CHEMISTRY 2009 REVISION SERIES

CHEMISTRY FORMULARS BOOK

CONTAINS ALL THE CHEMISTRY FORMULARS

By: Eddah Kipsat Kangogo

Produced and Marketed By;

Idealprice Consultants,

P.O. Box 15339-00100,

Nairobi.

Tel: 0716 41 39 41

Email: idealpricedirector@gmail.com

TABLE OF CONTENTS

PAGE

GAS LAWS

BOYLE'S LAW

The volume of a fixed mass of a gas at a constant temperature is inversely proportional to the pressure.

$P \propto \dfrac{I}{V}$ (temperature is constant)

$P = \dfrac{k}{V}$

$PV = k$

$\therefore \quad P_1V_1 = P_2V_2$

Problem
A gas occupies 600 cm³ at 760 mm Hg at 38⁰C. What will be the volume if pressure is reduced to 380 mm Hg at the same temperature.

Solution
$P_1 = 760$ mm Hg $V_1 = 600$ cm³
$P_2 = 380$ mm Hg $V_2 = \quad ?$

$P_1V_1 = P_2V_2$

$V_2 = \dfrac{P_1V_1}{P_2}$

$= \dfrac{760 \text{ mm Hg x } 600 \text{ cm}^3}{380 \text{ mm Hg}}$

$= \underline{1200 \text{ cm}^3}$

CHARLES' LAW

The volume of a fixed mass of gas, at constant pressure, is directly proportional to its absolute temperature (K)

V & T (Pressure constant)

$\dfrac{V}{T} = k$

$\therefore \dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

Problem
The volume of a gas was found to be 200 cm^3 at a temperature of 20^{0}C. The temperature of the gas was raised to 80^{0}C. Calculate the new volume of the gas.

Solution:

$V_1 = 200 \text{ cm}^3 \qquad T_1 = 20 + 273 = 293K$

$V_2 = \ ? \qquad\qquad T_2 = 80 + 273 = 353 \text{ K}$

$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

$V_2 = \dfrac{V_1 \ x \ T_2}{T_1}$

$= \dfrac{200 \text{ cm}^3 \ x \ 353K}{293K}$

$= \underline{240.9 \text{ cm}^3}$

THE IDEAL GAS EQUATION

It is possible to combine both Boyle's and Charles' Law to give the gas equation for any gas behaving ideally.

Boyle's Law $P_1V_1 = P_2V_2$

Charles' Law $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

Combined $\dfrac{P_1\,V_1}{T_1} = \dfrac{P_2\,V_2}{T_2}$

Problem:

It is found that the volume of a given mass of gas is $360 cm^3$ at 50^0C and
700 mmHg pressure. What will be the volume at s.t.p.

Solution

$P_1 = 700$ mm Hg $T_1 = 50 + 273 = 323$ K
$P_2 = 760$ mm Hg $T_2 = 273$ K (at s.t.p)
$V_2 = ?$ $V_1 = 360 cm^3$

$$\dfrac{P_1\,V_1}{T_1} = \dfrac{P_2\,V_2}{T_1}$$

$$V_2 = \dfrac{P_1V_1}{T_1} \times \dfrac{T_2}{P_2}$$

$$V_2 = \dfrac{700 \text{ mm Hg } \times\ 360 \text{ cm}^3 \times 273K}{760 \text{ mm } \times 323 \text{ K}}$$

$$= 280.3 \text{ cm}^3$$

THE EQUATION OF STATE
The general ideal gas equation below

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

can be improved by taking and including the Avogadro's law which states that equal volumes of all gases at the same temperature and pressure contains the same number of moles. Thus volume (v) is directly proportional to moles (n).

Boyle's Law:

$$V \propto \frac{1}{p} \quad (\text{T and n constant}) \dots\dots\dots (i)$$

Charles Law:
$$V \propto T \quad (\text{P and n constant}). \dots\dots\dots (ii)$$

Avogadro's Law:
$$V \propto n \dots\dots\dots\dots\dots\dots(iii)$$

Then (i), (ii) and (iii) can be generalised as:
$$V \propto \frac{1}{P} Tn$$

i.e. $V = \text{constant} \frac{1}{p} (Tn)$ or

$$PV = \text{constant } (Tn)$$

The proportionality constant is given the symbol R and is called the gas constant.

PV = nRT

$R = \dfrac{PV}{nT}$

At s.t.p. and using S.I. units the value of R can be calculated as shown below:

P = 101325 Nm^{-2}

V = 0.0224 dm^3

η = 1 mole (mol)

T = 273K

∴ $R = \dfrac{101325 \ Nm^{-2} \ x \ 0.0224 \ dm^3}{1 \ mol \ x \ 273 \ K}$

8.31 $Nm^{-2} \ K^{-1} \ mol^{-1} \ dm^3$

(NB: Nm^{-2} =J)

8.31$JK^{-1}mol^{-1}$

N.B: At s.t.p. and without considering S.I. units

P = 760 mmHg = 1 a.t.m

V = 22.4 l

n = 1 mol

The value and units of R is:

$R = \dfrac{PV}{nT}$

$= \dfrac{1 \ atm \ x \ 22.4\ell}{1 \ mol \ x \ 273 \ K}$

$= 8.2057 \times 10^{-2} \ell$ atm mol $^{-1}$ K $^{-1}$

Problem:

A carbonate was decomposed to give 11.0 g of carbon dioxide which occupied 10. 0 litres at 77^0C. Calculate its pressures (C = 12.0, O = 16.0)

Solution:

R.F.M. of carbon dioxide = 12.0 (2 x16.00)

$= 44$

$\therefore$ Molar mass of carbon dioxide = 44g mol $^{-1}$

$\therefore$ Moles of carbon dioxide $= \dfrac{11.0g}{44 \text{ gmol}^{-1}}$

$= 0.25$ mol

Using the equation of state

$PV = nRT$

$P = \dfrac{nRT}{V}$

n = 0.25 mol

T = 77 + 273 = 350K

R = 8.31 JK^{-1} mol $^{-1}$

V = 10.0 dm^3

P $= \underline{0.25 \text{ mol} \times 8.31 \text{JK}^{-1} \text{ mol}^{-1} \text{ dm}^3 \times 350\text{K}}$

10.0 dm^3

= 7.27 x 10^4 Nm^{-2} (J = Nm^{-2})

GRAHAM'S LAW OF DIFFUSION

This law states that at constant temperature and pressure the rate (R) of diffusion of a gas is inversely proportional to the square root of its density (d).

