meniscus should be read so 3.6 or 3.7 mL volume would be acceptable readings.

3. Add percentage errors: (0.12/17)100 + (0.16/273)100 = 0.7655 = 0.77 %

4. density = m/v
   v = m/density = 3.0 / 2.7 = 1.111 cm^3
   v = 51 × 3 × thickness
   thickness = 1.111 / (51 x 3) = 0.007262 = 7.26×10^{-3} cm

5. (a) Jenny   (b) No only random errors can be eliminated by repeating an experiment
   (c) Obtain new glassware and solutions

6. (a) actual error in each titre is half the smallest scale division 0.5 mL or 0.0005 L
   (b) % error: (0.5/20.9)100 = 2.39% .

7. parallax error – note the view of the circles around the burette

8. (a) Lyndon has random errors, Jenny has a close set of inaccurate results - systematic error
   (b) Jenny has high precision and low accuracy, while Lyndon has low accuracy and low precision
   (c) Jenny needs to adjust the sights or obtain new equipment. Lyndon needs coaching

9. (a) (0.6/600)100 = 0.1%
   (b) (0.6/250)100 = 0.24%
   (c) (0.6/30)100 = 2 %

10. (a) (0.05/10.5)100 = 0.48%
    (b) (0.05/25.3)100 = 0.20%
    (c) (0.05/37.2)100 = 0.13%

11. $M(NaHC_3)$ = 22.99 + 1.008 + 12.01 + 48 = 84.008
    $n(NaHC_3)$ = m/M = 2.445 / 84.008 = 0.0291 mol
    $c(NaHCO_3)$ = n/V = 0.0291 / 0.2500 = 0.1164 mol L^{-1}
    % error (assume no error for mass) = (0.3 / 250.0) ×100 = ± 0.12 %
    $c(NaHCO_3)$ = 0.1164 mol L^{-1} ± 0.12 %

    absolute error / 0.11642 = 0.12 %
    absolute error = 0.12/100 × 0.11642 = 0.00014 mol L^{-1}
    $c(NaHCO_3)$ = 0.11642 ± 0.00014 mol L^{-1}

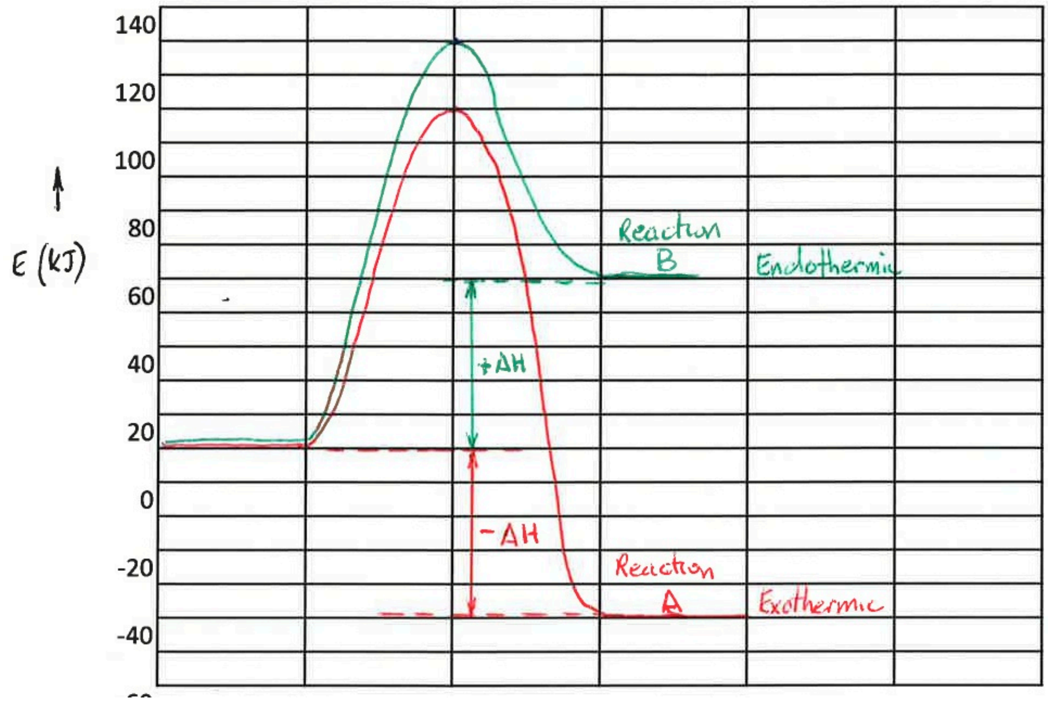
12. (a) Average titre = 22.53 mL (23.15 is outlier)
    Error due to glassware = (2 x 0.05) x 3 readings = 0.3 mL
    % error = 0.3/22.53 × 100 = 1.33%
    (b) Error due to range of titres = 22.60 – 22.45 = 0.15 mL
    % error = 0.15/22.53 × 100 = 0.67%
    (c) % uncertainty in conical flask will be due to pipette
    0.06/20.00 × 100 = 0.3%
    n(NaHCO3) = 0.0446 × 0.02000 = 8.92×10^{-4} mol
    (d) n(H+) = $n(NaHCO_3)$ = 8.92×10^{-4} mole
    C(HCl) = 8.92×10^{-4}/0.02253 = 3.96×10^{-2} mol L^{-1}
    % uncertainty (using glassware tolerance) = 1.33 + 0.3 = 1.63 %
    Absolute uncertainty = 1.63/100 × 3.96×10^{-2} = 6.45×10^{-4}

13. (a) average titre = (5.44 + 5.60 + 5.55)/3 = 5.53
Absolute Uncertainty (glassware) = (2 x 0.10) × 3 = 0.60 mL
% uncertainty = 0.6/5.53 × 100 = 11%
(b) average titre = (24.50 + 24.45 + 24.30)/3 = 24.42 mL
% uncertainty = 0.6/24.42 × 100 = 2.5 %
(c) The smaller the average titre, the greater the effect of the tolerance of the glassware on the uncertainty. From the data above, it can be seen that diluting reduces the error significantly.

Chemical equilibrium

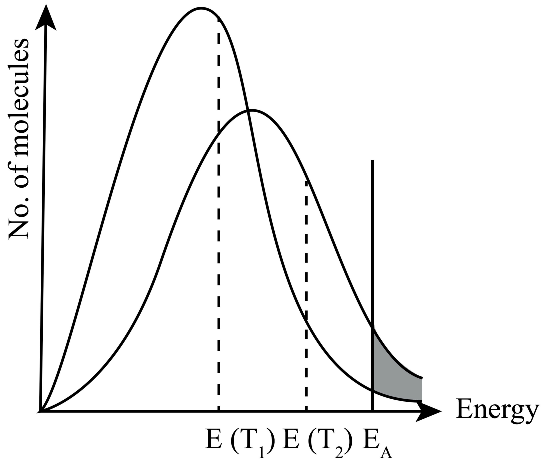
Set 4: Reaction rates and energy

1. (a) Perform the experiment on a balance and observe the rate of loss of mass
(b) Capture the hydrogen by downward delivery of water and read the level of gas at regular intervals
2. Ions in solution need no activation energy, have an infinite surface area while the sugar requires large activation energy and has relatively small surface area
3. (a) increased concentration - more collisions higher rate of forward reaction
(b) increasing the concentration of the acid - more collisions and a higher rate of reaction
4. (a) increasing pressure decreases volume means concentration increases so the rate will increase
(b) no effect as reactants are solutions
5. The catalyst provides a new pathway of lower activation energy. Offering a new pathway with lower activation energy means more particles can achieve activation and the rate will increase.
6. (a)



(b) The heat of reaction of an endothermic reaction is positive (+ΔH), heat is absorbed from the surroundings so the reaction vessel fells cold, while the exothermic reaction releases energy to the surroundings, fells hot, expressed as a negative heat of reaction (-ΔH).
(c) I Reaction A has the lower activation energy so you would expect it (given all other factors equal) to be the faster reaction
II The reverse of Reaction B would be faster as it has the lower activation energy, 70 kJ.

7. Increasing the temperature of a reaction increases its rate. More molecules or reacting particles have energy equal or greater than the activation energy as shown by the shaded section of the graph below. The higher temperature increases the number of collisions and the probability of a collision resulting in a reaction.



E(T) = average energy at temperature T

$T_1 < T_2$

The proportion of molecules with energy equal to or greater than the activation energy, E_A (shaded areas) increases with an increase in temperature

Set 5: Equilibrium constant expressions

1. $K = \frac{[H_2O]^2}{[H_2]^2[O_2]}$	8. $K = [CO_2]$
2. $K = \frac{[N_2]^2[O_2]}{[N_2O]^2}$	9. $K = \frac{[CO_3^{2-}][NH_4^+]}{[HCO_3^-][NH_3]}$
3. $K = \frac{[CH_3OH]}{[H_2]^2[CO_2]}$	10. $K = \frac{1}{[SO_3]}$
4. $K = [Ag^+]^2[CrO_4^{2-}]$	11. $K = [H_2O][CO_2]$
5. $K = \frac{[HCO_3^-][H^+]}{[CO_2]}$	12. $K = \frac{1}{[C\ell_2]}$
6. $K = \frac{[SO_4^{2-}][H_3O^+]}{[HSO_4^-]}$	13. $K = \frac{[Ca^{2+}][HCO_3^-]^2}{[CO_2]}$
7. $K = \frac{[CrO_4^{2-}]^2[H^+]^2}{[Cr_2O_7^{2-}]}$	14. $K = \frac{[HC\ell]^2}{[H_2O][CO_2]}$

Set 6: Equilibrium systems

1. (a) $K = \frac{[NH_3]^2}{[N_2][H_2]^2}$

   (b) (i) decrease (ii) increase (iii) increase (iv) no change

2. (a) $K = \frac{[H^+]^4[OC\ell^-]^2}{[C\ell_2]}$

   (b) (i) increase (ii) decrease (iii) increase (iv) decrease

3. (a) (i) decrease (ii) decrease (iii) increase

   (b) (i) decrease (ii) no change (iii) increase

4. (a) (i) increase (ii) increase (iii) decrease

   (b) (i) increase (ii) decrease (iii) decrease

5. (a) (i) increase (ii) decrease (iii) no change then decrease

   (b) (i) no effect (ii) same concentration (pressure) but more CO_2 is present (iii) increase

Answers

Acids and bases

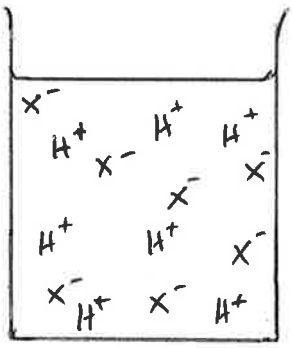
Set 8 Acids and bases

1. Conjugate acids: HF, HCO_3^-, $HC\ell O_4$, HSO_3^-, NH^{4+} 2. Conjugate bases: Br^-, SO_4^{2-}, HPO_4^{2-}, S^{2-}, NO_3^-, OH^-

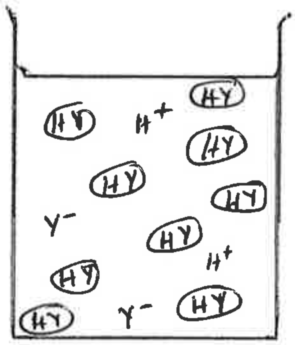
3. (a) $H_2SO_4(aq)\ )\ +\ H_2O(\ell)\ \rightarrow\ H_3O^+(aq) + SO_4^{2-}(aq)$
   (b) $H_2S(aq)\ )\ +\ H_2O(\ell)\ \rightleftharpoons\ H_3O^+(aq)\ +\ HS^-(aq)$
   (c) $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$
   (d) $N_2H4(aq)\ +\ H_2O(\ell)\ \rightleftharpoons\ H^+(aq)\ +\ HS^-(aq)$

4. A strong acid completely ionises in solution, while a weak acid only partially ionises in solution. Acid concentration refers to the amount of acid dissolved. A concentrated solution contains a high proportion of acid, while a dilute acid solution is mainly water with a very small proportion of acid.

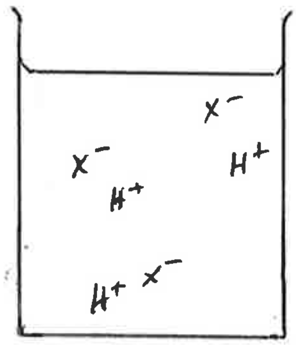
(a) Concentrated solution of a strong acid (HX)



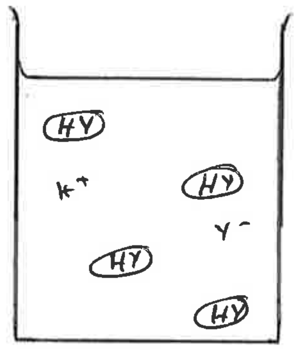
(b) Concentrated solution of a weak acid (HY)



(c) Dilute solution of a strong acid (HX)



(d) Dilute solution of a weak acid (HY)



5. I. conjugate acid–base pairs II. Reaction favours the:

a. $HF\ (aq)\ +\ H_2O\ (l)\ \rightleftharpoons\ F^-\ (aq)\ +\ H_3O^+\ (aq)$
acid base conjugate base conjugate acid — forward reaction

b. $HSO_4^-(aq)\ +\ NH_3(\ aq)\ \rightleftharpoons\ SO_4^{2-}\ (aq)\ +\ NH_4^+\ (aq)$
acid base conjugate base conjugate acid — forward reaction

c. $H_2CO_3\ (aq)\ +\ F^-(\ aq)\ \rightleftharpoons\ HCO_3^-\ (aq)\ +\ HF\ (aq)$
acid base conjugate base conjugate acid — reverse reaction

d. $H_2PO_4^-\ (aq)\ +\ H_2O\ (l)\ \rightleftharpoons\ H_3O^+\ (aq)\ +\ HPO_4^{2-}\ (aq)$
acid base conjugate acid conjugate base — forward reaction

Set 9: Acid and base strength

1. Concentration is a measure of the proportion of solute in a solution. Strength refers to the degree of ion formation that occurs when an acid or base is dissolved in water. For example, hydrogen chloride completely ionises in water and is classified as a strong acid: $HC\ell(aq) \rightarrow H^+(aq) + Cl(aq)$
When the very soluble hydrogen fluoride dissolves in water there is little ionisation and it is classified as a weak acid: $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$

Answers

2. (a) $HC\ell$, HNO_3, H_2SO_4, HBr, HI, $HC\ell O_4$,
(b) CH_3COOH, H_2S, HF, H_3PO_4, $H_2C_2O_4$, HSO_4^-, or any organic acid.
(c) NaOH, KOH, $Ba(OH)_2$, $Ca(OH)_2$, or any metal hydroxide or oxide.
(d) NH_3, CO_3^{2-}, CH_3NH_2 or any organic amine.

3. (a) Concentrated and weak (b) Dilute and strong (c) Concentrated and strong (d) Dilute and weak

4. (i) (a) $HBr(g) \rightarrow H^+(aq) + Br^-(aq)$ (b) ionisation
(c) HBr, OH^-, Br^-, H_3O^+, H_2O
(ii) (a) $CH_3COOH(l) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$ (b) ionisation
(c) OH^-, CH_3COO^-, H_3O^+, CH_3COOH, H_2O
(iii) (a) $H_2SO_4(\ell) \rightarrow H^+(aq) + HSO_4^-(aq)$ and $HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$
(b) ionisation (c) H_2SO_4, OH^-, SO_4^{2-}, HSO_4^-, H_3O^+, H_2O
(iv) (a) $NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (b) ionisation
(c) H_3O^+ or H^+, NH_4^+, OH^-, NH_3, H_2O
(v) (a) $Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$ (b) dissociation
(c) $Ba(OH)_2$, H_3O^+, Ba^{2+}, OH^-, H_2O

5. Stronger acid is $HC\ell O_4$ and the weaker base is $C\ell O_4^-$

6. (a) $H_2S(g) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$ and $HS^-(g) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + S^{2-}(aq)$
(b) Strongest acid is H_3O^+ and the strongest base is S^{2-}

7. (a) $H_3PO_4(\ell) \rightleftharpoons H+(aq) + H_2PO_4^-(aq) > H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq) > HPO_4^{2-}(aq) \rightleftharpoons H^+(aq) + PO_4^{3-}(aq)$
(b) H_2O, H_3PO_4, H_3O^+, $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}, OH^-

8. 99% sulfuric acid consists mostly of H_2SO_4 molecules, as there is little water to allow ionisation, so there are very few hydrogen ions to react with the iron. 2 mol L^{-1} sulfuric acid is a strong acid; there is full ionisation for the release of one hydrogen ion represented by the equation: $H_2SO_4(\ell) \rightleftharpoons H^+(aq) + HSO_4^-(aq)$
There is therefore a high concentration of hydrogen ions which is the species that reacts with the iron in a reaction represented by the equation $2H^+(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + H_2(g)$
Steel wool has a very high surface area and so there are more collisions and a higher rate of reaction.

9. For effective washing, large numbers of OH^- ions are required in the washing powder. To supply these substantial amounts of sodium hydroxide or sodium carbonate need to be present. The sodium hydroxide, being a strong base will produce a high concentration of OH^- ions which can be detrimental to fabrics. It is also dangerous to use, as concentrated OH^- solutions are corrosive to skin. Sodium carbonate, however, is a weak base that produces relatively low concentrations of OH^- ions but as these are consumed, more are produced until all of the carbonate ions are used up. The production of the OH^- ions from the carbonate ions is illustrated by the equation: $CO_3^{2-}(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

10. For this use the hydrogen ion concentration produced in the solution must be very low but there must be a process that replaces the hydrogen ions that are used up. It must therefore be a weak acid. As hydrochloric acid is a strong acid the concentration of hydrogen ions, even in dilute solutions, is relatively high and would damage human skin particularly in sensitive areas such as eyes and areas where fungal infections are likely to occur.