N.B. The different formulae relating to the above law are easily derived as it will be shown in the problems and solutions that follow.

Thus $R \propto \dfrac{1}{\sqrt{d}}$ (R = rate of diffusion in cm^{3}s^{-1}

d = density gcm^{-3})

$R = \dfrac{k}{\sqrt{d}}$

If the rates of diffusion of a gas A and B are compared, the equation can be derived as follows:

$R_A = \dfrac{k}{\sqrt{d_A}}$

$R_B = \dfrac{k}{\sqrt{d_B}}$

$\dfrac{R_A}{R_B} = \dfrac{k}{\sqrt{d_A}} \div \dfrac{k}{\sqrt{d_B}}$

$\dfrac{R_A}{R_B} = k \times \sqrt{d_B}$

R_B $\sqrt{d_A}$ k

$$\frac{R_A}{R_B} = \frac{\sqrt{d_B}}{\sqrt{d_A}}$$

Problem:

The density of nitrogen gas is 1.2506×10^{-3} g cm^{-3} and that of oxygen gas is 1.4290×10^{-3} g cm^{-3}.

(a) Which gas will diffuse faster?

(b)   How many times faster will the gas you have given in (a) above diffuse?

Solution:

(a) Nitrogen gas which has got a lower density will diffuse faster than oxygen.

(b) $\dfrac{R_{N_2}}{R_{O_2}} = \sqrt{\dfrac{d_{O_2}}{d_{N_2}}} = \sqrt{\dfrac{1.4290}{1.2506}} = \sqrt{1.14427}$

= 1.0689

N.B. If equal volumes of gases A and B diffuse the rates of diffusion are inversely proportional to the time of diffusion.

$$T_A \propto \frac{1}{R_A} \qquad \therefore T_A = \frac{k}{R_A}$$

$$T_B \propto \frac{1}{R_B} \qquad \therefore T_B = \frac{k}{R_B}$$

$$\frac{T_A}{T_B} = \frac{k}{R_A} \div \frac{k}{R_B}$$

$$\frac{T_A}{T_B} = k \times \frac{R_B}{}$$

T_B R_A k

$$\frac{T_A}{T_B} = \frac{R_B}{R_A} \quad \text{NB: } K = K$$

Note: $R_A = \dfrac{k}{\sqrt{d_A}}$ and

$R_B \qquad = \dfrac{k}{\sqrt{d_A}}$

$$\therefore \frac{T_A}{T_B} = \frac{k}{\sqrt{d_B}} \div \frac{k}{d_B}$$

$$= \frac{k}{\sqrt{d_B}} \; x \; \frac{\sqrt{d_A}}{k}$$

$$\therefore \frac{T_A}{T_B} = \frac{\sqrt{d_A}}{\sqrt{d_B}}$$

Problem:
A sample of hydrogen gas density 1 diffused in 82 seconds. The same volume of air diffused in 310 seconds. How many times is air denser than hydrogen.

Solution:
Using the Graham's Law of diffusion:

$$\frac{T_A}{} = \sqrt{d_A}$$

T_B $\sqrt{d_B}$ Let A be hydrogen, B be air

Square both sides:

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\ \right)\frac{\sqrt{d_A}}{\sqrt{d_B}}\ ^2$$

$$\left(\frac{TH_2}{T_{Air}}\right)^2 = \frac{dH_2}{d_{Air}}$$

$$\frac{82 \ x \ 82}{310 \ x \ 310} = \frac{1}{d_{Air}}$$

$d_{Air} = \dfrac{1 \ x \ 310 \ x \ 310}{82 \ x \ 82}$

        = 14.29 times

When molecular mass is considered in relation to Graham's Law of Diffusion, the rate of diffusion of a gas is inversely proportional to the square root of its molecular mass.

$R_A \, \alpha \ \dfrac{1}{\sqrt{M_A}}$

$R_A = \dfrac{k}{\sqrt{M_A}}$

$R_B \ \dfrac{\alpha \ 1}{M_B}$

$R_B = \ k$

$\sqrt{M_B}$

$$\frac{R_A}{R_B} = \frac{k}{\sqrt{M_A}} \div \frac{k}{\sqrt{M_B}}$$

$$= \frac{k}{\sqrt{M_A}} \ X \ \frac{\sqrt{M_B}}{k}$$

$$\frac{R_A}{R_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}}$$

Problem:
A given volume of oxygen takes 120 seconds to diffuse. Calculate the molar mass of gas B if the same volume diffuses in 90 seconds. (O = 16.0)

Solution:
From Graham's Law of diffusion
$$\frac{R_A}{R_B} = \frac{\sqrt{d_B}}{\sqrt{d_A}} \quad \text{.......................(1)}$$

$$\frac{T_A}{T_B} = \frac{\sqrt{d_A}}{\sqrt{d_B}} \quad \text{.......................(2)}$$

$$\frac{R_A}{R_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} \quad \text{.......................(3)}$$

N.B. The question refers to the relationship between time of diffusion and molecular mass (1) and (2) show that molecular mass of a gas b directly proportional to its density.

From (1)

$$\frac{R_A}{R_B} \quad \frac{\sqrt{d_B}}{\sqrt{d_A}}$$

$$\therefore \frac{R_B}{R_A} \quad \frac{\sqrt{d_A}}{\sqrt{d_B}} \quad ....(4)$$

From (3) $\quad \dfrac{R_A}{R_B} = \dfrac{\sqrt{M_B}}{\sqrt{M_A}}$

$$\therefore \frac{R_B}{R_A} = \frac{M_A}{M_B} ....(5)$$

It follows from 4 and 5 that:

$$\frac{\sqrt{d_A}}{\sqrt{d_B}} = \frac{\sqrt{M_A}}{\sqrt{M_B}} \quad ....6$$

But from (2)

$$\frac{T_A}{T_B} = \frac{d_A}{d_B}$$

and from (6)

$$\frac{\sqrt{d_A}}{\sqrt{d_B}} = \frac{\sqrt{M_A}}{\sqrt{M_B}}$$

$$= \frac{T_A}{} = \sqrt{M_a}$$

$$T_B \qquad \sqrt{M_B}$$

Squaring both sides

$$\left(\frac{T_A}{T_B}\right)^2 = \frac{M_A}{M_B}$$

Substitution (A) for oxygen and (B) for the unknown gas.

$$M_B = M_A \left(x \frac{T_B}{T_A}\right)^2$$

$$= 32 \left(x \frac{90}{120}\right)^2$$

$$32 \times \left(\frac{3}{4}\right)^2$$

$$= 32 \times \frac{9}{16}$$

$$= \underline{18}$$

The molar mass of B = 18 gmol^{-1}

Problem:
Some cotton wool was soaked into concentrated hydrochloric acid and another one soaked into concentrated X solution and were placed at different ends of a
99-cm long glass tube. After some time a white solid was formed at 55 cm from concentrated hydrochloric acid and 44 cm from X. Calculate relative molecular mass of X. [H=1, Cl = 35.5].

Solution:

The length L by HCl and X when diffusing depend on the relative molecular mass and therefore inversely proportional to the square root of molecular
 mass – Graham's law of diffusion.

$$LHCL \propto \frac{1}{\sqrt{M_{HCl}}}$$

$$L\,HCl = \frac{k}{\sqrt{M_{HCl}}}$$

$$Lx \propto \frac{1}{\sqrt{M_X}}$$

$$Lx = \frac{k}{\sqrt{Mx}}$$

$$\frac{LHC\ell}{LX} = \frac{k}{\sqrt{M_{HCl}}} \div \frac{k}{M_X}$$

$$\frac{LHC\ell}{Lx} = \frac{\sqrt{M_X}}{\sqrt{M_{HCl}}}$$

$$\frac{55}{44} = \frac{\sqrt{M_X}}{\sqrt{36.5}}$$

$$\left(\frac{55}{44}\right)^2 = \frac{M_X}{36.5}$$

$$M_x = \frac{55 \times 55 \times 36.5}{44 \times 44}$$

= <u>57.03</u>

TEMPERATURE SCALES:

CELSIUS SCALE:

This has been very widely used and originated in 1742 after a Swedish astronomer, Anders Celsius (1701 – 44). The upper fixed point is the boiling point of water called 100^0C and the lower one is the melting point called 0^0C at 101325 Nm^{-2} (or 1 atmosphere 760 mmHg) One hundredth of the interval between these two points is called a degree Celsius (1^0C).

ABSOLUTE OR KELVIN SCALE

The temperature, at which all gases would theoretically have Zero volume, is absolute Zero. This temperature in Celsius scale is about -273^0C which is theoretically the lowest possible temperature but in practice we cannot reduce the temperature of a gas to absolute Zero because all gases liquify above this temperature.

The scale which has -273^0C as zero is called thermodynamic scale or commonly known as Kelvin Scale invented by William Thomson 1824 – 1907, a British Physicist who was the baron of Kelvin. Degrees Celsius are converted to Kelvin symbol K with no degrees sign by adding 273.

Temperature in K = Temperature in ^0C + 273

Problem:
Convert (i) 25^0C to Kelvin
        (ii) 373 K to Celsius

Solution:
(i)   K = ^oC + 273

K = 25 + 273
   K = 298 K

(ii)   K = ^{o}C + 273
        ^{0}C = K – 273
           = 373 – 273
           = 100 ^{0}C

pH VALUES

The mathematical definition of pH is the negative logarithm to base ten of the molar hydrogen ions concentration. This scale was suggested by SØrensen; in 1909.

pH = -Log $_{10}$ [H^{+}]

[ ] indicates concentration and P stands for potenz, meaning strength.

Problem 1:
 What is the pH of:
 (i)   0.01M hydrochloric acid
 (ii)   0.02M hydrochloric acid

 (i) pH   = - log $_{10}$ H^{+}]
    pH   = - Log $_{10}$ 0.01
         = - Log $_{10}$ (1.0 x 10 $^{-2}$)
         = -(-2) Log$_{10}$ 10
         = 2 Log $_{10}$ 10
         = 2 x 1
         = 2

 (ii)   pH = $^{-}$Log $_{10}$ [H+]

$= -Log_{10} 0.02$

$= -Log_{10} (2.0 \times 10^{-2})$

$= -Log_{10} (2.0 10^{-2})$

$= -Log_{10} 2 - Log_{10} 10^{-2}$

$= -Log_{10} 2 - (-2 Log_{10} 10)$

$= -Log_{10} 2 + 2 Log_{10} 10$

$= -0.3010 + 2$

$= \underline{1.699}$

Problem 2:

A solution of carbon dioxide has hydrogen ions concentrations of $1.3 \times 10^{-4} M$. Find its pH.