Set 10 : Hydrolysis

1. (a) neutral (b) basic (c) basic (d) acidic (e) basic

2. (b) $PO_4^{3-}(aq) + H_2O(\ell) \rightleftharpoons HPO_4^{2-}(aq) + OH^-(aq)$
(c). $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$
(d_ $NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O+(aq)$
(e) $CH_3COO^-(aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

3. (a) Ammonium nitrate, calcium hydrogenphosphate, potassium sulfate, and ammonium chloride.
(b) The salts contain either an anion of a weak acid or the cation of a weak base.
(c) Ammonium nitrate (↓ pH) $NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
calcium hydrogenphosphate (↑pH) $HPO_4^{2-}(aq) + H_2O(\ell) \rightleftharpoons H2PO4^-(aq) + OH^-(aq)$
and $H_2PO_4^-(aq) + H_2O(\ell) \rightleftharpoons H_3PO_4(aq) + OH^-(aq)$
potassium sulfate (↓pH) $SO_4^{2-}(aq) + H_2O(\ell) \rightleftharpoons HSO_4^-(aq) + OH^-(aq)$
ammonium chloride (↓pH) $NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
(d) These salts contain only ions derived from strong acids and strong bases so they do not react with water to produce the strong acid or strong base.

4. $Ca(H_2PO_4)_2(s) \rightleftharpoons 2H_2PO_4^-(aq) + Ca^{2+}(aq)$ and $H_2PO_4^-(aq) + H_2O(\ell) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$

5. (a) Yes, it becomes basic.
(b) $Na_2CO_3(aq) \rightarrow 2Na^+(aq) + CO_3^{2-}(aq)$ and $CO_3^{2-}(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-\ (aq) + OH^-(aq)$

6. (a) $OH^-(aq) + CH_3COOH(aq) \rightleftharpoons H_2O(\ell) + CH_3COO^-(aq)$ (b) basic, pH > 7.
(c) $CH_3COO^-(aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

7. Yes it becomes basic as F^- is the anion of a weak acid: $F^-(aq)+ H_2O(\ell) \rightleftharpoons HF(aq) + OH^-(aq)$

8. The pH of a solution of ammonium ethanoate depends on the relative strength of the weak base ammonia and the weak acid ethanoic acid. The hydrolysis process is represented by the equations:
$NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$ and $CH_3COO^-(aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$
Their ionisation constants are both close to 1.8×10^{-5} so the solution will be neutral.

Set 11: Water equilibrium

1. $H_2O(\ell) + H_2O(\ell) \rightleftharpoons OH\text{-}(aq) + H_3O^+(aq)$

2. (a) $[OH^-] = 1.00 \times 10^{-14} / [H^+] = 6.76 \times 10^{-8}$ mol L^{-1} (b) Acidic

3. $[H^+] = 1.00 \times 10^{-14} / [OH^-] = 6.33 \times 10^{-9}$ mol L^{-1}

4. (a) $[H^+] = 1.00 \times 10^{-14} / [OH^-] = 6.45 \times 10^{-11}$ mol L^{-1}
(b) $[OH^-] = 2 \times [Ba(OH)_2]$; $[H^+] = 1.00 \times 10^{-14} / [OH^-] = 1.00 \times 10^{-14} / 7.80 \times 10^{-2} = 1.28 \times 10^{-13}$ mol L^{-1}

5. (a) $[OH^-] = 1.00 \times 10^{-14} / [H^+] = 9.62 \times 10^{-14}$ mol L^{-1}
(b) $H_2SO_4(\ell) \rightarrow H^+(aq) + HSO_4^-(aq)$ and $HSO_4^-(aq) \rightarrow 0.9HSO_4^-(aq) + 0.1H^+(aq) + 0.1SO_4^{2-}(aq)$
Overall $H_2SO_4(\ell) \rightarrow 0.9HSO_4^-(aq) + 1.1H^+(aq) + 0.1SO_4^{2-}(aq)$
$[H^+] = 1.1\ [H_2SO_4] = 1.1 \times 0.125 = 0.1375$ mol L^{-1} $[OH^-] = 7.27 \times 10^{-14}$ mol L^{-1}

6. (a) Ionisation of water is endothermic: heat + $H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$ a change in temperature will change the proportion of reactants and products and so change the equilibrium constant.
(b) K value decreases. A decreased in temperature causes the equilibrium position to move to restore some of the heat removed. H^+ and OH^- combine to produce water and heat, concentration become smaller.
(c) If temperature is increased a greater concentration of hydrogen ions will result.
(d) As the temperature is increased the rate of both the forward and reverse reactions will increase, but the endothermic forward reaction increases more than reverse reaction so hydrogen ion concentration increases.

7. (a) $10^{-14}/[H^+] = [OH^-] = 10^{-14}/1.55 \times 10^{-5} = 6.45 \times 10^{-10}$ mol L^{-1} OH^-
(b) Some release of SO_2 from the smelter with elevated levels of CO_2 dissolving in the rainwater.
(c) $SO_2(aq) + H_2O(\ell) \rightleftharpoons HSO_3^-\ (aq) + H^+(aq)$ and $CO_2(aq) + H_2O(\ell) + HCO_3^-(aq) + H^+(aq)$

8. As volumes were equal, the average $[H^+] = (1.6 \times 10^{-4} + 1.3 \times 10^{-6}) /2 = 8.065 \times 10^{-5}$ mol L^{-1}
$[H^+] = 8.07 \times 10^{-5}$ mol L^{-1} As $10^{-14}/[H^+] = [OH^-] = 10^{-14}/8.07 \times 10^{-5} = 1.24 \times 10^{-10}$ mol L^{-1}

9. (a) Stomach Acid : $n = c \times v = 1.5 \times 2.5 \times 10^{-4} = 3.75 \times 10^{-4}$ mol H^+
$\underline{Al_2O_3}$: $n = m/M = 5 \times 10^{-3}/(26.98 + 3(17.00)) = 6.412 \times 10^{-5}$ mol $Al(OH)_3$ ∴ there are 1.93×10^{-4} mol OH^- available
$\underline{Mg(OH)_2}$: $n = m/M = 5 \times 10^{-3}/(24.31 + 2(17.00)) = 8.575 \times 10^{-5}$ mol $Mg(OH)_2$ ∴ there are 1.715×10^{-4} mol OH^- available
Total OH^- = 3.645×10^{-4} mol OH^- available
The acid is INXS by $3.75 \times 10^{-4} - 3.645 \times 10^{-4} = 1.05 \times 10^{-5}$ mol
$c = n/v = 1.05 \times 10^{-5} / 1.5 = 7.00 \times 10^{-6}$ $[OH^-] = 1.43 \times 10^{-9}$ mol L^{-1}

(b) Excess $A\ell(OH)_3$ and $Mg(OH)_2$ would remain undissolved (both insoluble in water) and the concentration of both hydrogen and hydroxide ions would therefore be 1.00×10^{-7} mol L^{-1}.

10. (a) $V(Mg(OH)_2) = 4.86$ mL
(b) $[H^+] = 8.34 \times 10^{-3}$ mol L^{-1} $[OH^-] = 1.20 \times 10^{-12}$ mol L^{-1}

Set 12: Indicators and their use

1. (a) An organic acid or base
(b) The acid must be distinctly different in colour from its conjugate base:
e.g.: H(Litmus) (aq) ⇌ H^+(aq) + $(Litmus)^-$(aq)
Red   Blue

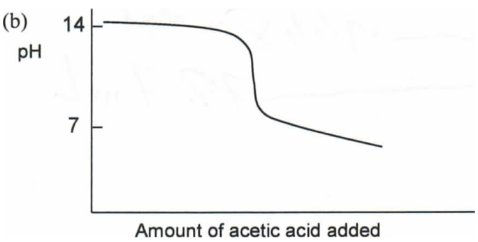
2. (a) H(Indicator)(aq) ⇌ H^+(aq) + $(indicator)^-$(aq)
(b) Addition of an acid increases $[H^+]$, causes more H(Indicator) to be produced and a reduction in the concentration of $(Indicator)^-$. The colour changes from the $(Indicator)^-$ colour to the H(Indicator) colour.
(c) Addition of a base reduces $[H^+]$ as H^+ reacts with OH- to produce water. This causes the production of more $(Indicator)^-$ and less H(Indicator). The colour changes from H(Indicator) colour to $(Indicator)^-$ colour.
(d) *Addition of Acid:* increase in the rate of the reaction producing H(Indicator) with no immediate change to the reaction producing $(Indicator)^-$ hence a colour change from (Indicator)" colour to H(Indicator) colour.
Addition of Base: a reduction in $[H^+]$ causes a reduction in the rate of the reaction producing H(Indicator) with no immediate change in the rate of the reaction producing $(Indicator)^-$ hence a colour change from H(Indicator) colour to $(Indicator)^-$ colour.

3.

(a)	Phenolphthalein	Alizarin Yellow	Indigo Carmine
(b)	<pH=8.3 Colourless)	<pH = 10.1 (Yellow)	<pH = 11.4 (Blue)
	>pH = 10 (Pink)	>pH = 12.0 (Red)	>pH = 13.0 (Yellow)
(c)	8.3 to 10	|10.1 to 12.0	11.4 to 13.0

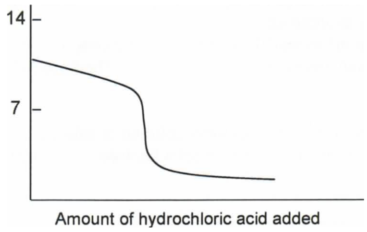
4.

(a)	Methyl red	Methyl orange	Bromophenol blue	Methyl violet
(b)	<pH = 4.4 (Red) >pH = 6.2 (Yellow)	<pH = 3.1 (Red) >pH = 4.4 (Yellow)	<pH = 3.0 (Yellow) >pH = 4.6 (blue)	<pH = 0 (Yellow) >pH = 1.6 (Violet)
(c)	4.4 to 6.2	3.1 to 4.4	3.0 to 4.6	0 to 1.6

5. (a) H_2O, Na^+, CH_3COO^-, OH^-, CH_3COOH, H^+
(b)


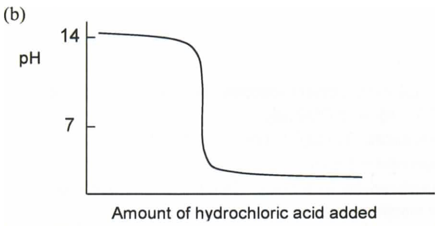
(c) The solution is basic: $CH_3COO^-(aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$
(d) Phenolphthalein. The end point (colour changes) must occur at the equivalence point. Equivalence point is basic use indicator that changes colour within pH 7 and 11. Phenolphthalein changes in pH range 8.3 to 10.

6. (a) H_2O, $C\ell^-$, NH_4^+, H_3O^+, NH_3, OH^-
(b)



(c) The solution is acidic: $NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
(d) Methyl orange, methyl red or bromothymol blue. Acid end point use indicator that changes colour at a pH between about 3 and 7.

7. (a) H_2O, Ca^{2+} / $C\ell^-$, OH^- / H^+
(b)



(c) The solution is neutral. Calcium ion and chloride ion do not undergo hydrolysis.
(d) End point pH = 7: Indicator that changes colour in the range of pH = about 3 to 11.

8. (a) Phenolphthalein (b) More acid will be used (c) Concentration measured lower than it actually is

Set 13: The pH scale

1. (a) $[H^+] = [HC\ell] = 0.100$ mol L^{-1} $[OH']= 1.00 \times 10^{-13}$ mol L^{-1}; pH = 1.00
(b) $[H^+] = [HNO_3] = 0.00500$ mol L^{-1} $[OH] = 2.00 \times 10^{-12}$ mol L^{-1}; pH = 2.30
(c) [OH-] = [NaOH] = 0.0100 mol L^{-1} $[H^+] = 1.00 \times 10^{-12}$ mol L^{-1}; pH = 12.0
(d) $[H^+] = [HC\ell] = 2.00$ mol L^{-1} $[OH^-] = 5.00 \times 10^{-15}$ mol L^{-1}; pH = 0.300
(e) $[H^+] = [OH^-] = 1.00 \times 10^{-14}$ mol L^{-1} and the pH = 7.00. Neutral as solutions of Na^+ ions and $C\ell^-$ ions do not hydrolyse in water.

2. (a) $[H^+] = 1.00 \times 10^{-3}$ mol L^{-1} $[OH^-] = 1.00 \times 10^{-11}$ mol L^{-1}
(b) $[H^+] = 1.00 \times 10^{-11}$ mol L^{-1} $[OH^-] = 1.00 \times 10^{-3}$ mol L^{-1}
(c) $[H^+] = 10.0$ mol L^{-1} $[OH^-] = 1.00 \times 10^{-15}$ mol L^{-1}
(d) $[H^+] = 2.75 \times 10^{-5}$ mol L^{-1} $[OH^-] = 3.63 \times 10^{-10}$ mol L^{-1}
(e) $[H^+] = 2.51 \times 10^{-8}$ mol L^{-1} $[OH^-] = 3.98 \times 10^{-7}$ mol $L-^1$

3. Concentration changed by a factor of 1000

4. Depleted Solution: pH = 2 ∴ $[H^+] = 10^{-2}$ so n = c × v = 0.01 × 2 = 0.02 mol H^+
Added acid : n = c × v = 3.00 x 3.00 = 9.00 mol H^+
Total acid = 9.02 mol New c = n/v = 9.02 / 5 = $[H^+]$ = 1.80 mol L^{-1}

5. pH 5 = 10^{-5} mol L^{-1} = 0.00001 mol L^{-1} pH 3.6 = $10^{-3.6}$ mol L^{-1} = 2.52×10^{-4} mol L^{-1}
$c_1v_1 = c_2v_2$ = $10^{-5} \times X = 0.025 \times 2.52 \times 10^{-4}$ = 630 mL
Water required = 630 - 25.0 = 605 mL

6. pH 12 ∴ pOH =2 so $[OH^-]$ = 0.01 mol L^{-1} pH 11.7 ∴ pOH =2.3 so $[OH^-] = 10^{-2.3}$ = 0.0050 mol L^{-1}
∴ he needs to add 0.01 - 0.0050 = 0.005 mol/L
He has only 100mL so needs to add 0.0005 mol NaOH
$m(NaOH)_{\text{to be added}}$ = nM = 0.0005 × 39.998 = 0.00200 g = 20.0 mg

7. (a) Drain : $n = c \times v = 0.236 \times 0.200 = 0.0472$ mol
Runoff : $n = c \times v = 0.156 \times 0.300 = 0.0468$ mol
New $c = n/v = (0.0472 + 0.0468) / (0.2 + 0.3) = 0.188$ mol L^{-1} OH^-
∴ pOH = 0.726 ∴ pH = 14 – 0.726 = 13.3
(b) $V(HC\ell) = n(H^+) / c = 0.094 / 1 = 0.094$ L = 94 mL per 500 mL ∴ 188 mL per litre

8. pH 5.5 ∴ $[H^+] = 10^{-5.5} = 3.162 \times 10^{-6}$ mol L^{-1}
$n = c \times v = 3.162 \times 10^{-6} \times 15000 = 4.743 \times 10^{-2}$ mol H^+
NaOH : 10g ∴ $n=m/M = 10/39.99 = 0.25$ mol of OH^-
Result : 0.2026 mol NaOH INXS ∴ $c=n/v = 0.2026/15000 = 1.351 \times 10^{-5}$ mol L^{-1} OH^-
∴ the pOH = 4.87 ∴ pH = 14 – 4.87 = 9.13

9. pH 7.20 ∴ $[H^+] = 10^{-7.2} = 1.584 \times 10^{-8}$ mol L^{-1} H^+
$n = c \times v = 1.584 \times 10^{-8} \times 2.0 \times 10^{6} = 0.03168$ mol H^+
pH 7.8 ∴ $[H^+] = 10^{-7.8} = 6.3095 \times 10^{-8}$ mol L^{-1} H^+
$n = c \times v = 6.3095 \times 10^{-8} \times 2.0 \times 10^{6} = 0.12619$ mol H^+
Needs to increase mol H^+ by 0.12619 - 0.03168 = 0.09451 mol
$V(HC\ell) = n(H^+_{required}) / c = 0.09451/12.0 = 7.87$ mL

10. (a) pH 6.75 ∴ $[H^+] = 10^{-6.75} = 1.778 \times 10^{-7}$ mol L^{-1} H^+
pH 5.1∴ $[H^+] = 10^{-5.1} = 7.943 \times 10^{-6}$ mol L^{-1} H^+
Average = 4.0605×10^{-6} mol L^{-1} H^+
$pH = -\log_{10}[H^+] = -\log_{10}(4.059 \times 10^{-6}) = 5.39$

(b) pH 6.75 ∴ $[H^+] = 10^{-6.75} = 1.778 \times 10^{-7}$ mol L^{-1} H^+
pH 8.00 ∴ pOH = 6 ∴ $[OH-] = 10^{-6} = 1 \times 10^{-6}$ mol L^{-1} OH^-
Mix 1 L of each
OH^- INXS by : $1 \times 10^{-6} - 1.68 \times 10^{-7} = 8.22 \times 10^{-7}$ mol OH^-
$c = n/v = 8.22 \times 10^{-7}/2 = 4.11 \times 10^{-7}$ mol L^{-1} OH^-
$pOH = -\log_{10}[OH^-] = -\log_{10}(4.11 \times 10^{-7}) = 6.39$
∴ pH = 14-6.39 = 7.61

Set 14: Buffers

1. Buffer solutions resist a change in pH even with the addition of substantial amounts of hydrogen or hydroxide ions. Many specific reactions that occur in biological systems occur only at specific pH values. Some reactions produce or use up hydrogen ions in these solutions. Buffers prevent large changes in the pH of solutions such as - blood, cell contents and lymph system allowing vital reactions to continue.