Solution:

$pH = -Log_{10} [H^+]$

$= -Log_{10} (1.3 \times 10^{-4})$

$= -Log_{10} (1.3 + Log_{10} 10^{-4})$

$= -Log_{10} 1.3 - Log_{10} 10^{-4}$

$= -Log_{10} 1.3 + 4 Log_{10} 10$

$= 0.11 + 4$

$= \underline{3.89}$

Problems 3:

Find the concentration of H^+ of a solution of pH 4.5.

Solution:

$pH = -Log_{10}[H^+]$

$4.5 = -Log_{10} [H+]$ or

$-Log_{10} [H^+] = 4.5$

$[H^+] = 10^{-4.5}$
$[H^+] = 10^{0.5} \times 10^{-5}$
$[H^+] = 3.2 \times 10^{-5}$

N.B: -4.5 = 0.5 – 5

ENTHALPY CHANGES

Δ H = MC Δ T
Δ H is negative when the reaction is exothermic – heat lost.
Δ H is positive when the reaction is endothermic – heat gained.
C is specific heat capacity of water and is given as 4.2 J g^{-1} $^{0}C^{-1}$
T is change in temperature in ^{0}C.
M is mass.

N.B. When using the formula appropriate units must be used e.g. if C is given as 4.2 KJ kg^{-1} $^{0}C^{-1}$, mass. (M) must be converted to kg if given in grams.

Problem:
In an experiment 20.0 cm³ of 2 M NaOH completely neutralized 15.5 cm³ of a dibasic acid. Calculate the heat of neutralization if the change in temperature was 6.3 ^{0}C. (Given the density of solutions as 1 gcm^{-3} and specific heat capacity of water as 4.2 KJ $kg^{-1}$$^{0}C^{-1}$

Solution:
First step:
To calculate moles of NaOH and hence moles of the dibasic acid used.

Molarity of NaOH = 2M

1000 cm³ Contains 2 moles

1 cm³ Contains $\underline{2\ mol}$
                        $10^3 cm^3$

20.0 cm³ will contain $\underline{2\ mol \times 20.0\ cm^3}$
                              $10^3\ cm^3$
                           $= \underline{0.04\ mol.}$

The equation of sodium hydroxide and the dibasic acid is:
    $H_2X\ (aq)\ +\ 2Na\cancel{OH}\ \cancel{(}aq)$ $Na_2X(aq) + 2H_2O(l)$
The ratio of $H_2\ X$:   NaOH
          1   :   2

The moles of dibasic acid $= \underline{0.04}$
                              2
                           $= \underline{0.02\ mol.}$

Second Step:
To calculate the molar heat of neutralization of the reaction
Total Volume of solution   =   (20.1 + 15.5) cm³
                    = 35.5 cm³
 Density of solution   = 1g cm^{-3}
 ∴ Mass of solution   = 35.5 cm³ x 1gcm^{-3}
                  =   35.5g = 35.5 x 10^{-3}kg
 ΔH   = MCΔT
     -   35.5 x 10^{-3}kg x 4.2 KJkg^{-1} ^{0}C $^{-1}$ x 6.3 K
     =   0.9393KJ
0.02   mol give 0.9393KJ
     1, mol will give   = $\underline{\ 0.9393KJ}$
                          0.02 mol

$$= -46.97 \text{ kJ mol}^{-1}$$

Heat is given off when an acid neutralizes a base.

$$\therefore \Delta H = -46.97 \text{ KJ mol}^{-1}$$

FARADAY'S LAW OF ELECTROLYSIS

Important terminologies to remember:
(i) Current (I) measured in amperes (A). This is a unit of current strength
(ii) Volt (V): This is a measure of potential difference
(iii) Coulomb (C): This is a measure of the quantity of electricity.

The relationship between coulombs, current and time is shown by the following equation.

Coulomb = current (ampere) x time (seconds)

$$C = It.$$

A coulomb is the quantity of electricity passing when 1 ampere flows for 1 second through an electrolyte.

FARADAY'S FIRST LAW OF ELECTROLYSIS.

The mass (M) of substance liberated during electrolysis is directly proportional to the quantity of electricity passed through the solution.

$$M \propto I t$$

$$M = KIt$$

K is a constant given as E and it is an important quantity for any element, and is known as electrical equivalent.

$$M = E I t$$
$$E = \frac{M}{I t}$$

If M is in grams then the units for E is g/C or gc^{-1} i.e. gram / coulomb of electricity is passed through an electrolyte.

Problem 1:
What is the quantity of electricity that is produced when a current of 0.20 A pass through a solution for 30 minutes.

Solution 1:
$$C = It$$
$$= 0.20 \text{ A x } 30 \text{ x } 60 \text{ s}$$
$$= \underline{360 \text{ coulombs}}$$

Problem 2:
How much current will pass through a solution for 10 minutes to produce 300 coulombs of electricity?

Solution 2:
$$C = I t$$
$$I = \frac{C}{t}$$
$$= \frac{300C}{10 \text{ x } 60 \text{ s}}$$

$$= 0.5 \ \frac{C}{s}$$
$$= \underline{0.5A}$$

Problem 3:
Calculate the quantity of electricity required to liberate 1 mole of copper if the electrochemical equivalent of copper is 3.290×10^{-4} g C^{-1} [Cu = 63.5]

Solution 3:

$$E = \frac{M}{I\,t}$$

Molar mass of copper = 63.5g mol^{-1} E is electrochemical equivalent
= 3.290×10^{-4} g C^{-1} I t = quantity of electricity = coulombs (C)

$$\therefore \quad E = \frac{M}{C}$$

$$C = \frac{M}{E}$$

$$= \frac{63.5 \text{ g mol}^{-1}}{3.290 \times 10^{-4} \text{ g C}^{-1}}$$

= 193009 C mol^{-1}

FARADAY'S SECOND LAW OF ELECTROLYSIS.

When the same quantity of electricity is passed through solutions of different electrolytes, the masses of the substances liberated are proportional to their chemical equivalents or in simple terms one mole of various atoms liberated by one or more moles of electrons.

Faraday's constant
 A faraday is the quantity of electricity required to deposit 1 mole of a substance.

Example:

The electrochemical equivalent of silver is $0.001118gC^{-1}$ and molar mass of silver is $107.880g$ mol $^{-1}$.

If 0.001118 g of silver is deposited by 1 coulomb of electricity then:

The quantity of electricity (coulombs) required to deposit one mole of silver   (107.880g) is:

$$\frac{107.880 \text{ g mol}^{-1}}{0.001118 \text{ g C}^{-1}}$$

$$\cong \underline{96500} \text{ C}$$

N.B: A Faraday (F) = 96500 coulombs is the charge on 1 mole of electrons.

The charge on: 1 mole of Ag^+ is 1F
                1 mole of Cu^{2+} is 2F
                1 mole of Fe^{3+} is 3F

Therefore to liberate 1 mole of Ag, Cu and Fe is 1,2,3, Faraday's are needed respectively in accordance with Faraday's Second Law.

Problem 1
What is the charge on one electron?

Solution 1:
Charge for 1 mole of electrons = 96500 C mol $^{-1}$
1 mole of electrons = 6.02×10^{23} electrons mol^{-1}

Charge on an electron   = $\dfrac{96500 \text{ C mol}^{-1}}{6.02 \times 10^{23} \text{ electron mol}^{-1}}$

$$= 1.6 \times 10^{-19} \text{ coulombs electron}^{-1}$$
$$= 1.6 \times 10^{-19} \text{ Ce}^{-1}$$

Problem 2:

0.1184g of Copper is deposited when a current of 2A is passed for 180 seconds. What is the copper ion involved? (Show the working)

   1 Faraday = 96500 coulombs

   Molar mass of copper = 64g mol^{-1}

Solution 2:

First step:

Calculation to find the number of faradays used

$$C = 1 \, t$$
$$1 = 2A \text{ and } t = 180 \text{ s}$$
$$C = 2A \times 180 \text{ s}$$
$$= 360 \text{ As}$$
$$= \underline{360 \text{ coulombs}}$$

Faradays   = $\dfrac{C}{96500}$

   $= \dfrac{360 \text{ C}}{96500 \text{ C}}$

   $= 0.\underline{00373 \text{ F}}$

Second step:

Calculation of the moles of copper deposited. Mass of copper deposited

 = 0.1184 g.

Molar mass of copper = 64g mol^{-1}

Moles of copper   = $\underline{0.1184g}$
                                  64 g mol^{-1}

                           = $\underline{0.00185\ mol}$

<u>Third step:</u>
Calculation of the charge on copper.
0.00185 mole of copper deposited by 0.00373 F
1 mole of copper will be deposited by:

     $\underline{0.00373F - x\ 1\ mol}$
        0.00185 mol
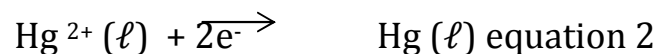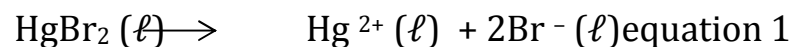   = 2.016 F
     $\approx \underline{2\ F}$

This shows that 2 moles of electrons or 2 F of electrons were involved to deposit 1 mole of copper.
$\therefore$ The copper ion involved was Copper (II) thus Cu^{2+}

Problem 3:
Two molten salts were electrolysed in a series. One salt was mercury (II) bromine and the other was a salt of an unknown metal M. In the time taken to deposit 4g of mercury only 0.6g of metal M was produced. Calculate the charge on the ion of M. Hg = 200, M = 60.

Solution 3:
$HgBr_2\ (\ell) \longrightarrow$ $Hg^{2+}\ (\ell)\ + 2Br^-\ (\ell)$ equation 1

$Hg^{2+}\ (\ell)\ + \overline{2e^-} \longrightarrow$ $Hg\ (\ell)$ equation 2

Step I:

To find the number of Faraday's used:

Mass of mercury   = 4g

Molar mass of mercury = 200 mol^{-1}

Moles of mercury = $\dfrac{4g}{200g\ mol^{-1}}$

$= \underline{0.02\ mol}$

From equation (2)

1 mole of Hg needs 2F

∴ 0.02 mole of Hg will need $2\ \dfrac{F\ x\ 0.02\ mol}{1\ mol}$

$= \underline{0.04\ F}$

∴ 0.04 F were used during electrolysis of the two salts as per question.
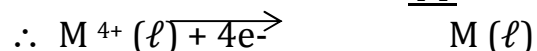
Step 2:

To calculate the charge on M.

Mass of metal M   = 0.6g

Molar mass of M   = 60g mol^{-1}

∴ moles of M   = $\dfrac{0.6g}{60\ g\ mol^{-1}}$

$= \underline{0.01\ mol}$

mol of M was deposited by 0.04 F

∴ 1 mol of M would be deposited by $\dfrac{0.04\ F\ x\ 1\ mol}{0.01}$ mol

$= \underline{4\ F}$

∴ $M^{4+}(\ell) + 4e^- \rightarrow M(\ell)$

∴ The charge on the ion of M is 4^+ and thus M^{4+}

EINSTEIN'S MASS – ENERGY EQUATION

It can be recalled when Dalton almost convinced everybody that matter can neither be created nor destroyed, but he was almost right and for most purposes this is so especially during chemical reactions.