2. $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(\ell)$ $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$
Thus a buffer can accept or donate a proton to approximately maintain pH

3. Buffer solutions can be produced that have specific and known pH value. The fixed pH values are use as standards to calibrate the meters.

4. (a) Hypochlorite ions added to pool water as sodium hypochlorite solution or calcium hypochlorite solid to kill micro organisms. Weak acid hypochlorous acid forms: $OC\ell^-(aq) + H_2O(\ell) \rightleftharpoons HOC\ell(aq) + OH^-(aq)$
The buffer uses up some of these OH^- ions stopping the pool water becoming alkaline too quickly.
(b) $OH^-(aq) + HCO_3^-(aq) \rightleftharpoons H_2O(l) + CO_3^{2-}(aq)$ and $HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$: H^+ reacts with the OH^-. Both processes use up OH^- ions.

5. (a) H_2O and HCO_3^- ion (b) $CO_2(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$
H^+ ion is used up by reacting with the HCO_3^- and OH^- ions is used up by reacting with CO_2 directly, $OH^-(aq) + CO_2(aq) \rightleftharpoons HCO_3^-(aq)$ or with H^+ ions, results in more H^+ ions. $H^+(aq) + OH^-(aq) \rightleftharpoons H_2O(\ell)$

6. Method 1: Add an equal volume of 1 mol L^{-1} sodium ethanoate solution
Method 2: Add an equal volume of a 0.5 mol L^{-1} solution of sodium hydroxide. This would react with half the acetic acid to produce acetate ion as in the equation: $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(\ell)$

7. Method 1 Make a solution in water of the sodium citrate mixed with an equal number of moles of citric acid.
Method 2 Make a solution in water of the sodium citrate add 1½ times number of moles of hydrochloric acid.
This reacts with half the citrate ion: $C_6H_5O_7^{3-}(aq) + 3H^+(aq) \rightleftharpoons H_3C_6H_5O_7(aq)$

8. A change in temperature changes the equilibrium concentration of the species in equilibrium and as one of the species is always either H^+ or OH^- ions, changing their concentrations changes the pH.

Set 15: Acid-base titrations 1

1. (a) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
$n(H^+) = cV = (2.00 \times 0.100) = 0.200$ mol
$n(OH^-) = n(NaOH) = n(HCl) = n(H^+)$
$V(NaOH) = n/c = 0.200 / 0.500 = 0.400$ L or 400 mL — $V = 0.400$ L
(b) $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(\ell)$
$n(CH_3COOH) = cV = (1.50 \times 0.150) = 0.225$ mol
$n(OH^-) = n(NaOH) = n(CH_3COOH)$
$V(NaOH) = n/c = 0.225 / 0.500 = 0.450$ L or 450 mL — $V = 0.450$ L
(c) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
$n(H^+) = 2n(H_2SO_4) = cV = 2(0.250 \times 0.020) = 0.0100$ mol
$n(OH^-) = n(NaOH) = n(H^+)$
$V(NaOH) = n/c = 0.0100 / 0.500 = 0.0200$ L or 20.0 mL — $V = 0.0200$ L
(d) $H_3PO_4(aq) + 3OH^-(aq) \rightarrow PO_4^{3-}(aq) + 3H_2O(1)$
$n(H^+) = 3n(H_3PO_4) = cV = 3(0.800 \times 0.0750) = 0.180$ mol
$n(OH^-) = n(NaOH) = n(H^+)$
$V(NaOH) = n/c = 0.180 / 0.500 = 0.360$ L or 360 mL — $V = 0.360$ L

2. (a) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
$n(OH^-) = n(NaOH) = cV = (0.600 \times 0.200) = 0.120$ mol
$n(OH^-) = n(H^+)$
$n(H_2SO_4) = ½\, n(H^+) = 0.0600$ mol
$V(H_2SO_4) = n/c = 0.0600 / 0.200 = 0.300$ L or 300 mL — $V = 0.300$ L
(b) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
$n(H_2SO_4) = n(Ba(OH)_2) = cV = (0.100 \times 0.0500) = 0.00500$ mol
$V(H_2SO_4) = n/c = 0.00500 / 0.200 = 0.0250$ L or 25.0 mL — $V = 0.0250$ L

3. $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
$n(H^+) = cV = (0.105 \times 0.0211) = 0.00221$ mol
$n(OH^-) = n(KOH) = n(H^+)$
$c(KOH) = n/V = 0.0221 / 0.0250 = 0.0886$ mol L^{-1}
8.86×10^{-2} mol L^{-1}

4. $H_2SO_4\ (aq) + 2NaOH\ (aq) \rightarrow Na_2SO_4\ (aq) + 2H_2O(\ell)$
$n(H_2SO_4) = ½\, n(NaOH) = ½\, (cV) = ½\, (2.00 \times 0.0222) = 0.0222$ mol
$c(H_2SO_4) = n/V = 0.0222 / 0.00500 = 4.44$ mol L^{-1}

5. $Na_2CO_3\ (aq) + 2HNO_3\ (aq) \rightarrow 2NaNO_3\ (aq) + CO_2\ (g) + 2H_2O(\ell)$
$n(HNO_3) = cV = (1.00 \times 0.00350) = 0.00350$ mol
$n(Na_2CO_3) = ½\, n(HNO_3) = 0.00175$ mol
$c(Na_2CO_3) = n/V = 0.00175 / 0.0250 = 0.0700$ mol L^{-1}
7.00×10^{-2} mol L^{-1}

6. $Mg(OH)_2 + 2HC\ell \rightarrow MgC\ell_2 + 2H_2O$
$M(Mg(OH)_2) = 24.31 + 2(16 + 1.008) = 58.326$
$n(Mg(OH)_2) = m/M = 0.450 / 58.326 = 0.00771$ mol
$n(HC\ell)$ reacting $= 2n(Mg(OH)_2) = 0.0153$ mol
$V(HC\ell)$ reacting $= n/c = 0.0154 / 0.150 = 0.103$ L
$V(HC\ell)$ reacting $= 0.103$ L

7. $CaO + 2HC\ell \rightarrow CaC\ell_2 + H_2O$
 $n(HC\ell) = cV = (1.50 \times 0.250) = 0.375$ mol
 $n(CaO) = ½\, n(HC\ell) = ½\,(0.375) = 0.1875$ mol
 $m(CaO) = nM = 0.1875 \times (40.08 + 16.00) = 10.5$ g
 $m(CaO) = 10.5$ g

8. $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2CO_2 + 2H_2O$
 m = 600 g m? V?
 $M\,(NaHCO_3) = 22.99+1.008+12.01+48 = 84.008$
 $M\,(H_2SO_4) = 2(1.008)+32.07+4(16.00) = 98.086$
 (a) $n(NaHCO_3) = m/M = 600 / 84.008 = 7.142$ mol
 $n(H_2SO_4) = ½\, n(NaHCO_3) = 3.571$ mol
 $m(H_2SO_4) = nM = 3.571 \times 98.086 = 350$ g
 (b) $V(H_2SO_4) = n/c = 3.571 / 12.0 = 0.297$ L (297 mL)

9. (a) i) 0.107 mol L^{-1} (ii) 3.89 g L^{-1} (b) 0.935 L (935 mL) (c) 0.140 L (140 mL)

10. 7.34×10^{-2} mol L^{-1}
11. 25.2 mL of KOH

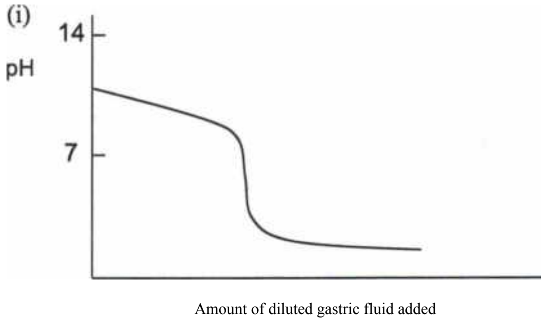
12. 57.5%
13. 192 g mol^{-1}

14. 0.954 g of Na_2CO_3

Set 16 : Acid-bases titrations 2

1. [Acid] = 1.38×10^{-5} mol L^{-1}
2. [Acid] = 2.53 mol L^{-1}
3. $[HCO_3^-] = 6.32 \times 10^{-6}$ mol L^{-1}
4. [OH-] = 1.59×10^{-6} mol L-^{1}
5. [lactic acid] = 9.97×10^{-6} mol L^{-1}
6. $pH = -\log_{10}[H^+] = -\log_{10}(1\ 1.2) = -1.05$
7. $[H_3C_6H_5O_7]_{ppm} = 31.4$ ppm
8. (a) $NH_3(aq) \rightleftharpoons H^+(aq) + NH_4^+(aq)$
 (b) $pH = -\log_{10}[H^+] = -\log_{10}(8.737 \times 10^{-3}) = 2.06$

(i)



 (ii) methyl orange, methyl red or bromothymol blue.
 (iii) As the equivalence point is acidic an indicator that changes colour at a pH between about 3 and 7 is required. Methyl orange (3.1 - 4.4), methyl red (4.4 - 6.2) and bromothymol blue (3.0 - 4.6) all change colour within this range.

9. [Fe]ppm = 20.1 ppm
10. %Pb = 90.4%

Set 17: Acids and bases in action: no answers provided

Oxidation and reduction

Set 18: Oxidation number

1.

(a)	+4	(b)	-2	(c)	+6	(d)	+2	(e)	+6	(f)	+5
(g)	-3	(h	+2	(i)	+5	(j)	+5	(k)	-4	(l)	+4
(m)	-2	(n)	0	(o)	+2	(p)	+4	(q)	+1	(r)	-3
(s)	+5	(t)	-2	(u)	+4	(v)	+2	(w)	+1	(x)	+2
(y)	+2	(z)	+3								

2. (a) Mg (0 +2) O (0 -2)
 (b) Na (0 + 1) H (+1 0)
 (c) I (-1 0) C(0 -1)
 (d) S (-2 0) N (+5 +2)
 (e) S (-2 0) Mn (+7 +2)
 (f) Sn (+2 +4) O (0 -2)
 (g) Br (-1 0) S (+6 +4)
 (h) Fe (+2 +3) Cr (+6 +3)
 (i) None (this is an acid/base reaction)
 (j) N (-3 0) N (+3 0)

Answers

(k) None (this is a precipitation reaction)
(l) None (this is an acid/carbonate equation)
(m) None (acid/base neutralisation equation)
(n) None (this is a precipitation reaction)

Set 19: Balancing half equations

1. $Mg \rightarrow Mg^{2+} + 2e^-$ Oxidation
2. $S + 2e^- \rightarrow S^{2-}$ Reduction
3. $2Cl^- \rightarrow Cl_2 + 2e^-$ Oxidation
4. $Ca \rightarrow Ca^{2+} + 2e^-$ Oxidation
5. $I_2 + 2e^- \rightarrow 2I^-$ Reduction
6. $Zn \rightarrow Zn^{2+} + 2e^-$ Oxidation
7. $Cu^+ \rightarrow Cu^{2+} + e^-$ Oxidation
8. $Au^+ + e^- \rightarrow Au$ Reduction
9. $2H^+ + 2e^- \rightarrow H_2$ Reduction
10. $Cu^{2+} + 2e^- \rightarrow Cu$ Reduction
11. $AsO_3^{3-} + H_2O \rightarrow AsO_4^{3-} + 2H^+ + 2e^-$ Oxidation
12. $S_2O_3^{2-} + 5H_2O \rightarrow 2SO_4^{2-} + 10H^+ + 4e^-$ Oxidation
13. $NO_3^- + 10H^+ + 8e^- \rightarrow NH_4^+ + 3H_2O$ Reduction
14. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ Reduction

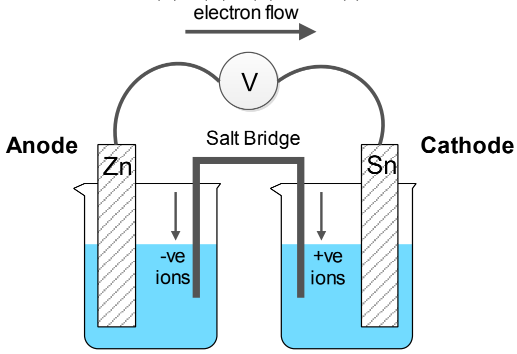
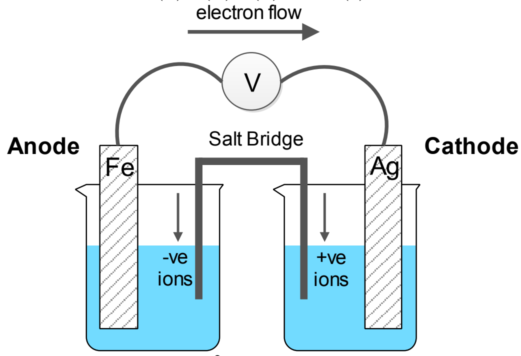
Set 20: Balancing redox equations

1. $Br_2 + 2I^- \rightarrow 2Br^- + I_2$
2. $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$
3. $Mg + Pb^{2+} \rightarrow Mg^{2+} + Pb$
4. $Mg + 2H^+ \rightarrow Mg^{2+} + H_2$
5. $2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$
6. $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$
7. $2Al + 3Zn^{2+} \rightarrow 2Al^{3+} + 3Zn$
8. $Cu + 2Fe^{3+} \rightarrow Cu^{2+} + 2Fe^{2+}$
9. $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$
10. $C\ell_2 + 2I^- \rightarrow 2C\ell^- + I_2$.
11. $2Li + 2H_2O \rightarrow 2Li^+ + 2OH^- + H_2$
12. $Cu + 2NO_3^- + 4H^+ \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$
13. $Cu + SO_4^{2-} + 4H^+ \rightarrow Cu^{2+} + SO_2 + 2H_2O$
14. $2H_2O_2 \rightarrow 2H_2O + O_2$
15. $Cr_2O_7^{2-} + 8H^+ + 3C_2H_5OH \rightarrow 2Cr^{3+} + 3CH_3CHO + 7H_2O$
16. $Mg + 2H_2O \rightarrow Mg^{2+} + H_2 + 2OH^-$
17. $Cu_2O + 2H^+ \rightarrow Cu + Cu^{2+} + H_2O$
18. $4Au + 16CN^- + 3O_2 + 12H^+ \rightarrow 4[Au(CN)_4]^- + 6H_2O$

19. (a) $I_2 + 2e^- \rightarrow 2I^-$ (b) $S_2O_3^{2-} + 5H_2O \rightarrow 2SO_4^{2-} + 8e^- + 10H^+$
(c) $S_2O_3^{2-} + 5H_2O + 4I_2 \rightarrow 2SO_4^{2-} + 10H^+ + 8I^-$
20. (a) $CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 2H^+ + 2e^-$ (b) $O_2 + 2H_2O + 8e^- \rightarrow 4OH^-$
(c) $2CH_3CH_2OH + O_2 \rightarrow 2CH_3COOH$
21. (a) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (b) O_2 is reduced and C in the glucose is oxidised
(c) O_2 is the oxidising agent, $C_6H_{12}O_6$ is the reducing agent
22. (a) Ox: $Mg \rightarrow Mg^{2+} + 2e^-$ Red: $Ti^{4+} + 4e^- \rightarrow Ti$ RedOx: $2Mg + TiC\ell_4 \rightarrow 2MgC\ell_2 + Ti^{4+}$
(b) $TiC\ell_4$ is reduced, Mg metal is oxidised
23. (a) $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ (b) NO_2 is both (c) A disproportionation reaction

Set 21: Galvanic cells

1.