In 1905 Albert Einstein showed that matter can be converted into energy and vice versa through his famous equation which shows the relationship between energy and matter.

$E = MC^2$ Where: -
E = Energy liberated in joules
M = Loss of mass in kilograms
C = Velocity of light in metres per second   (3.0×10^8 mg^{-1})

Problem
What would be the energy if a mole of uranium – 235 was used up in a nuclear reaction?

Solution
Molar mass of Uranium – 235 = 235 g mol^{-1}
Mass in kg = $\dfrac{235}{10^3}$ kg

$C = 3.0 \times 10^8$ ms^{-1}
$E = MC^2$

$= \dfrac{235kg}{10^3} \times (3.0 \times 10^8 \text{ ms}^{-1})^2$

$= 2.115 \times 10^{16}$ kgm^{2}s^{-2}
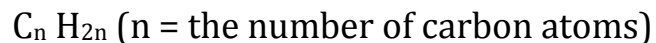
$= \underline{2.115 \times 10^{16} \text{ J}}$

HYDROCARBONS

Simple homologous hydrocarbons such as alkanes, alkenes, alkenes and alkynes are each represented by a simple formula.
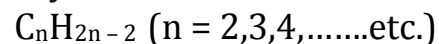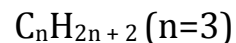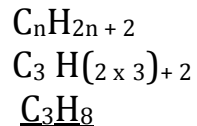
1. Alkanes:
   $C_n H_{2n+2}$ (n = the number of carbon atoms)

2. Alkenes
   $C_n H_{2n}$ (n = the number of carbon atoms)

3. Alkynes
   $C_n H_{2n-2}$ (n = 2,3,4,.......etc.)

Problem:
Give the molecular formula, structural formula and name for each of the three groups above when n = 3.
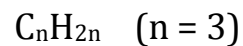
Solution:
ALKANES
$C_n H_{2n+2}$ (n=3)
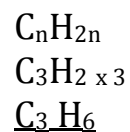
(i)   Molecular formula is:
$$C_n H_{2n+2}$$
$$C_3 H_{(2 \times 3)+2}$$
$$\underline{C_3 H_8}$$

(ii).   Structural formula of $C_3 H_8$ is $CH_3 CH_2 CH_3$

(iii)   Name is Propane

ALKENES:

C_nH_{2n} (n = 3)

(i)   Molecular formula is:

C_nH_{2n}
$C_3H_{2 \times 3}$
$\underline{C_3\ H_6}$

(ii)   Structural formula of C_3H_6 is:
CH$_3$ CH = CH

(iii)   Name is Prop – 1 - ene

ALKYNES.

$C_n\ H_{2n} – 2$ (n = 3)

i)   Molecular formula is:
$C_n\ H_{2n-2}$
$C_3\ H\ (_{2 \times 3})$ $_{-2}$
$\underline{C_3\ H_4}$

ii) Structural formula of $C_3\ H_4$ is:
CH$_3$ C ≡ CH

iii) Name is Prop - 1 – yne

ALKANOLS:

These are the alcohols and they can be represented by a general formula of:
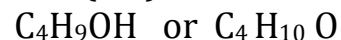
$C_nH_{2n+2}O$ or $C_nH_{2n+1}OH$

Problem:

Give the molecular formula, straight chain or structural formula and name of the alcohol when n = 4.

Solution:

General formula is $C_nH_{2n+1}OH$ or $C_nH_{2n+2}O$

(i)   Molecular formula is:

$C_4H_{(2 \times 4)+1}OH$ or $C_4H_{(2 \times 4)+2}O$

C_4H_9OH or $C_4H_{10}O$

(ii)   Structural formula of C_4H_9OH or $C_4H_{10}O$ is

$CH_3CH_2CH_2CH_2OH$

(iii)   Name is Butanol or Butan – 1 – ol.

VOLUMETRIC ANALYSIS

The main objective of volumetric analysis is to determine the amount of a substance in a given sample. When dealing with volumetric analysis the concept of concentration cannot be avoided. Molarity i.e. moles per litre or decimeter is widely used unit of concentration.

Molarity = moles   ie molarity = moles

litre   litre

N.B. Unit for molarity is M i.e. molar

Problem:
What is the molarity of sodium hydroxide solution when 4g are dissolved to make 250 cm³. (Na = 23.0, O = 16.0, H = 1.0)

Solution:
Mass of NaOH   = 4g

R.F.M. of NaOH = 23 + 16 + 1
                = 40
Molar mass of NaOH = 40 g mol $^{-1}$

Moles of NaOH = $\dfrac{4g}{40g\ mol^{-1}}$
                = 0.1 mol

Molarity = $\dfrac{moles}{litre}$ ie molarity = $\dfrac{moles}{litre}$

Volume of NaOH = 250cm³ = $\dfrac{250}{1000}$ = 0.25ℓ

Molarity of   NaOH   = $\dfrac{0.1\ mol}{0.25\ell}$
                = 0.4 mol / ℓ
                = 0.4 M

DILUTING A SOLUTION:

When a solution of a known concentration is diluted it is possible to apply a simple formula to calculate whatever is unknown.

Molarity x Volume = Molarity x volume
   (original)   (diluted)

Let: Original morality   = M_1
    Original volume   = V_1
    Diluted Molarity   = M_2
    Diluted Volume   = V_2

Thus: $M_1V_1 = M_2V_2$

Problem:
100 cm^2 of 2M HCl was diluted to 250cm^3, What is the molarity of the diluted solution?

Solution:
Let: M_1 = Molarity of original HCl

     V_1 = Volume of original HCl

     M_2 = Molarity of diluted HCl

     V_2 = Volume of diluted HCl

    ∴ $M_1V_1 = M_2V_2$ let:

$$M_2 = \frac{M_1V_1}{V_2} \qquad\qquad M_1 = 2M$$
$$M_2 = ?$$

$$= \frac{2M \times 100 \text{ cm}^3}{250 \text{ cm}^3} \qquad\qquad V_1 = 100\text{cm}^3$$
$$V_1 = 250 \text{ cm}^3$$
$$= 0.8M$$

The formula $M_1V_1 = M_2V_2$ can be modified slightly to be applied for a reaction in which 1 mole of an acid reacts with 1 mole or 2 moles of an alkali (a base) or a carbonate.
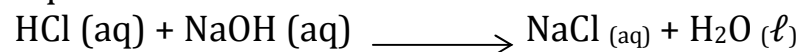
Case 1: Mole ratio of acid: mole ratio of alkali /base = 1:1

Problem:
In a titration reaction 25cm³ of 0.1M HCl neutralized 20 cm³ of NaOH. Calculate the concentration of the alkali in moles per litre.

Solution:
Equation for the reaction:
HCl (aq) + NaOH (aq) $\longrightarrow$ NaCl $_{(aq)}$ + H$_2$O $_{(\ell)}$

Moles HClC$_1$:   Moles of NaOH = 1 : 1
Let:
$$\frac{M_aV_a}{M_bV_b} = \frac{1}{1} \qquad\qquad M_a = \text{Molarity of acid} = 0.1 \text{ M}$$
$$M_b = \text{Molarity of base} = ?$$

$$M_aV_a = M_bV_b \qquad\qquad V_a = \text{Volume of acid} = 25 \text{ cm}^3$$
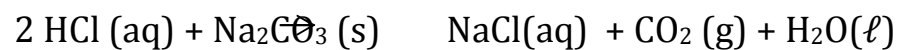$$V_b = \text{Volume of base} = 20 \text{ cm}^3$$

$$Mb = \underline{M_aV_a}$$

V_b

$= \dfrac{0.1\ M \times 25\ cm^3}{20\ cm^3}$

$= \underline{0.125\ M}$

Case 2: Mole ratio of acid: mole ratio of a base = 2 : 1

Problem:
15 cm³ of 0.1 M Na_2CO_3 reacted completely with 20cm³ of HCl. Calculate the moles of HCl used.

Solution:
2 HCl (aq) + Na₂C̶O₃ (s)   NaCl(aq) + CO_2 (g) + $H_2O(\ell)$

$\dfrac{M_aV_a}{M_aV_b} = \dfrac{2}{1}$ $\dfrac{M_a\ V_a}{M_b\ V_b} = \dfrac{2}{1}$

$2M_bV_b = M_aV_a$

Let:

M_a = molarity of acid = ?

M_b = molarity of base = 0.1 M

$M_a = \dfrac{2M_bV_b}{V_a}$ V_a = volume of acid = 20 cm³

V_b = volume of base = 15 cm³

$= \dfrac{2 \times 0.1 \times 15\ cm^3}{20\ cm^3}$

$= 0.15\ M$

Molarity (M) = $\dfrac{moles}{litre}$

V_a = 20 x 10^{-3} ℓ
M   =   0.15 M

∴moles = molarity x litre

∴ moles of HCl = 0.15 mol ℓ^{-1} x 20 x $10^{-3}\ell$
= 3 x 10^{-3} mol i.e 0.003 mol

N.B.: It is important to note that these calculations are easily done using first
principles method from which the formulae are derived. A slight
omission in the formula leads to wrong answers which may also look
very unrealistic.

To determine the number of water of crystallization in a hydrated salt:

A number of methods may be applied but the one to consider at this point is that of heating the hydrated salt to a constant mass having removed all the water of crystallization before decomposition takes place if any.

A known mass of hydrated salt $MX.yH_2O$ when heated to a constant mass gives the following equation.

$MX.yH_2O$ (s) $\longrightarrow$ MX (s) + yH_2O (ℓ)
Mass of $MX.yH_2O$(s) = w g
Mass of MX   = a g
Mass of yH_2O = (w – a) g

Using relative atomic masses
1. R.F.M. of MX can be calculated
2. yH_2O becomes y (R.F.M. of H_2O) = y [(2 x 1) + 16]
                                                            = 18 y.

The following simple relationship can be applied

$$\frac{\text{mass of water of crystallization}}{\text{mass of anhydrous salt}} = \frac{18y}{\text{R.F.M of MX}}$$

Thus: $\dfrac{(W - a)\,g}{a} = \dfrac{18y}{\text{R.F.M. of MX}}$
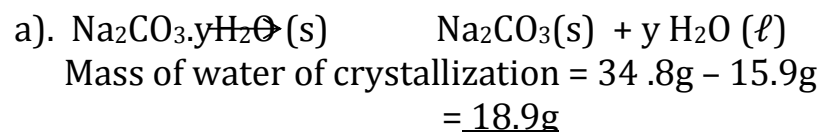
Problem:

34.8g of hydrated sodium carbonate was strongly heated to a constant mass of 15.9g.

(a) Calculate the number of water of crystallization in the sample.

(b)   Comment on the value you have got in (a) above.