(i)	(ii)
(a), (d), (e) and (f)  1.0 M Zn^{2+} 1.0 M Sn^{2+}	(a), (d), (e) and (f)  1.0 M Fe^{2+} 1.0 M Ag^+
(b) $Zn \rightarrow Zn^{2+} + 2e^-$ // $Sn^{2+} + 2e^- \rightarrow Sn$	(b) $Ag^+ + e^- \rightarrow Ag$ // $Fe \rightarrow Fe^{2+} + e^-$
(c) $Zn + Sn^{2+} \rightarrow Zn^{2+} + Sn$	(c) $2Ag^+ + Fe \rightarrow 2Ag + Fe^{2+}$
(g) $E^o = +0.62$ V	(g) $E^o = +1.24$ V

Answers

2. (a) $Cr + 3Ag^+ \rightarrow Cr^{3+} + 3Ag$ $E^o = +1.54$ V
   (b) $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$ $E^o = +2.70$ V
   (c) $Mg + 2Ag^+ \rightarrow Mg^{2+} + 2Ag$ $E^o = +3.61$ V
   (d) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$ $E^o = +0.59$ V
   (e) $C\ell_2 + 2I^- \rightarrow 2C\ell^- + I_2$ $E^o = +0.82$ V

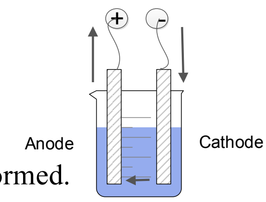
3. (a) yes $E^o = +0.97$ (b) no $E^o = -0.94$ (c) no $E^o = -1.53$ (d) no $E^o = -0.34$

4. (a) $Mg + 2H^+ \rightarrow Mg^{2+} + H_2$ $E^o = +2.36$ V
   $Sn + 2H^+ \rightarrow Sn^{2+} + H_2$ $E^o = +0.14$ V
   $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$ $E^o = +0.76$ V
   $Sr + 2H^+ \rightarrow Sr^{2+} + H_2$ $E^o = +2.90$ V
   $Cu + 2H^+ \rightarrow Cu^{2+} + H_2$ $E^o = -0.34$ V
   $Ag + H^+ \rightarrow Ag^+ + H_2$ $E^o = -0.80$ V
   Only those with a positive E^o will be spontaneous. Mg, Sn, Zn, Sr
   (b) The total E^o must be positive for the first but negative for the second.
   (i) Sn or Ni (ii) acidified H_2O_2 or MnO_4^- (iii) Pb, Sn, Ni, Co
   (iv) $O_2/4H^+$, $Cr_2O_7^{2-}$, $C\ell_2$ (v) Au, $C\ell^-$

5. (a) $Fe^{2+} + Fe^{2+} \rightarrow Fe^{3+} + Fe$ $E^o = -1.21$V not spontaneous
   (b) $H_2O_2 + H_2O_2 \rightarrow 2H_2O + O_2$ $E^o = +1.06$ V spontaneous
   (c) $C\ell_2 + C\ell_2 \rightarrow HOC\ell + HC\ell$ $E^o = -0.27$ V not spontaneous

6. (a) $C\ell_2 + 2Br^- \rightarrow 2C\ell^- + Br_2$ +0.28 V
   (b) No reaction
   (c) $2A\ell + 6H^+ \rightarrow 2A\ell^{3+} + 3H_2$ +1.68 V
   (d) $Fe + Sn^{2+} \rightarrow Fe^{2+} + Sn$ +0.30 V
   (e) No Reaction
   (f) $Cr_2O_7^{2-} + 8H^+ + 3H_2S \rightarrow 2Cr^{3+} + 7H_2O + 3S$ +1.19 V
   (g) No Reaction
   (h) Both Br^- and Fe^{2+} are oxidized

Set 22: Electrolytic Cells



1. (a) See diagram
   (b) Anode: $2I^-(aq) \rightarrow 2e^- + I_2(aq)$ Cathode : $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
   (c) -0.54 + 0.34 = -0.20 V The cell would require at least 0.20 V to be supplied
   (d) The blue solution would fade, salmon pink deposit on electrode and brown solution formed.

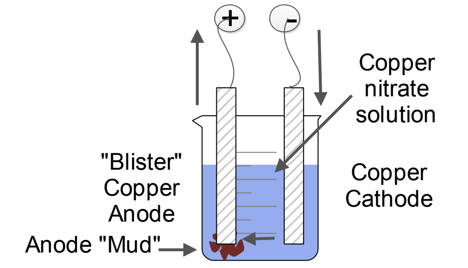
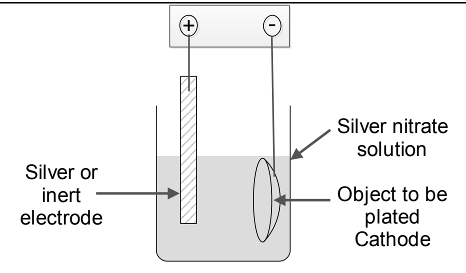
2.

	HBr	NiI_2	$KC\ell$
Products	H_2 and Br_2	Ni and I_2	$C\ell_2$ and K
Anode	$2Br^-(aq) \rightarrow 2e^- + Br_2(aq)$	$2I^-(aq) \rightarrow I_2(aq) + 2e^-$	$2Cl^- \rightarrow 2e^- + Cl_2$
Cathode	$2H^+(aq) + 2e^- \rightarrow H_2(g)$	$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	K+ + e- $\rightarrow$ K
Overall	$2H^+(aq) + 2Br^-(aq) \rightarrow H_2(g) + Br_2(aq)$	$2I^-(aq) + Ni^{2+}(aq) \rightarrow Ni(s) + I_2(aq)$	$2K^+ + 2Cl^- \rightarrow K + Cl_2$
Min Voltage	1.08 V	0.78 V	Cannot be determined from data sheet as not standard conditions
Observe	Colourless gas and orange solution	Colourless gas and brown solution	Green pungent gas and silver solid

	$PbBr_2$	$CoCl_2$
Products	Pb and Br_2	Co and Cl_2
Anode	$2Br^-(aq) \rightarrow 2e^- + Br_2(aq)$	$2Cl^- \rightarrow 2e^- + Cl_2$
Cathode	$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$
Overall	$Pb^{2+} + 2Br^- \rightarrow Pb + B_{r2}$	$Co^{2+} + 2Cl^- \rightarrow Co(s) + Cl_2(g)$
Min Voltage	Cannot be determined from data sheet as not standard conditions	Cannot be determined from data sheet as not standard conditions
Observe	Red liquid and silver/grey solid	Green pungent gas and silver solid

3. (a) Aluminium metal and chlorine gas (b) Hydrogen and oxygen gas. E^o favours less reactive substances

4.

	
Electrorefining of copper	Silver plating a spoon

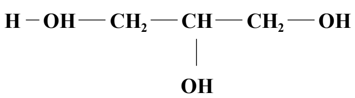
Set 23: Oxidation and Reduction: no answers provided

Organic materials

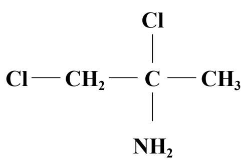
Set 24: Organic compounds

1. (a) propan-2-ol
   (b) 2-methylbutan-l-ol
   (c) propan-1-amine
   (d) 5-methylhexan-3-ol
   (f) 2-methylbutan-2-ol
   (g) 4-chloro-4-methylhexan-l-ol
   (h) 3-methylcyclopentanol
   (e) 5-chloro-4-ethylheptan-2-amine

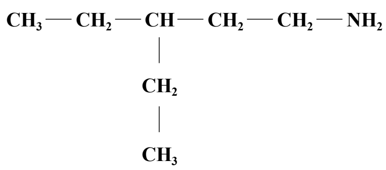
2.
   (a) $CH_3CH_2CH_2CH_2CH_2OH$
   (b) $CH_3CH_2CHCH_2CH_2NH_2$
   (c)



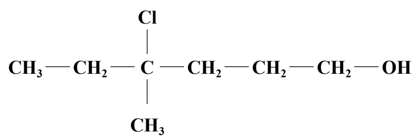
   (d) $BrCH_2CH_2CH_2OH$
   (e)



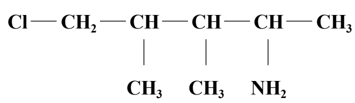
   (f)



   (g)

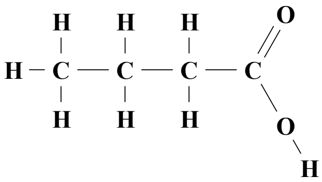
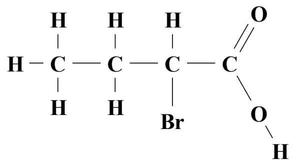
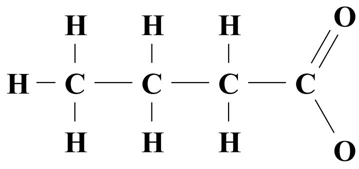
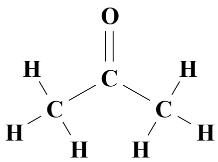
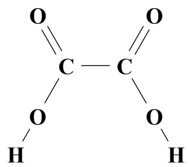
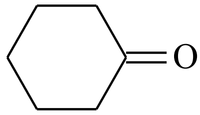
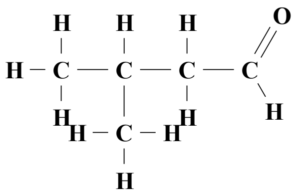
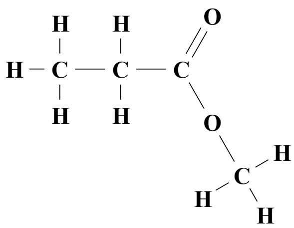
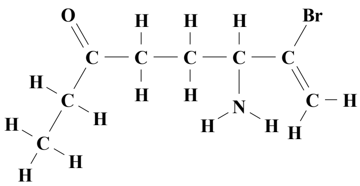
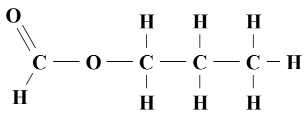


   (h)

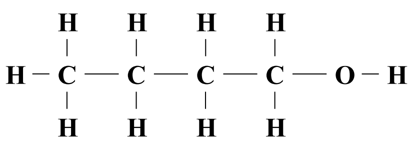
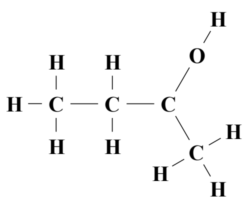
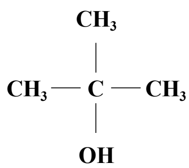
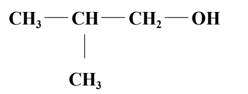


3. (a) methanal
   (b) pentan-2-one
   (c) propanal
   (d) 2-chloro-4-methylhexanal
   (e) butanone (butan-2-one)
   (f) 2,5-dimethylhexan-3-one
   (g) butanoic acid
   (h) 3-chloropropanoic acid
   (i) sodium propanoate
   (j) methyl ethanoate

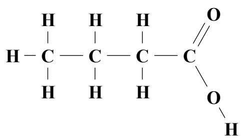
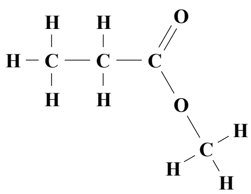
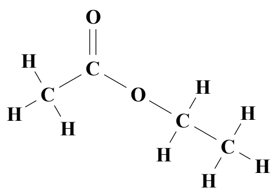
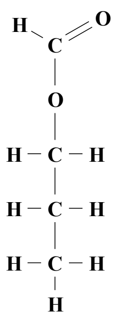
4.

(a) 	(e) 	(i) 
(b) 	(f) 	(j) 
(c) 	(g) 	
(d) 	(h) 	

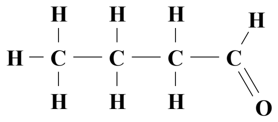
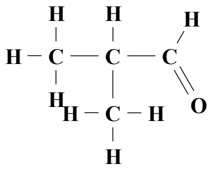
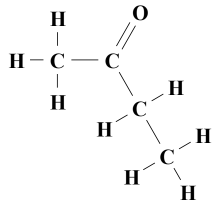
5 (a)

	 $CH_3CH_2COHCH_3$	 $CH_3C(CH_3)OHCH_3$	 $CH_3CH(CH_3)CH_2OH$
butan-l-ol	Butan-2-ol	2-methylbutan-2-ol	2-methylpropan-l-oI

5 (b)

			
butanoic acid	methyl propanoate	ethyl ethanoate	propyl methanoate

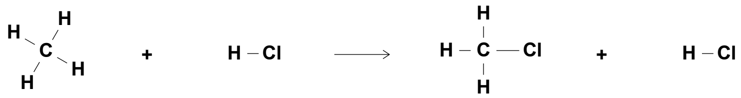
5 (c)

		
butanal	methyl propanal	butan-2-one

Set 25: Reactions of organic compounds

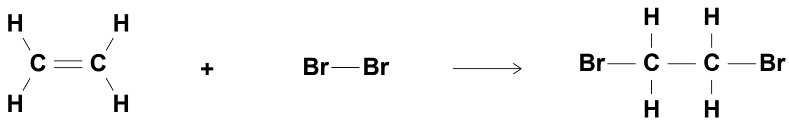
1. (a) $CH_3CH_2CH_3 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

2. (a) $CH_4 + C\ell_2 \rightarrow CH_3C\ell + HC\ell$

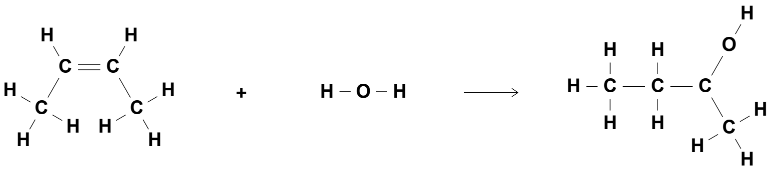


chloromethane, dichloromethane, trichloromethane, tetrachloromethane

(b) $CH_2{=}CH_2 + Br_2 \rightarrow BrCH_2CH_2Br$ 1,2-dibromomethane

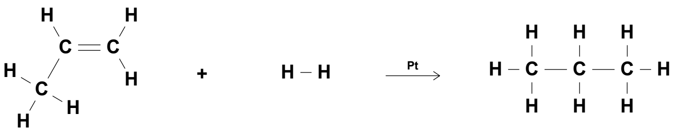


(c) $CH_3CHCHCH_3 + H_2O \rightarrow CH_3CH_2COHCH_3$



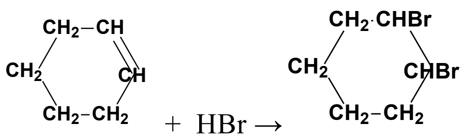
Butan-2-ol

(d) $CH_3CHCH_2 + H_2 \rightarrow CH_3CH_2CH_3$

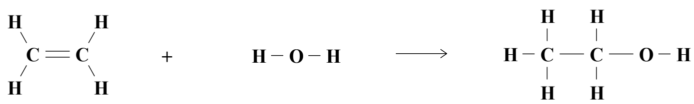


Propane

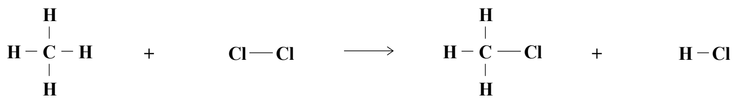
(e) $C_6H_{10} + HBr \rightarrow C_6H_{11}Br$



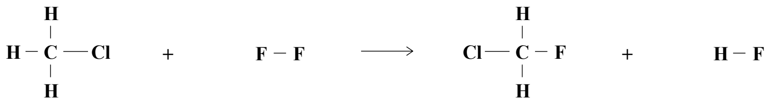
3. (a) ethene and water.



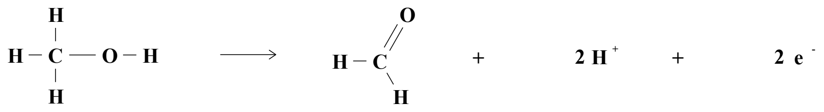
(b) Step 1: methane, chlorine, ultraviolet light.



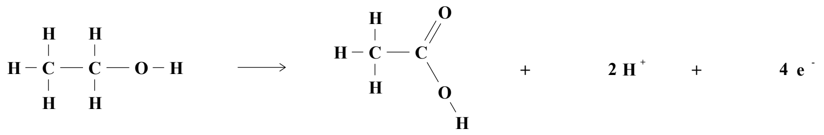
Step 2: chloromethane, fluorine and ultraviolet light.



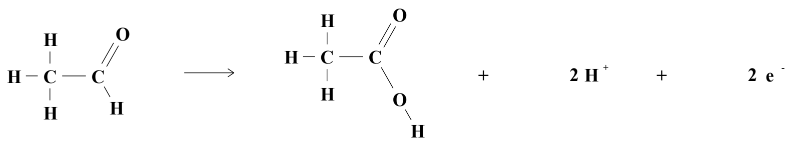
4. (a)



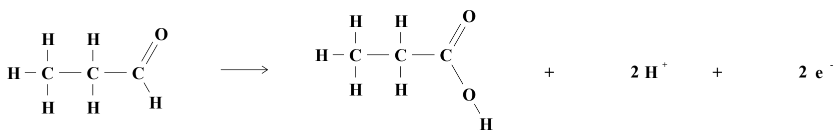
(b)



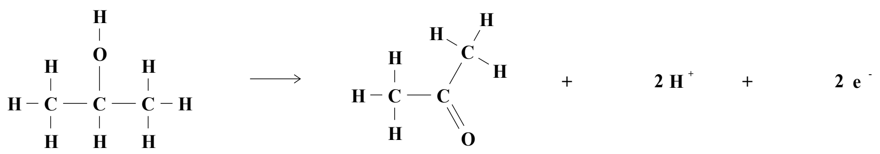
(c)



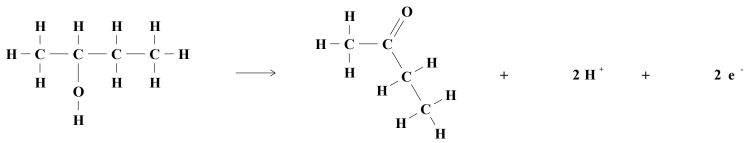
(d)



(e)



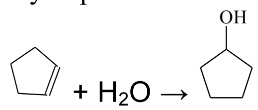
(f)



5 (a) $5CH_3CH_2CH_2CH_2COH + 2MnO_4^- + 6H^+ \rightarrow 5CH_3CH_2CH_2CH_2COOH + 2Mn^{2+} + 3H_2O$ pentanoic acid
(b) $5CH_3CH_2CH_2OH + 4MnO_4^- + 12H^+ \rightarrow 5CH_3CH_2COOH + 4Mn^{2+} + 11H_2O$ propanoic acid
(c) $5\ CH_3CHOHCH_3 + 2MnO_4^- + 6H^+ \rightarrow 5CH_3COCH_3 + 2Mn^{2+} + 8H_2O$ propanone
(d) $3CH_3CH_2CH_2CH_2OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3CH_2CH_2CCHO + 2Cr^{3+} + 7H_2O$ butanal
(e) $3CHCCHO + Cr_2O_7^{2-} + 8H^+ \rightarrow 3\ CH_3COOH + 2Cr^{3+} + 4H_2O$ ethanoic acid
(f) $3CH_3OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3HCOOH + 4Cr^{3+} + 11H_2O$ methanoic acid
(g) $3CH_3CHOHCH_2CH_3 + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3COCH_2CH_3 + 2Cr^{3+} + 7H_2O$ butan-2-one
(h) $5CH_3CH_2CH_2OH + 2MnO_4^- + 6H^+ \rightarrow 5\ CH_3CH_2CHO + 2Mn^{2+} + 8H_2O$ propanal

6. (a) $2CH_3OH + 2Na$ — $H_2 + 2CH_3O^- + 2Na^+$ methoxide ion
(b) $2CH_3CHOHCH_3 + 2Na \rightarrow H_2 + 2CH_3(ONa)CHCH_3$ sodium prop-2-oxide
(c) $CH_3CH_2COOH + CH_3CH_2CH_2CH_2OH \xrightarrow{-H^+} CH_3CH_2COOCH_2CH_2CH_2CH_3 + H_2O$ butyl propanoate
(d) $HCOOH + CH_3CHOHCH_3 \rightarrow HCOOCH(CH_3)CH_3 + H_2O$ 2-propyl methanoate
(e) $CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$ propanoate ion
(f) $CH_3COO^- + H^+ \rightarrow CH_3COOH$ ethanoic acid

7. (a) butan-2-ol, and acidified MnO_4^- or acidified $Cr_2O_7^{2-}$.
$5CH_3CHOHCH_2CH_3 + 2MnO_4^- + 6H+ \rightarrow 5\ CH_3COCH_2CH_3 + 2Mn^{2+} + 8H_2O$
(b) methane, CH_4, and chlorine. $CH_4 + C\ell_2 \rightarrow CH_3C\ell + HC\ell$ then
$CH_3C\ell + C\ell_2 \rightarrow CH_2C\ell_2 + HC\ell$ finally $CH_2C\ell_2 + C\ell_2 \rightarrow CHC\ell_3 + HC\ell$
(c) pentan-l-ol, $CH_3CH_2CH_2CH_2CH_2OH$, and acidified MnO_4^- or acidified $Cr_2O_7^{2-}$.
$5CH_3CH_2CH_2CH_2OH + 4MnO_4^- + 12H^+ \rightarrow 5\ CH_3CH_2CH_2CH_2COOH\ + 4Mn^{2+} + 11H_2O$
(d) propanoic acid, propan-l-ol, $CH_3CH_2CH_2OH$ and conc sulfuric acid.
$CH_3CH_2COOH + CH_3CH_2CH_2OH \rightarrow CH_3CH_2COOCH_2CH_3 + H_2O$
(e) Cyclopentene and water.



(f) hex-2-ene, $CH_3CH{=}CHCH_2CH_2CH_3$ and bromine.
$CH_3CH{=}CHCH_2CH_2CH_3 + Br_2 \rightarrow CH_3CHBrCHBrCH_2CH_2CH_3$
(g) propene, $CH_3CH{=}CH_2$ and hydrogen chloride: $CH_3CH{=}CH_2 + HC\ell \rightarrow CH_3CHC\ell CH_3$

(h) pentan-l-ol, $CH_3CH_2CH_2CH_2CH_2OH$, and acidified $Cr_2O_7^{2-}$ in limited quantities.
$3CH_3CH_2CH_2CH_2CH_2OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3\ CH_3CH_2CH_2CH_2CHO\ + 2Cr^{3+} + 7H_2O$
(i) ethanol, CH_3CH_2OH, methanoic acid and sulfuric acid: $CH_3CH_2OH + HCOOH \rightarrow HCOOCH_2CH_3 + H_2O$
(j) but-1-ene, $CH_2{=}CHCH_2CH_3$, and water: $CH_2{=}CHCH_2CH_3 + H2O \rightarrow CH_3CHOHCH_2CH_3$

Set 26: Calculations involving carbon compounds

1. $CH_3CH{=}CH_2 + H_2O \rightarrow CH_3CH_2CH_2OH$
n(propanol) = m/M = 1000 / 60.09 = 16.64 mol
$m(CH_3CH{=}CH_2)$ = nM = 16.64 x 42.078 = 700.1 g = 0.700 kg

2. $2\ CH_3OH + 2\ Na \rightarrow 2\ CH_3ONa + H_2$
(a) $n(CH_3OH)$ = m/M = 250 / 32.04 = 7.803 mol
$m(CH_3ONa)$ = nM = 7.803 x 54.024 = 42155 = 422 g
(b) $n(H_2) = ½\ n(CH_3OH)$
$V(H_2)$stp = n x 22.71 = 3.901 x 22.71 = 88.6 L
(c) Using PV = nRT, V = nRT/P = 7.803 x 8.314 x (273+23.0) / 102.4 = V_2 = 93.8 L

3. $C_3H_8\ + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$
$V(CO_2) = 3V(C_3H_8)$ = 3 x 1.00 = 3.00 L

4. $CH_3(CH_2)_{11}C_6H_4SO_3H + NaOH \rightarrow CH_3(CH_2)_{11}C_6H_4SO_3Na + H_2O$
(a) Sulfonic acid : n = m/M = = 196 mol
Sodium hydroxide : n = m/M = 8500 / 39.99 = 212.6 mol
∴ NaOH is INXS and sulfonic acid is the limiting reagent
$m(CH_3(CH_2)_{11}C_6H_4SO_3Na)$ = 348.5 x 196 = 68.3 kg
(b) $m(NaOH)_{left}$ = 212.6 – 196 = 16.6 mol
M = n x M = 16.6 x 39.99 = 664 g = 0.664 kg

5. (a) $n[C_{10}H_8]$ = m/M = 50.0 / 128.2 = 0.3900 mol
= n/v = 0.3900 / 0.250 = 1.56 mol L^{-1}
(b) $C_1V_1 = C_2V_2$ = 1.56 x 0.25 = 2.80 x V_2
∴ V_2 = 0.1393 L
$V(H_2O)_{to\ remove} = V_1 - V_2$ = 0.250 -0.1393 = 0.1106 = 0.111 L = 111 mL

6. $2\ (CH_3(CH_2)_{16}COONa(aq) + CaCl_2\ (aq)\ \rightarrow ((CH_3(CH_2)_{16}COO)_2)Ca(s) + 2\ NaCl(aq)$
$n((CH_3(CH_2)_{16}COO)_2)Ca$ = m/M = 1.25 / 607.02 = 2.059 x 10^{-3} mol
∴ there was 2 x 2.059 x 10^{-3} mol of soap
M = n x M = 2 x 2.059 x 10^{-3} x 306.45 = 1.262 g soap
% = soap / mixture x 100 = 1.262 / 10.0 x 100 = 12.6%

7. $HTa + NaOH \rightarrow NaT + H_2O$
(a) n(NaOH) = c x V = 1.506 x 10^{-5} x 0.01635 = 2.462 x 10^{-7} mol NaOH used
As mol ratio is 1:1 there were 2.462 x 10^{-7} mol HTa in 20 mL must
[titratable acid] = n/V = 2.462 x 10^{-7} / 0.02 = 1.23 x 10^{-5} mol L^{-1}

(b) Ionised to 2% means there is 1.23 x 10^{-5} x 0.02 = 2.46 x 10^{-3} mol H^+
pH = 2.609

8. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$
$5\ CH_3CH_2OH + 4\ MnO_4^- + 12H^+ \rightarrow 4\ Mn^{2+} + 5\ CH_3COOH + 11H_2O$

5.00 mL sample	Diluted to 500 mL	20 mL sample taken

Titres: 23.56, 23.38, 23.12, 23.05 So mean of last two = 23.085 mL
n(MnO_4^-) = c x V = 0.0216 x 0.023085 = 0.000498636 mol
∴ as MR = 4:5 there was 5/4 x 0.000498636 mol alcohol in the 20 mL sample = 0.000623295 mol
So in the whole 500 mL there was 25 x 0.000623295 = 0.015582375 mol in 5 mL wine
So in 1L there was 200 x 0.015582375 = 3.116 mol L^{-1} = 3.12 mol L^{-1}

(b) $[CH_3CH_2OH]_{\text{wine in g per L}}$ = n x M = 3.12 x 46.06 = 144 g L^{-1}

9 $CH_3NH_2 + HCl \rightarrow CH_3NH_3Cl$

25.00 mL sample	Diluted to 250 mL	20 mL sample taken

Titres : 25.08, 24.86, 25.13, 24.79, 24.88 Mean of last 4 = 24.915 mL
n(HCl) = c x V = 0.0507 x 0.024915 = 0.001263 mol HCl
∴ there were 0.001263 mol of methanamine in the 20 mL sample
∴ in the diluted sample there were 12½ times as much = 12.5 x 0.001263 = 0.0157899 mol methanamine in 25 mL original sample
∴ in 1L there was 40 x as much = 40 x 0.0157899 = 0.632 mol L^{-1}

(b) m = n x M = 0.632 x 31.0571 = 19.628 g / L
ρ = m/V so m = ρ x V = 1.07 x 1000 = 1070 g/L
%(CH_3NH_2) = 19.628 / 1070 x 100 = 1.83 %

10. $CH_3CHOHCH_3 \rightarrow CH_3COCH_3 + 2H^+ + 2e^-$
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
$5CH_3CHOHCH_3 + 2MnO_4^- + 6H^+ + \rightarrow 5CH_3COCH_3 + 2Mn^{2+} + 8H_2O$

5.00 mL sample	Diluted to 250 mL	20 mL sample taken

n(MnO_4^-) = c x V = 0.0203 x 0.02873 = 0.0005832 mol
As MR is 2: 5 there were 5/2 x 0.0005832 mol propan-2-ol in the 20 mL sample
= 0.001458 mol
∴ in the 250 mL solution there was 12½ times as much = 12.5 x 0.001458 = 0.018225 mol
This was originally from a 5.00 mL
C = n/V = 0.018225 / 0.005 = 3.645 mol L-1 in the original substance
m = n x M = 3.645 x 60.0950 = 219 g L^{-1}

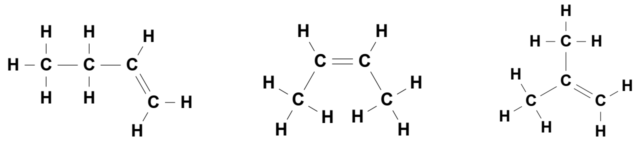
Set 27: Empirical, molecular and structural formula

1. (a) Let there be 100 g of substance

Symbol	Mass	Mol
C	85.7g	85.7/12.01 = 7.1357
H	14.3 g	14.3 / 1.008 = 14.186

Ratio = 1:2 ∴ the Empirical Formula is CH_2

(b) PV = nRT so n = PV / RT = (105 x 1.18) / (8.314 x 298) = 0.0500 mol
If 2.80 g is 0.005 mol then 1 mol is 2.80/0.05 = 56 g
Mass of the EF is 14 – the MF mass is 56. The ratio is 4:1 so the MF is C_4H_8



(c)

(d) Bromine adds to atoms either end of the double bond so the double bond is between atoms 2 and 3 therefore formula is but-2-ene

2. (a)

CHO	+	O_2	→	CO_2	+	H_2O
3.45 g				6.6 g		4.05 g
- 1.802 C				n = m/M		n = m/M
-0.45337 H				=6.6/44 = 0.1500 mol		=4.05/18.01 = 0.22487 mol H_2O
∴ 1.19463 g of O				∴ 0.150 mol of C		∴ 0.4498 mol of H
n = m/M = 1.19463 / 16 = 0.0747 mol				m = n x M = 0.150 x 12.01 = 1.802 g of C		= 0.45337 g of H

$C_{0.150}H_{0.4498}O_{0.0747}$ divide though by 0.0747 = $C_2H_6O_1$

(b) PV = nRT so n = PV / RT = (98.0 x 0.950) / (8.314 x 373) = 0.030021 mol
If 1.38 g is 0.0300 mol then 1 mol is 1.38/0.03 = 46 g
$M_r(C_2H_6O)$ = 46.068 Relative molecular mass is the same as the relative empirical formula mass so the molecular formula is C_2H_6O

(c) Possible structures include: CH_3CH_2OH and CH_3-O-CH_3

(d) CH_3CH_2OH

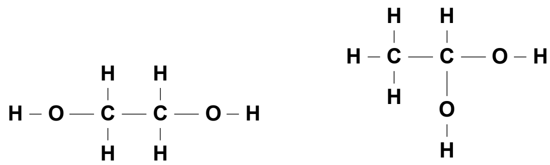
3. (a)

CHO	+	O_2	→	CO_2	+	H_2O
0.682 g				0.968 g		0.594 g
- 0.2642 g C				n = m/M		n = m/M
-0.06649 g H				=0.968/44 = 0.022 mol		=0.594/18.01 = 0.03298 mol H_2O
∴ 0.35131 g of O				∴ 0.022 mol of C		∴ 0.06596 mol of H
n = m/M = 0.35131 / 16 = 0.021956 mol				m = n x M = 0.022 x 12.01 = 0.2642 g of C		= 0.06649 g of H

Formula : $C_{0.022}H_{0.06596}O_{0.021956}$ = CH_3O

(b) For 0.744 g sample
PV = nRT so n = PV / RT = (95.0 x 0.497) / (8.314 x 473) = 0.0120062 mol
If 0.744 g is 0.0120062 mol then 1 mol is 0.744 / 0.0120062 = 61.97 g
M_r = 61.975, C_2H_6O

(c) Possible structures are.



4.

CHNO	+	O_2	→	CO_2	+	H_2O
1.180 g				1.758 g		0.900 g
- 0.4804 g C				n = m/M		n = m/M
-0.1007 g H				=1.758/44 = 0.03995		=0.900/18.01
-0.560268 g of N_2				mol		= 0.04997 mol H_2O
∴ 0.038632 g of O				∴ 0.0400 mol of C		∴ 0.100 mol of H
n = m/M = 0.038632 / 16				m = n x M = 0.0400		= 0.1007 g H
= 0.0024145 mol				x 12.01 = 0.4804 g C		

A second sample: 1.180 g
n = PV / RT = (105.0 x 0.471) / (8.314 x 298) = 0.0200 mol nitrogen gas N_2
m = n x M = 0.0200 x 28.013 = 0.560268 g of N_2
$n(N_2) = m(N_2)/M(N_2)$ = 0.560268 / 28.02 = 0.02 mol
n(N) = 2 $n(N_2)$ = 0.04 mol

(a) Empirical Formula : $C_{0.0400}H_{0.100}N_{0.0400}O_{0.0024145}$ = $\mathbf{C_2H_5N_2O}$

A third sample: 0.5896 g
n = PV / RT = 95.5 x 0.281 / 8.314 x 323.15 = 9.988 x 10^{-3} mol
M = m/n = 0.5896 / 9.988 x 10^{-3} = 59.03

(b) E.F. mass = 73 yet M = 59 as per sample 3 the Molecular formula C_2H_5NO has M = 59 but this is not the EF based on sample 2 so there is an error in the question.

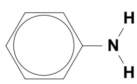
(c) Possible structures for a compound with this molecular formula, C_2H_5NO include.
NH_2CH_2CHO CH_3CONH_2

5. (a)

CHN	+	O_2	→	CO_2	+	H_2O
0.620 g				1.76 g		
- 0.4804 g C				n = m/M		
-0.093 g of N				=1.76/44 = 0.04 mol		
∴ 0.0466 g of H				∴ 0.0400 mol of C		
n(H) = m/M = 0.0466 / 1.008				m = n x M = 0.0400 x 12.01		
= 0.0462 mol				= 0.4804 g of C		
n(N) = m/M = 0.093/14						
= 0.00664 mol						

2nd sample
0.232 g n = PV / RT = (101.3 x 0.0295) / (8.314 x 288) = 0.001248 mol gas N_2
$m(N_2)$ = n x M = 0.001248 x 28.01 = 00.349 g
∴ % N_2 = 0.0349 / 0.232 x 100 = 15.04%
∴ in the original experiment there was 0.1504 x 0.620 = 0.093 g of nitrogen
Empirical Formula $C_{0.0400}H_{0.0462}N_{0.00664}$ = $\mathbf{C_6H_7N}$

(b) *3rd sample – let V = 1L*
n = PV / RT = (101.3 x 1) / (8.314 x 373) = 0.03266
ρ = m /v so m = ρ x V = 3.04 g
∴ 3.04 g = 0.03266 mol
So 1 mol = 93.080 g
$M_r(C_6H_7N)$ = 93.126, So Molecular formula = Empirical Formula = C_6H_7N



(c) A possible structure ..

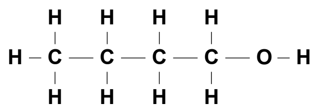
6. (a)

CHO	+	O_2	→	CO_2	+	H_2O
0.666 g				1.584 g		0.810 g
- 0.43236 g C				n = m/M		n = m/M
-0.0907 g H				=1.584/44 = 0.036 mol		=0.810/18.01
∴ 0.142976 g of O				∴ 0.036 mol of C		= 0.045 mol H_2O
n = m/M = 0.142976 / 16				m = n x M = 0.036 x		∴ 0.0900 mol of H
= 0.008936 mol O				12.01 = 0.43236 g of C		= 0.0907 g of H

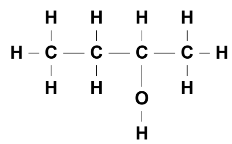
Empirical formula + $C_{0.036}H_{0.0900}O_{0.008936}$ = $C_4H_{10}O$

(b) Let there be 1L of gas
n = PV / RT = (101.3 x 1) / (8.314 x 473) = 0.025759
ρ = m /v so m = ρ x V = 1.91 g
∴ 1.91 g = 0.025759 mol so 1 mol = 1.91 / 0.025759 = 74.148
$M_r(C_4H_{10}O)$ = 74.12 so MF = EF = $C_4H_{10}O$

(c) There are 7 isomers including:
butan-1-ol, butan-2-ol, 2-methyl-propan-1-ol,
2,2-dimethylpropan-2-ol



(d) Based on the observed reactivity the structure of the compound is



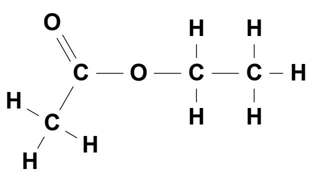
7 (a)

CHO	+	O_2	→	CO_2	+	H_2O
1.760 g				3.52 g		1.44 g
- 0.9608 g C				n = m/M		n = m/M
-0.1612 g H				=3.52/44 = 0.08 mol		=1.44/18.01
∴ 0.638 g of O				∴ 0.08 mol of C		= 0.080 mol H_2O
n = m/M = 0.638 / 16 =				m = n x M = 0.08 x		∴ 0.160 mol of H
0.03987 mol O				12.01 = 0.9608 g of C		= 0.1612 g of H

Empirical formula = $C_{0.08}H_{0.160}O_{0.03987}$ = C_2H_4O

Let there be 1L of gas
n = PV / RT = (105.0 x 1) / (8.314 x 423) = 0.02985 mol
ρ = m /v so m = ρ x V = 2.62 g
∴ 2.62 g = 0.02985 mol so 1 mol = 2.62 / 0.02985 = 87.7721
$Mr(C_2H_4O)$ = 44.0526 ∴ MF = EF x 2 = $C_4H_8O_2$

(c) Three solutions all esters e.g.

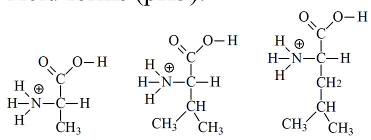


Answers

Set 28: Amino Acids

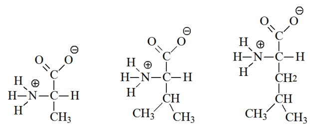
1.

(a) Acid forms (pH3):



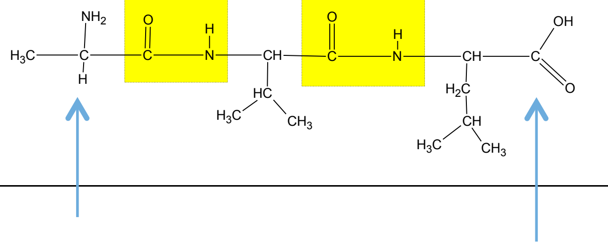
Alanine Valine Leucine

(b) Zwitterion forms:



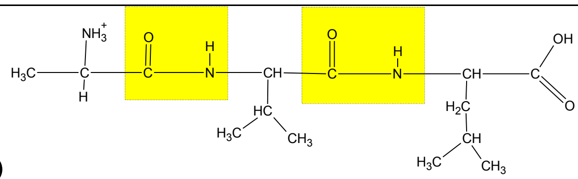
Alanine Valine Leucine

(c) Peptide bonds are shown highlighted



(d) amino terminus ------------ carboxy terminus

By convention, peptides are names from the amino to the carboxy terminus



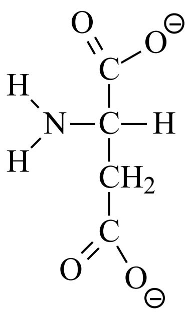
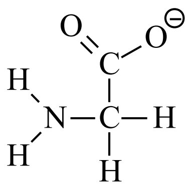
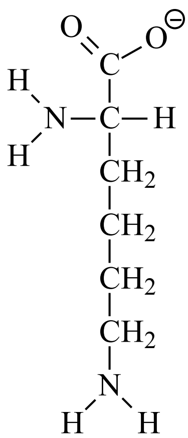
(e)

2. Enzymes are biological catalysts that speed up chemical reactions. In biological systems, other ways of speeding up reactions, such as increasing temperature, concentration or pressure are often not achievable without killing the organism. Without enzyme catalysts, many cellular reactions would not take place under cellular conditions.

3. 3 – you would need a water molecule to break each peptide bond (as one water was released when each peptide bond was formed)

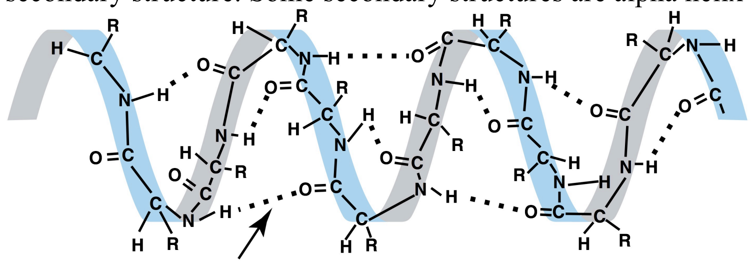
4. 99 - one water molecule is created with each peptide bond formed, so 1 water is released when the first 2 amino acids join then one water is released for each peptide bond formed when adding an addition amino acid.

5.

Name	Symbol	Name	Symbol	Name	Symbol
aspartic acid	**Asp**	**glycine**	**Gly**	**lysine**	**Lys**
Structure 		Structure 		Structure 	

Set 29: Proteins

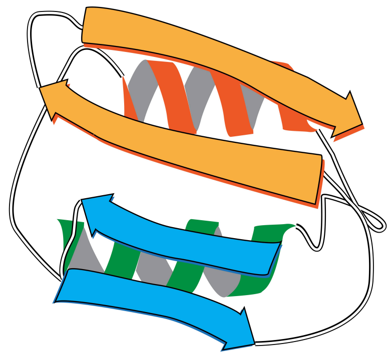
1. • The primary structure is the linear sequence of amino acid residues in a protein.
   - The secondary structure is the structure that arises from the arrangement of hydrogen bonds that occurs between the oxygen and the hydrogen atoms of the amide bonds that occur in the proteins backbone. Oxygen's and hydrogen's on the side chains also form hydrogen bonds, but these ones do not participate in secondary structure. Some secondary structures are alpha helix (shown below) and beta sheet.



Hydrogen bonds between amino acids at different locations in polypeptde chain

α-helix

   - The tertiary structure is the overall shape that a polypeptide chain forms. This shape arises largely through the interactions of the side chains, and includes hydrogen bonding, hydrophobic interactions, ionic bonding (NH_3^+ ….. COO^-), and disulphide bonding between cysteine side chains (cys-S-S-cys). See figure opposite.



2.

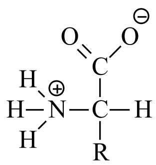
Protein structure	Bonding forces
Primary	covalent bonds
Secondary	hydrogen bonds
Tertiary	dispersion forces, hydrogen bonds, ionic bonds, disulfide bonds

3. (a) The α-helix secondary structure, every N-H group donates a hydrogen bond to the C=O group of an amino acid four residues earlier in the chain. Beta sheets consist of strands connected by at least two backbone hydrogen bonds, forming a pleated sheet
   (b) A quaternary structure because there are multiple peptide chains (protein molecules) in each complex.
   (c) Glutamic acid is hydrophilic and would aggregate around water molecules, valine is hydrophobic. It could also disrupt any hydrogen bonding or ionic bonding (salt bridges) the glutamic acid residue was involved in.

4. The different amino acid sequences and consequently their 3d structure, makes different proteins unique.

5. A protein's shape is determined by its sequence of amino acids. The different side chains on these determine the mix of hydrogen bonds, ionic bonds, disulfide bridges or dispersion forces that give it its shape.

6. (a)



   (b) The length and nature of the amino acids and their affinity for other species.

7. (a) α-helices are held together by hydrogen bonds.
   (b) N-H and C=O
   (c) β-sheets are held together by multiple hydrogen bonds
   (d) N-H and C=O
   (e) Hydrogen bonds are secondary bond and will rupture at high temperatures – eg: cooking meat.

8. Disulfide bridges are the strongest and most thermo stable. They are covalent bonds requiring approximately 60kJ/mole to break, compared to 20kJ/mol for hydrogen bonds.

9. The presence of concentrated sodium hydroxide will cause the amide groups to hydrolyse. This means that proteins will split into their component amino acids. At lower concentrations, hydrogen bonding and tertiary structure will be disrupted. The flesh will dissolve.

Answers

Properties, reactions and chemical synthesis

Set 30: Reaction types

1. (a) $CH_3COOH(\ell) + H_2O(\ell) \rightarrow CH_3COO^- (aq) + H_3O^+ (aq)$

(b) $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+ (aq) + H_3O^+ (aq)$ — $NaHCO_3 (s) \rightarrow Na^+ (aq) + HCO^- (aq)$

(c) $NaHCO_3 (s) \rightarrow HCO_3^-(aq) + Na^+ (aq)$ — $HCO_3^- (aq) + H_2O(\ell) \rightarrow CO_3^{2-}(aq) + H_3O^+(aq)$

(d) $NaHSO_4(s) \rightarrow Na^+(aq) + HSO_4^-(aq)$ — $HSO_4^-(aq) + H_2O(\ell) \rightarrow SO_4^{2-}(aq) + H_3O^+(aq)$

(e) $K_2CO_3 (s) \text{-}\!\!\rightarrow 2K^+ (aq) + CO_3^{2-} (aq)$ — $CO_3^{2-}(aq) + H_2O(\ell) \rightleftharpoons HCO_3^- (aq) + OH^- (aq)$

(f) $NH_4CH_3COO(s) \rightarrow NH_4^+ (aq) + CH_3COO^- (aq)$ — $NH_4^+ (aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

$CH_3COO\text{-} (aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^- (aq)$

2. (a) i) $H^+ (aq) + OH^- (aq) \rightarrow H_2O(\ell)$

ii) Two colourless solutions are mixed together. No visible reaction; some heat evolved.

(b) i) $Ba(OH)_2(s) + 2H^+ (aq) \rightarrow Ba^{2+} (aq) + 2H_2O(\ell)$

ii) A white solid dissolves in a colourless solution.

(c) i) $MgO(s) + 2H^+ (aq) \rightarrow Mg^{2+} (aq) + H_2O(\ell)$

ii) A white solid dissolves in a colourless solution.

(d) i) $CH_3COOH(aq) + NH_3 (aq) \rightarrow NH_4^+ (aq) + CH_3COO^- (aq)$

ii) Two colourless solutions mixed. No visible reactions. There is a reduction in the vinegar smell.

(e) i) $Zn(s) + 2H^+ (aq) \rightarrow Zn^{2+} (aq) + H_2 (g)$

ii) A silver solid dissolves in a colourless solution; colourless, odourless gas evolved

(f) i) $2CH_3COOH(aq) + Mg(s) \rightarrow Mg^{2+} (aq) + 2CH_3COO^- (aq) + H_2 (g)$

ii) A silver solid dissolves in a colourless solution; colourless, odourless gas evolved.

(g) i) $Cu(s) + 4H^+ (aq) + 2NO_3^-(aq) \rightarrow Cu^{2+} (aq) + 2NO_2 (g) + 2H_2O(\ell)$

ii) Brown solid dissolves in colourless solution to produce brown, pungent gas and a blue solution.

(h) i) $Ni(s) + 2H^+ (aq) \rightarrow Ni^{2+} (aq) + H_2 (g)$

ii) Silver solid dissolves in colourless solution forms colourless, odourless gas and green solution.

(1) i) $Fe(s) + 2H^+ (aq) \rightarrow Fe^{2+} (aq) + H_2 (g)$

ii) Silver solid dissolves in colourless solution, colourless, odourless gas evolved and a pale green soln.

3. (a) i) $Br_2 (\ell) + 2I^- (aq) \rightarrow 2Br^- (aq) + I_2 (s)$

ii) Brown/orange liquid added to colourless solution. Brown/orange fades and dark brown solid forms

b) i) $Mg(s) + Fe^{2+} (aq) \rightarrow Mg^{2+} (aq) + Fe(s)$

ii) Silver solid to pale green solution. Black precipitate on silver solid; pale-green soln to colourless.

c) i) $Cu(s) + 2Ag^+ (aq) \rightarrow Cu^{2+} (aq) + 2Ag(s)$

ii) Brown solid to colourless solution. Black precipitate on brown solid; colourless solution turns blue.

d) i) $Zn(s) + Ni^{2+} (aq) \rightarrow Zn^{2+} (aq) + Ni(s)$

ii) Silver solid to green solution. Black precipitate on silver solid; green solution fades to colourless.

e) i) $2Na(s) + 2H2O(\ell) \rightarrow 2Na^+ (aq) + 2OH^- (aq) + H_2 (g)$

ii) A silver/white solid reacts vigorously with a colourless liquid to form a colourless, odourless gas.

f) i) $2K(s) + 2HzO(\ell) \rightarrow 2K^+ (aq) + 2OH^- (aq) + H_2 (g)$

ii) A silver/white solid reacts vigorously with a colourless liquid to produce a colourless, odourless gas.

g) i) $C\ell_2 (g) + 2Br^- (aq) \rightarrow 2C\ell^- (aq) + Br_2 (aq)$

ii) A green pungent gas dissolves in a colourless solution to form a brown/orange solutions.

4. a) i) $Ag+(aq) + C\ell^- (aq) \rightarrow AgC\ell(s)$

ii) Two colourless solutions are mixed to form a white precipitate.

b) i) $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

ii) Two colourless solutions are mixed to form a cream/white solid.

c) i) $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$

ii) Two colourless solutions are mixed to form a yellow precipitate.

d) i) $Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO4(s)$

ii) Two colourless solutions are mixed to form a white precipitate

e) i) $Ba^{2+}(aq) + OH^-(aq) + SO_4^{2-}(aq) + H^+(aq) \rightarrow BaSO_4(s) + H_2O(\ell)$

ii) Two colourless solutions are mixed to form a white precipitate.

f) i) $Fe^{2+}(aq) + CO_3^{2-}(aq) \rightarrow FeCO_3(s)$

ii) Pale green solution mixed with colourless solution forms pale green precipitate. Green solution fades.

g) i) $3\ Zn^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Zn_3(PO_4)_2(s)$
ii) Two colourless solutions are mixed together to form a white precipitate.
h) i) $Cu^{2+}(aq) + 2\ OH^{-}(aq) \rightarrow Cu(OH)_2(s)$
ii) Blue solution mixed with a colourless solution to form a blue precipitate. Blue solution colour fades.
i) i) $2\ Cr^{3+}(aq) + 3\ CO_3^{2-}(aq) \rightarrow Cr_2(CO_3)_2(s)$
ii) Green solution mixed with colourless solution to form a green precipitate. Green solution colour fades.

Set 31: Percentage composition and yield

1. a) $M(Fe_2O_3) = 159.7$ g mol^{-1}
%Fe:= 111 7 / 159.7 x100 = 69.9%
b) %Heamatite:65/69.9 x100 = 92.9%

2. $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$
m(remaining) = m(Cu) = 0.630 g
m(Zn) = 2.71 - 0.630 = 2.08 g
%Zn: 2.08/2.71 x 100 = 76.8%

3 a) $n(Br_2)$ = 125 / (79.9 x 2) = 0.782 mol
$n(C_6H_6)$ = 60.0 / 78.108 = 0.768 mol
1 mol of Br_2 requires 1 mol of C_6H_6
0.782 mol of Br_2 requires 0.782 mol of C_6H_6
$n(C_6H_6$ required) > $n(C_6H_6$ available)
C_6H_6 is LR
$n(C_6H_3Br) = n(C_6H_6)$ = 0.768 mol
$m(C_6H_5Br)$ = 0.768 x 157 = 121 g
b) %yield= 93 2/121 x 100 = 77.3 %

4. a) $Ca(OH)_2 \rightarrow CaO + H_2O$
b) %CaO: 4 33/5.67 x100 = 76.4 %

5. a) $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
$n(Ba^{2+}) = n(CuSO_4.5H_2O)$
$n(CuSO_4.5H_2O)$ = 1.11/249.69 = 4.45 x 10^{-3} mol = $n(BaC\ell_2)$
$m(BaC\ell_2)$ = (4.45 x 10^{-3})x(137.3 + 70.9) = 0.926 g
c) $n(CuC\ell_2.2H_2O) = n(BaC\ell_2$ used) = 4.45 x 10^{-3} mol
$m(CuC\ell_2.2H_2O)$ = (4.45 x 10^{-3}) x 170.482 = 0.758 g
%yield:- 0 345/0.758 x 100 = 45.5 %

6. $n(Na_2S_2O_7) = ½\ n(S)$
n(S) = 17500/32.06 = 5.46 x 10^2 mol
$n(Na_2S_2O_7)$ = ½ (5.46 x 10^2) = 2.73 x 10^2 mol
$m(Na_2S_2O_7)$ = (2.73 x 10^2) x (45.98+64.12+112) = 6.06 x 10^4 g
%yield:50000/60617 x 100 = 82.5 %

7. let X = $m(NaHCO_3)$
Y = $m(Na_2CO_3)$
X + Y = 100
Y = 100 - X

$n(Na_2CO_3)$ = 90.7 / 106 = 0.856 mol
$n(Na_2CO_3$ total) = ½ $n(NaHCO_3$ initial) + $n(Na_2CO_3$ initial)
= (½ x X/84.01) + Y/100
0.856 = X/168 + (100-x)/106
62X = 1556.352
X=25.1 g
Y = 74.9 g
$\%Na_2CO_3$ = 74.9 / 100 x 100 = 74.9 %

8.

1	2	3	4	5
1.63g wire	Dissolved in acid	Made up to 250 mL	20 mL sample	Titrated with 18.1 mL of 0.0209 M $K_2Cr_2O_7$

Step 5

Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$

Oxidation: $Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Combined : $Cr_2O_7^{2-} + 14H^+ + 6e^- + 6Fe^{2+} \longrightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+} + 6e^-$

Mol Ratio $Cr_2O_7^{2-}$: Fe = 1:6

<u>In 20mL sample</u>

n $(Cr_2O_7^{2-})$- = c xv = 0.0181 x 0.0209 = 0.0003783 mol

∴ $n(Fe^{2+})$ = 6 x 0.00037829 = 0.002269 mol Fe^{2+}

m(Fe) = 0.002269 x 55.85 = 0.1267 g

∴ In 250 mL there was 12.5 x 0.1267 = 1.584 g Fe

∴ percentage purity of the wire = 1.5844/1.63 x 100 = 97.2% pure

9.

1	2	3
1.27 g mineral	Converted to $K_2Cr_2O_7$	Titrated with 37.5 mL of 0.400 M $FeSO_4$

Step 3

Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$

Oxidation: $Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Combined : $Cr_2O_7^{2-} + 14H^+ + 6e^- + 6Fe \longrightarrow 2Cr^{3+} + 7H_2O + 6Fe^{2+} + 6e^-$

Mol Ratio $Cr_2O_7^{2-}$: Fe = 1:6

n (Fe^{2+})- = c xv = 0.0375 x 0.400 = 0.015 mol Fe^{2+}

∴ $n(Cr_2O_7^{2-})$ = 1/6 x 0.015 = 0.0025 mol

∴ n(Cr) = 2 x 0.0025 = 0.005 mol

∴ m(Cr) = 52.00 x 0.005 = 0.26 g

∴ percentage purity of mineral = 0.26/1.27 x 100 = 20.5 % pure

10.

1	2
0.752 g impure Na_2SO_3	Titrated with 17.2 mL of 0.0993 M $K_2Cr_2O_7$

Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$

Oxidation: $SO_3^{2-} \longrightarrow SO_4^{2-} + 2e^-$

Combined : $Cr_2O_7^{2-} + 14H^+ + 6e^- + 3SO_3^{2-} \longrightarrow 2Cr^{3+} + 7H_2O + 3SO_4^{2-+} + 6e^-$

Mol Ratio $Cr_2O_7^{2-}$: SO_3^{2-} = 1:3

n $(Cr_2O_7^{2-})$- = c xv = 0.0172 x 0.0993 = 0.0017079 mol

∴ $n(SO_3^{2-})$ = 3 x 0.0017079 = 0.005123 mol

∴ $m(Na_2SO_3)$ = 126.043 x 0.005123 = 0.6458 g

∴ percentage purity = 0.6458/0.752 x 100 = 85.9 % pure

11.

1	2	3	4	5
3.08 g sample	Dissolved in sulfuric acid	Made up to 250 mL	25 mL sample	Titrated with 28.7 mL of 0.0260 M $KMnO_4$

Reduction: $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$

Oxidation: $Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Combined : $MnO_4^- + 8H^+ + 5e^- + 5Fe^{2+} \longrightarrow 5Fe^{3+} + 5e^- + Mn^{2+} + 4H_2O$

Mol Ratio MnO_4^- : Fe^{2+} = 1:5

n (MnO_4^-)- = c xv = 0.0287 x 0.0260 = 0.0007462 mol

In 25 mL sample

$\therefore$ n(Fe) = 5 x 0.0007462 = 0.003731 mol

$\therefore$ n(Fe_2O_3) = 0.003731 / 2 = 0.0018655 mol

$\therefore$ m(Fe_2O_3) = 0.0018655 x 159.688 = 0.297898 g

In whole sample

$\therefore$ m(Fe_2O_3) = 10 x 0.297898 = 2.97898 g

$\therefore$ percentage purity = 2.97898 / 3.08 x 100 = 96.7 % pure

12.

1	2	3	4
FeO and Fe_2O_3	Dissolved in sulfuric acid	Two equal aliquots	1. Titrated with 15.0 mL of 6.30 g L^{-1} $KMnO_4$ 2. Reduced with zinc and Titrated with 25.1 mL of 6.30 g L^{-1} $KMnO_4$

Zinc has the effect of reducing all the Fe^{3+} to Fe^{2+}

Step 4

6.30 g L-1 = 6.3 / 158.0339 = 0.03986 mol / L^{-1} MnO_4^-

Reduction: $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$

Oxidation: $Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Combined : $MnO_4^- + 8H^+ + 5e^- + 5Fe^{2+} \longrightarrow 5Fe^{3+} + 5e^- + Mn^{2+} + 4H_2O$

Mol Ratio MnO_4^- : Fe^{2+} = 1:5

Titration 1

n (MnO_4^-)- = c xv = 0.03986 x 0.0150 = 0.0005979 mol

$\therefore$ n(Fe^{2+}) = 5 x 0.0005979 = 0.0029895 mol

Titration 2

n (MnO_4^-)- = c xv = 0.03986 x 0.0251 = 0.001000 mol

$\therefore$ n(Fe^{2+}) = 5 x 0.001000 = 0.005002 mol

$\therefore$ n(Fe^{2+}) =n(FeO)= 0.002990 mol

n(Fe^{3+}) = 2 x n(Fe_2O_3) = 0.005002 - 0.002990 = 0.002013

$\therefore$ n(Fe_2O_3) = ½ x 0.002013 = 0.001006

For the half sample

$\therefore$ m(FeO) = 0.002990 x 71.844 = 0.2148 g

$\therefore$ m(Fe_2O_3) = 0.001006 x 159.688 = 0.1607 g

For the whole sample

$\therefore$ m(FeO) = 0.2148 x 2 = 00.4296 g

$\therefore$ m(Fe_2O_3) = 0.1607 x 2 = 0.3214 g

Set 32: Limiting reagents

1. a) 1 mole of $Pb(NO)_3)_2$ requires 2 moles of KI
   0300 mole of $Pb(NO)_3)_2$: requires 2 x 0.300 = 0.600 mol of KI
   n(KI required) > n(KI available)
   $\therefore$ KI is LR
   b) n(PbI_2) = ½ n(KI)
   = ½ x 0.400 = 0.200 mol
   n(PbI_2) = 0.200 x 461.0 = 92.2 g

2. a) n(NaOH) = 5.55/39.998 = 0.139 mol
   n(HCℓ) = 4.88/36.458 = 0.134 mol
   1 mol of NaOH requires 1 mol of HCℓ
   0.139 mol of NaOH requires
   0.139 mol of HCℓ
   n(HCℓ required) > n(HCℓ available)
   HCℓ is LR
   b) N(NaCℓ) = n(HCℓ) = 0.134 mol
   m(NaCℓ) = 0.134 x 58.44 = 7.82 g

3. a) $n(CH_3COOH)$= 4.78/60.052 = 7.96 X 10^{-2} mol
$N(CaCO_3)$ = 2.22/100.08 = 2.22 x 10^{-2} mol
1 mole of $CaCO_3$ requires 2 moles of CH_3COOH
2.22 x 10^{-2} mol of $CaCO_3$ requires 2 x (2.22 x 10^{-2}) = 4.44 x 10^{-2} mol CH_3COOH
n(CH_3COOH requ) < n(CH_3COOH avail)
∴ $CaCO_3$ is LR
b) $n(CO_2) = n(CaCO_3)$ = 2.22 x 10^{-2}mol
$m(CO_2)$ = (2.22 x 10^{-2}) x 44.01 = 0.976 g

c) $n(Ca(CH_3COO)_2) = n(CaCO_3)$ = 2,22 x 10^{-2} mol
$m(Ca(CH_3COO)_2)$ = (2.22 x 10^{-2}) x 158.148 = 3.51 g

4. a) n(Mg)=6.08/24.3 = 0.250 mol
$n(H_2SO_4)$ = 20.0/98.076 = 0.2039 mol
1 mol of Mg requires 1 mol of H_2SO_4
0.250 mol of Mg requires 0.250 mol of H_2SO_4
n(H_2SO_4 req) > n(H_2SO_4 avail)
∴ H_2SO_4 is LR
b) $n(H_2) = n(H_2SO_4)$ = 0.2039 mol
$m(H_2)$ = 0.2039 x 2.016 = 0.411 g
c) $n(MgSO_4.7H_2O) = n(H_2SO_4)$ = 0.2039 mol
$m(MgSO_4.7H_2O)$ = 0.2039 x 246.472 = 50.3 g

5. a) n(NaOH) = 1.600/3998 = 4.00 x 10^{-2} mol
$n(H_2SO_4)$ = 1.472/98.076 = 1.5 x 10^{-2} mol
1 mol of H_2SO_4 requires 2 mol of NaOH
1.5 x 10^{-2} mol of H_2SO_4 requires 2 x (1.50 x 10^{-2}) = 3.00 x 10^{-2} mol
n(NaOH req) < n(NaOH avail)
∴ H_2SO_4 is LR
b) $n(Na_2SO_4) = n(H_2SO_4)$ = 1.50 x 10^{-2} mol
$m(Na_2SO_4)$ = (1.50 x 10^{-2}) x 142.04 = 2.13 g
c) n(NaOH rem) = 4.00 x 10^{-2} - 3.00 x 10^{-2} = 1.00 x 10^{-2} mol
m(NaOH) = (1.00 x 10^{-2}) x 39.998 = 0.400 g

6. a) n(Ag) = 16.25/107.9 = 0.151 mol
n(HNO3) = 18.4/63.018 = 0.292 mol
1 mol of Ag requires 4/3 mol of HNO_3
0.151 mol of Ag requires 4/3 x 0.151 = 0.201 mol
n(HNO_3 req) < n(HNO_3) avail)
∴ Ag is LR
b) n(NO) = 1/3 n(Ag) = 1/3x0.151 = 0.0503 mol
m(NO) = 0.0503 x 30.01 = 1.51 g
c) n(HNO_3rem) = 0.292 - 0.201= 0.091 mol
m(HNCh) = 0.091 x 63.018 = 5.75 g

7. a) $n(KO_2)$= 5.00/71.1 = 7.03 X 10^{-2} mol
$n(CO_2)$ = 9.00/44.01 = 0.204 mol
1 mol of CO_2 requires 2 mol of KO_2
0.204 mol requires 2 x 0.204 = 0.408 mol of KO_2
n(KO_2 required) > n(KO_2 avail)
∴ KO_2> is LR
$n(K_2CO_3)$ = ½ $n(KO_2)$ = ½ (7.03 x 10^{-2}) = 3.52 x 10^{-2} mol
$m(K_2CO_3)$ = (3.52 x 10^{-2}) x 138.21 = 4.86 g
b) $n(O_2)$ = 3/2 $n(KO_2)$ = 3/2 x (7.03 x 10^{-2}) = 0.105 mol
$m(O_2)$ = 0.105 x 32.00 = 3.36 g
n(CO_2 rem) = 0.204 – ½ (7.02 x 10^{-2})= 0.269 mol
$m(CO_2)$ = 0.269 x 44.01 = 7.43 g

8. $n(Ca_3(PO_4)_2) = 25.0 \times 10^6 / 310.18 = 8.06 \times 10^4$ mol
$N(H_3PO_4) = 30.0 \times 10^6 / 97.94 = 3.06 \times 10^5$ mol
1 mol of $Ca_3(PO_4)_2$ requires 4 mol of H_3PO_4
8.06×10^4 mol of $Ca_3(PO_4)_2$ requires $4 \times (8.06 \times 10^4) = 3.224 \times 10^5$ mol of H_3PO_4
$n(H_3PO_4$ req$) > n(H_3PO_4$ avail$)$
∴ H_3PO_4 is LR
$n(Ca(H_2PO_4)_2) = ¾ (n(H_3PO_4$ avail$) = ¾ (3.06 \times 10^5) = 2.296 \times 10^5$ mol
$m(Ca(H_2PO_4)_2) = (2.296 \times 10^5) \times 234.052 = 5.37 \times 10^7$ g (53.7 tonne)

9. $n(CO2) = 2.94/44.01 = 6.68 \times 10^{-2}$ mol
$n(Na_2CO_3) = n(CO_2) = 6.68 \times 10^{-2}$ mol
$m(Na_2CO_3) = (6.68 \times 10^{-2}) \times 105.99 = 7.08$ g
$\%Na_2CO_3$:= 7.08/7.20 x 00 = 98.3%

10. $n(C\ell_2)$= 2.84/70.9 = 4.01×10^{-2} mol
mol $n(MnO_2) = n(C\ell_2) = 4.01 \times 10^{-2}$ mol
$m(MnO2) = (4.01 \times 10^{-2}) \times 86.94 = 2.49$ g
$\%MnO_2$ = 3.49/3.52 X 100 = 99.0%

Set 33: Calculations involving gases

1. a

P	V	n	R	T
120.1	0.45		8.314	299

n=0.0217 mol

b

P	V	n	R	T
99.3	0.889		8.314	314.15

n=0.0338 mol

c

P	V	n	R	T
145	27.5		8.314	328.15

n=1.462 mol

2.(a)

P	V	n	R	T	Mass
105	0.59		8.314	298.15	2.22

n= 0.023678613 mol
If 0.023678613 mol = 2.22 g
Then 1 mol = 93.8 g

(b)

P	V	n	R	T	Mass
98.5	1.22		8.314	348.15	0.456

n= 0.041516396 mol
If 0.041516396 mol = 0.456 g
Then 1 mol = 11.0 g

(c)

P	V	n	R	T	Mass
68.4	3.33		8.314	393.15	6.46

n= 0.069683834 mol
If 0.069683834 mol = 6.46 g
Then 1 mol = 92.7 g

3.

P	V	n	R	T	Mass
98	0.6684		8.314	298.15	0.741

n= 0.026425163 mol
If 0.026425163 mol = 0.741 g
Then 1 mol = 28.04 g
C_2H_4

4. P V n R T

P	V	n	R	T
105	0.0255		8.314	298.15

n= 0.001080151 mol of CO_2

∴ there were 0.001080151 mol of $CaCO_3$

= 100 x 0.001080151 = 0.108 g $CaCO_3$

5. $2NH_3(g) + H_2SO_4(aq) \longrightarrow (NH_4)_2SO_4$

nNH_3 = 1.50 / 22.71 = 0.06605 mol

nH_2SO_4 = c x V = 2.54 x 0.050 = 0.127 mol

(a) To use all the NH_3 we need 1/2 that number of moles of H_2SO_4 = 1/2 x 0.06605 = 0.03303 mol acid needed and have 0.127 mol – so acid is in excess and the LR is NH_3

(b) $n(NH_4)_2SO_4$ produced = ½ n(NH_3 used) = ½ (0.06605) = 0.03303 moles: mass ammonium sulfate = M x n = 132.094 x 0.03303 = 4.36 g

(c) nH_2SO_4 left over = 0.127 available - 0.03303 used = 0.09397 mol in excess

6. $NaHCO_3 + HCl \longrightarrow CO_2 + H_2O + NaCl$

$nNaHCO_3$ = 0.273 / 84.00 = 0.0032497 mol

$nHC\ell$ = c x V = 2.50 x 0.050 = 0.125 mol

(a) ∴ $NaHCO_3$ is the LR

(b) $n(CO_2) = n(NaHCO_3)$: $V(CO_2)$ = nRT/ P = 0.085 L

7. $Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

nCu = 1.33 / 63.55 = 0.0208 mol

$nHNO_3$ = c x V = 6.00 x 0.025 = 0.15 mol

(a) To use all the Cu we need 0.0208 x 4 mol HNO_3= 0.0832 mol
We have more so the Cu is the LR

(b) ∴ nNO_2 = 2 x 0.0208 = 0.0416 mol
V = 1.02 L

8. $MnO_2 + 4H^+ + 2Cl^- \longrightarrow Mn^{2+} + Cl_2 + 2H_2O$

Or: $MnO_2 + 4HC\ell \rightarrow MnC\ell_2 + C\ell_2 + 2H_2O$

$nMnO_2$ = 3.44 /86.93 = 0.0396 mol

$nHC\ell$ = 6.20 x 0.150 = 0.093 mol

$nHC\ell$ needed = nH^+ used = 4 x $nMnO_2$ = 0.158 mol

You need more $HC\ell$ than you have so $HC\ell$ is the limiting reagent

∴ $nC\ell_2$ = ¼ $HC\ell$ = ¼(0.093) = 0.02325 mol

P = nRT/ V = 238.26 kPa = 238 kPa

9. $(NH_4)_2SO_4 + 2KNO_3 \longrightarrow K_2SO_4 + 4H_2O + 2N_2$

$n(NH_4)_2SO_4$ = 30.0/132.140 = 0.227031 mol

$nKNO_3$ = 34.0/ 101.1032 = 0.33629 mol

To use all the $(NH_4)_2SO_4$ we would need 2 x 0.22703 mol KNO_3 = 0.45406 mol

(a) KNO_3 is the LR and is used up.

(b) n(NH4)2SO4 used = 1/2 nKNO3 = 0.16814 mol: n(NH4)2SO4 left over = 0.22701 – 0.16814 = 0.05887 mol is INXS
m = n x M = 0.058886 x 132.140 = 7.78 g

(c) $nN_2 = nKNO_3$: P = nRT/ V = 1814 kPa

Set 34: Empirical formulas 1

1.

(a)	Fe	Cl
m	2.76	3.51
n	2.76	3.51
	55.85	35.45
	0.0494	0.0990
Ratio (÷- by smallest)	0.0494	0.990
	0.0494	0.494
	I	2

E.F. = $FeC\ell_2$

(b)

	C	H
m	2.06	0.430
n	2.06	0.430
	12.01	1.008
	0.172	0.427
Ratio (÷ by smallest)	0.172	0.427
	0.172	0.172
	2	5

EF C_2H_5

(c)

	K	Mn	O
m	3.71	5.21	6.07
	3.71	5.21	6.07
	39.1	54.94	16.00
	9.49×10^{-2}	9.48×10^{-2}	0.379
Ratio (÷ by smallest)	9.49×10^{-2}	9.48×10^{-2}	0.379
	9.48×10^{-2}	9.48×10^{-2}	9.48×10^{-2}

E.F. = $KMnO_4$

(d)

	Na	S	O
m	3.86	5.38	10.7
n	3.86	5.38	10.7
	22.99	32.06	16.00
	0.168	0.168	0.6688
Ratio (÷ by smallest)	1.68	0.168	0.6688
	0.168	0.168	0.168
	1	1	4

E.F = $NaSO_4$

2. (a)

	Ca	O	H
	54.1	43.2	2.70
	54.1	43.2	2.70
	40.08	16.00	1.008
	1.35	2.70	2.68
Ratio (÷ by smallest)	1.35	2.70	2.68
	1.35	1.35	1.35
	1	2	2

E.F. = CaO_2H_2 ($Ca(OH)_2$)

(b)

	Pb	N	O
m in 100 g	62.5	8.50	29.0
n	62.5	8.50	29.0
	207.2	14.01	16.00
	0.302	0.607	1.812
Ratio (÷ by smallest)	0.302	0.607	1.812
	0.302	0.302	0.302
	1	2	6

E.F. = PbN_2O_6,($Pb(NO_3)_2$)

(c)

	C	O	H
m in 100 g	60.0	26.7	13.3
n	60.0	26.7	13.3
	12.01	16.00	1.008
	5.00	1.669	13.2
Ratio (÷ by smallest)	5.00	1.669	13.2
	1.669	1.669	1.669
	3	1	8

E.F. = C_3H_8O

3.

	S	O
m in 100 g	40.0	60.0
n	40.0	60.0
	32.06	16.00
	1.25	3.75
Ratio (÷ by smallest)	1.25	3.75
	1.25	1.25
E.F. = SO_3	1	3

4. %C = 1.25/2.12 x 100 = 58.96%
%H = 0.161/1.64 x100 = 9.82%
%O = 100-(58.96 + 9.82) = 31.22%

	C	O	H
m in 100 g	58.96	31.22	9.82
n	58.96	31.22	9.82
	12.01	16.00	1.008
	4.91	1.95	9.74
Ratio (÷ by smallest)	4.91	1.95	9.74
	1.95	1.95	1.95
	2.5	1	5
x2	5	2	10

E.F. = $C_5H_{10}O_2$

5.

	Te	O
m	4.00	1.00
n	4.00	1.00
	127.6	16.00
	3.13×10^{-2}	6.25×10^{-2}
Ratio (÷ by smallest)	3.13×10^{-2}	6.25×10^{-2}
	3.13×10^{-2}	3.13×10^{-2}
	1	2

E.F. = TeO_2

Answers

6. %O = (52.0 + 13.0) = 35.0%

	C	O	H
m in 100 g	52.0	35.0	13.0
n	52.0	35.0	13.0
	12.01	16.00	1.008
	4.33	2.19	12.9
Ratio (÷ by smallest)	4.33	2.19	12.9
	2.19	2.19	2.19
	2	1	6

E.F. = C_2H_6O

7.

	Fe	O
m	7.83	11.2-7.83 = 3.37
n	47.83	3.37
	55.85	16.00
	0.140	0.211
Ratio (÷ by smallest)	0.140	0.211
	0.140	0.140
x 2	2	3

E.F. = Fe_2O_3

8.

	Fe	Cℓ	Fe	Cℓ
m	44.0	100-44.0 =56	34.4	100-34.4 = 65.6
n	44.0	56.5	34.4	65.6
	55.85	35.45	55.85	35.45
	0.788	1.58	0.616	1.85
Ratio (÷ by smallest)	0.788	1.58	0.616	1.85
	0.788	1.58	0.616	0.616
	1	2	1	3
	E.F. = FeCℓ$_2$		**E.F.= FeCℓ$_3$**	

9.

	N	O
m in 100 g	63.6	36.4
n	63.6	36.4
	14.01	16.00
	4.54	2.275
Ratio (÷ by smallest)	4.54	2.275
	2.275	2.275
	2	1

E.F. = N_2O

	N	O
m in 100 g	46.7	53.3
n	46.7	53.3
	14.01	16.00
	3.33	3.33
Ratio (÷ by smallest)	3.33	3.33
	3.33	3.33
	1	3.33

E.F. = NO

	N	O
m in 100 g	30.4	69.6
n	30.4	69.6
	14.01	16.00
	2.17	4.35
Ratio (÷ by smallest)	2.17	4.35
	2.17	2.17
	1	2

E.F. = NO_2

Answers

10. $n(Cl^-) = n(AgCl) = 9.47 / 143.35 = 6.61 \times 10^{-2}$ mol
$m(Cl^-) = (6.61 \times 10^{-2}) \times 35.45 = 2.34$ g

	Ti	Cℓ
m	3.40 - 2.34 =1.06	2.34
n	1.06	2.34
	47.88	35.45
	2.21×10^{-2}	6.61×10^{-2}
Ratio (÷ by smallest)	2.21×10^{-2}	6.61×10^{-2}
	2.21×10^{-2}	2.21×10^{-2}
	1	3

E.F. = $TICℓ_3$

11. $n(CO_2) = 0.660/12.01 = 1.50 \times 10^{-2}$ mol
$n(H_2O) = 0.270/18.016 = 1.50 \times 10^{-2}$ mol
$n(C) = n(CO_2)$
$m(CO_2) = 12.01 \times 1.50 \times 10^{-2}) = 0.180$ g
$n(H) = 2(n(H_2O)$
$m(H_2) = 2 \times 1.008 \times 1.50 \times 10^{-2}) = 0.0302$ g
$m(O) = 0.290 – (0.180 + 0.0302 = 0.0798$ g
$n(O) = 0.0798/16.00 = 4.99 \times 10^{-3}$ mol

	C	H	O
n	1.50×10^{-2}	3.00×10^{-2}	4.99×10^{-3}
Ratio	1.50×10^{-2}	3.00×10^{-2}	4.99×10^{-3}
	4.99×10^{-3}	4.99×10^{-3}	4.99×10^{-3}
	3	6	1

E.F. = C_3H_6O

12. $n(CO_2) = 0.403 / 12.01 = 9.16 \times 10^{-3}$ mol
$n(C) = n(CO2)$
$m(C) = 12.01 \times 9.16 \times 10^{-3}) = 0.110$ g
$n(H_2O) = 0.165/18.016 = 9.16 \times 10^{-3}$ mol
$n(H)= 2\ n(H_2O)$
$m(H)= 2 \times 1.008 \times (9.16 \times 10^{-3}) = 0.0185$ g

	C	H	O
n	9.16×10^{-3}	1.83×10^{-2}	9.16×10^{-3}
Ratio	9.16×10^{-3}	1.83×10^{-2}	9.16×10^{-3}
	9.16×10^{-3}	4.99×10^{-3}	4.99×10^{-3}
	1	2	1

E.F. = CH_2O

13 $n(CO2) = 1.600 / 12.01 = 3.64 \times 10^{-2}$ mol
$n(C) = n(CO_2)$
$m(C) = 12.01 \times (3.64 \times 10^{-2}) = 0.437$ g
$n(H_2O) = 0.770 / 18.016 = 4.274 \times 10^{-2}$ mol
$n(H) = 2\ n(H_2O) =$
$m(H) = 2 \times 1.008 \times (4.274 \times 10^{-2}) = 0.0862$ g
$n(N) = 0.1697/14.01 = 1.21 \times 10^{-2}$
$m(O) = 1.279 – (0.437 + 0.0862 + 0.1697) = 0.586$
$n(O) = 0.586/16.00 = 3.66 \times 10^{-2}$ mol

	C	H	O	**N**
N	3.64×10^{-2}	8.62×10^{-2}	3.66×10^{-2}	1.21×10^{-2}
Ratio	3.64×10^{-2}	8.62×10^{-2}	3.66×10^{-2}	1.21×10^{-2}
	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	3	7	3	1

E.F. = $C_3H_7O_3N$

Set 35: Empirical formulas 2

1. $n(CO_2) = 0.531/44.01 = 1.21 \times 10^{-2}$ mol $= n(CO_3^{2-})$
$m(CO_3^{2-}) = 60.01 \times (1.21 \times 10^{-2}) = 0.724$ g
$n(H_2O) = 0.219 / 18.016 = 1.21 \times 10^{-2}$ mol $= n(OH^-)$
$m(OH^-) = (1.21 \times 10^{-2}) \times 17.008 = 0.2067$ g
$m(Cu) = 2.088 - (0.724 + 0.2067) = 1.157$ g
$n(Cu) = 1.157 / 63.55 = 1.82 \times 10^{-2}$ mol

	Cu	CO_3^{2-}	OH
n	1.82×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
Ratio	1.82×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	1.5_	1	1
x 2	3	2	2

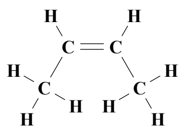
E.F. = $Cu_3(CO_3)_2(OH)_2$

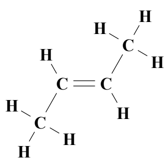
2. (a)

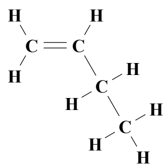
	C	H
m in 100 g	85.7	14.3
n	85.7	143
	12.01	1.008
	= 7.14	= 14.18
Ratio	7.14	14.18
	7.14	7.14
	1	2

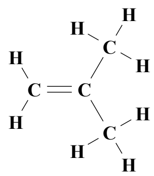
E.F. = CH_2

(b)
$n = 1.18 \times 10^5 / 298 \times 8.315 = 5.00 \times 10^2$ mol
$M = 2.80 / 5.00 \times 10^{-2} = 56.00$ g mol^{-1}
MF = 56 / 14.00 = 4
MF = C_4H_8
(c)

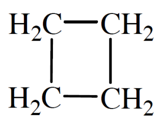








(d)



3. %Pb = 2 93 / 3.41 x100 = 85.9 %
$n(AgCl) = 1.16 / (107.9 + 35.45) = 8.09 \times 10^{-3}$ mol $= n(C\ell^-)$
$M(C\ell^-) = (8.09 \times 10^{-3}) \times 35.45 = 0.287$ g
%Cl = 0287 / 2.93 x100 = 9.79 %
%O = 100 - (85.9 + 9.79) = 4.31 %

	Pb	Cℓ	O
M in 100 g	859	9-79	431
N	85.9	9.79	4.31
	207.2	35.45	16.00
	=0.415 mol	= 0.276 mol	= 0.269
ratio	0.415	0.276	1
	0.269	0.269	
	=1.5	=1	1

E.F. = $Pb_3C\ell_2O_2$

4. (a)

$n(CO_2) = 6.60 / 44.01 = 0.150$ mol$= n(C)$
$m(C) = 0.150 \times 12.01= 1.80$ g
$n(H_2O) = 4.05 / 18.016 = 0.224$ mol
$n(H) = 2 \times 0.224 = 0.450$ mol
$m(H) = 0.450 \times 1.008 = 0.453$ g
$m(O) = 3.45 - (1.80 + 0.453) = 1.197$ g
$n(O) = 1.197 / 16.0 = 0.0750$ mol

	C	H	O
n	0.150	0.450	0.0750
ratio	0.150	0.450	0.0750
	0.0750	0.0750	0.0750
	2	6	1

E.F. = C_2H_6O

(b)

$n = 0.950 \times 98 / 373 \times 8.315 = 3.00 \times 10^{-2}$ mol
$M = 1.38 / 3.00 \times 10^{-2} = 46.0$ g mol^{-1}
EFM=MFM
MF = C_2H_6O

(c) CH_3CH_2OH

5. (a)

$n(CoCO_3) = 0.849 / (58.93 + 12.01 + 48.00) = 7.14 \times 10^{-3}$ mol
$M(Co) = (7.14 \times 10^{-3}) \times 58.93 = 0.421$ g
%Co = 0.421/ 1.22 x100 = 34.5 %
$n(C) = 3\ 43 / 44.01 = 7.79 \times 10^{-3}$ mol
$M(C) = (7.79 \times 10^{-3})) \times 12.01 = 0.936$ g
%C = 0.936 / 3.33 x 100 28.1 %
%O = 100 -(34.5 + 28.1) = 37.4 %

	Co	C	O
M in 100 g	34.5	28.1	37.4
N	34.5	28.1	3.74
	58.93	12.01	16.00
	= 0.585 mol	=2.34 mol	=2.34 mol
Ratio	1	234	234
		0.585	0.585
	1	4	4

E.F. = CoC_4O_4

(b)

EFM = 58.93 + (4 x 12.01) + (4 x 16.00) = 170.93
Ratio = 341.9 / 120.93 = 2
MF = 2 x EF = $Co_2C_8O_8$

6. (a)

	C	C	N
n	2.64	1.62 x 2	$0.236 \times 10^5 \times 2$
	44.01	18.016	298 x 8.315
n	$= 6.00 \times 10^{-2}$	=0.1798	$= 2.00 \times 10^{-2}$
ratio	6.00×10^{-2}	0 1798	1
	2.00×10^{-2}	2.00×10^{-2}	
	3	9	

E.F. = C_3H_9N

(b)

n = $0.254 \times 95.5 / (19 + 273) \times 8.315 = 9.99 \times 10^{-3}$ mol

M = $0.5896 / 9.99 \times 10^{3} = 59.0$ g

EFM = $(3 \times 12.01) + (9 \times 1.008) + 14.01 = 59.1$ g

EFM = MFM

MF = C_3H_9N

7. (a)

	C	Cℓ	H
	1.189 x12.01	1.292 x35.45	0.662-(0.3245+0.3195)
	44.01	143.35	
	= 0.3245 g	= 0.3195 g	=0.0180 g
n	0.3245	0.3195	0.0180
	12.01	35.45	1.008
	= 0.0271 mol	= 9.01×10^{-3} mol	=0.0179 mol
Ratio	0.0271	1	0.0179
	9.01×10^{-3}		9.01×10^{-3}
	= 3	=1	= 2

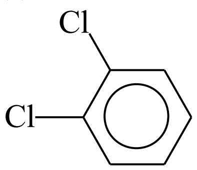
E.F. = $C_3H_2C\ell$

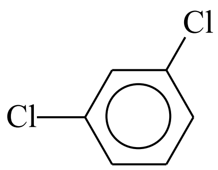
(b) EFM = $(3 \times 12.01) + (2 \times 1.008) + 35.45 = 73.5$

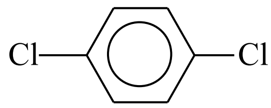
Ratio = 147 / 73.5 = 2

MF = 2 x EF = $C_6H_4C\ell_2$

(c)







8.

	C	H	N
	1.76 x12.01	0.420x2xl.008	0.0295x101.3x2x14.1
	44.01	18.016	(15 + 273) x 8.315
	= 0.480g	= 0.0470g	= 0.0350g
%	0.480 x100	0.0470	0.0350
(m in 100 g)	0.620	0.620	0.232
	= 77.4%	= 7.58%	= 15.1%
n	77.29	7.52	15.1
	12.01	1.008	14.01
	= 6.44	= 7.52	=1.08
ratio	6.44	7.52	1
	1.08	1.08	
	=6	=7	=1

E.F. = C_6H_7N

(b) n = $100 \times 101.3 / (100 + 273) \times 8.315 = 3.27 \times 10^{-2}$ mol

M = $3.04 / 3.27 \times 10^{-2} = 93.1$ g mol^{-1}

EFM = $(6 \times 12.01) + (7 \times 1.008) + 14.01 = 93$

MF = EF = C_6H_7N

9. $\%H_2O = (5\ 43 - 4\ 88) / 5.43 \times 100 = 10.4\%$
$m(Ni) = 0.578 / (58.69 + 32.06) \times 58.69 = 0.374$ g
$\%Ni = 0.374 / ((2.00/4.88) \times 5.43) \times 100 = 16.8\%$
$\%C_2O_4 = 50.5\%$
$\%K = 100 - (10.4 + 16.8 + 50.5) = 22.3\ \%$

	K	Ni	C_2O_4	H_2O
%	22.3	16.8	50.5	10.4
(m in 100g)				
n	22.3	16.8	50.5	10.4
	39.1	58.69	88.02	18.016
	= 0.570mol	= 0.286mol	0.574mol	0.577mol
ratio	0.570	1	0.574	0.577
	0.286		0.286	0.286
	=2	=1	=2	=2

E.F. = $K_2Ni(C_2O_4)_2.2.H_2O$

10. $n(BaSO_4) = 0.4671 / (137.3 + 32.06 + 64.00) = 2.00 \times 10^{-3}$ mol = n(S)
$m(S) = (2.00 \times 10^{-3}) \times 32.06 = 6.42 \times 10^{-2}$ g
$n(OH^-) = 0.250 \times 0.024 = 6.00 \times 10^{-3}$ mol
$n(HC\ell) = n(NaOH) - 2n(H_2SO_4)$
$n(C\ell^-) = n(OH^-) - 2n(S) = 6.00 \times 10^{-3} - 4.00 \times 10^{-3} = 2.00 \times 10^{-3}$ mol
$m(C\ell^-) = 35.45 \times (2.00 \times 10^{-3}) = 0.0709$ g

	S	$C\ell$	O
%	6.42×10^{-2}x100	0.0709 x100	100 -(23.7+26.2)
(m in 100 g)	0.2702	0.2702	
	= 23.7%	= 26.2 %	=50.1 %
n	23.7	26.2	50.1
	32.06	35.45	16.00
ratio	= 0 739 mol	=0.739 mol	= 3.13/0.739 mol
	1	1	4.25
	1	1	3.13/ 0.739
	1	1	4.25
x4	4	4	17

E.F. = $S_4C\ell_4O_{17}$

Set 36: Chemical Synthesis: no answers provided