Solution:

a). $Na_2CO_3.yH_2O\,(s) \quad\quad Na_2CO_3(s) \; + \; y\,H_2O\,(\ell)$

    Mass of water of crystallization = 34 .8g – 15.9g

                         = 18.9g

Mass of anhydrous Na_2CO_3 = 15.9g

$\therefore \dfrac{\text{mass of water of crystallization}}{\text{mass of anhydrous } Na_2CO_3} = \dfrac{yH_2O}{\text{R.F.M. of } Na_2CO_3}$

N.B. R.F.M. of Na_2CO_3 = (2 x 23) + 12 + (3 x 16)

                 = 106

    y(R.F.M. of H_2O) = y [(2x 1) + 16]

                = 18y

    <u>mass of water of crystallisation</u>   18.9g = 18y

mass of anhydrous salt   15.9g   106

$$\therefore = \frac{18.9g}{15.9\ g} = \frac{18y}{106}$$

$$18.9g \times 106 = 15.9g \times 18Y$$
$$y = \frac{18.9g \times 106}{15.9g \times 18}$$

$$= 7$$

Alternative Method:

$Na_2CO_3.yH_2O_{(s)} \longrightarrow \quad Na_2CO_3\ (s) + yH_2O\ (\ell)$

$$
\begin{array}{ccc}
Na_2CO_3 & : & yH_2O = 1 : y \\
Na_2CO_3 & : & H_2O \\
15.9 & : & 18.9 \\
\underline{15.9} & : & \underline{18.9} \\
106 & : & 18 \\
\underline{0.15} & : & 1.05 \\
\underline{0.15} & : & \underline{1.05} \\
0.15 & : & 0.15 \\
1 & : & 7
\end{array}
$$

$\therefore y = 7$ and thus $Na_2CO_3.7H_2O$

(b) Hydrated sodium carbonate is a decahydrate i.e. $Na_2CO_3.10\ H_2O$

It is an efflorescent i.e. it loses some of its water of crystallization to the atmosphere when exposed to the air and thus a figure less that 10.

PRACTICE QUESTIONS

1. In a chemical reaction a gas produced at 740 mm Hg occupied 600 cm^3. Calculate the pressure it would exert if the volume is halved at the same temperature.
2. The temperature and volume of a gas at 700 mm Hg was found to be at 70^{0}C and 350 cm^3 respectively. Calculate the new temperature if the volume is raised to 400 cm^3 at the same pressure.
3. Calculate the volume at s.t.p. of a gas which occupies 257cm^3 at 570 mm Hg and −16^{0}C.
4. 2.56g of Sulphur formed a vapour at 546^{0}C and 1 atm, Pressure, which had a volume of 672 cm^3 [S = 32.]

    CALCULATE:
    (a) the volume of vapour at 1 atm
    (b)   the mass of 22.4 ℓ of sulphur vapour at s.t.p.
    (c) the relative formula of sulphur
    (d)   the formula of sulphur molecule

5. A sample of 12.25g of potassium chloride decompose to give oxygen gas.
    2 KCℓO$_3$ (s) $\longrightarrow$ 2 KCℓ (s) + 3O$_2$ (g)
    Calculate the volume of oxygen at s.t.p.
    (Given R= 8.21 x 10^{-2} atm mol $^{-1}$K^{-1} and K = 39. Cl = 35.5, O = 16)

6. $60cm^3$ of oxygen gas diffuse through a porous pot in 10 seconds and $100cm^3$ of chlorine diffuse through the same pot in 25 seconds. If the density of Oxygen is 16 times that of hydrogen, what is the density of chlorine compared to hydrogen.

7. 0.2g of metal was dissolved in dilute acid, and 306 cm^3 of dry hydrogen were evolved. The volume of the gas was measured at 20^0C and
   730 mm Hg.
   (a) Calculate the volume of the gas at s.t.p.
   (b) Why should the temperature be in K or absolute scale: use the formula used in 'a' above to explain.
   (c) Calculate the mass of hydrogen if its density at s.t.p. is
       0.00009 gcm^{-3}
   (d) Calculate the equivalent of the metal
   (e) Calculate the atomic mass of metal if its valency is 3.

8. Convert the following as directed.
   (a) Degree Celsius to Kelvin
       (i) -13^0C
       (ii) 37^0C
       (iii) 223^0C

   (b) Kelvin to Celsius
       (i)   378 K
       (ii)   40 K
       (iii)   878 K

9. Calculate the amount of heat in joules required to raise the temperature of 50g of water by 50^0C
         $\Delta H = MC\Delta T$, Specific heat capacity of water = 4.2 Jg^{-1} $^0C^{-1}$

10.   Calculate the molar heat of neutralization in kJ when 500cm^3 of 2M HCl
   reacts completely with the same amount and concentration of sodium
   hydroxide and the temperature rise being 13.7^{0}C. Take specific heat
   capacity of solution to be 4.2 Jg^{-1} ^{0}C^{-1} and the density of solution to be
   gcm^{-3}

11.   A steady current of 0.2A is passed through a circuit for 4825s.
   Calculate the quantity of electricity in coulombs that flows through the circuit.

12.   Calculate the quantity of electricity required to liberate 1 mole
   of Silver if the electrochemical equivalent of silver is 1.118 x 10^{-3} gC^{-1} and Ag = 108.

13.   Dehydration of an organic compound P gives Q. Hydrogenation
   of Q in presence of powdered nickel give R with Molecular formula C_3H_8.
   (a)Write the structural formula of R
   (b)   (i) Use the following reaction to identify P

   ~~Q~~ ——————— ~~H₂ / Ni (s)~~>   R

       (ii) Write down the molecular formula of Q.

   (c) Use the following reactions to identify P
              Conc. H_2SO_4
       P ——————————————→   Q
   (d)   Then write the general formula of :-
      (i)   P
      (ii)   Q

(iii)   R

14.   10.6g of sodium carbonate (Na_2CO_3) were dissolved to make a
   litre solution
   (Na = 23, C = 12, O = 16)
   Calculate the molarity of sodium ions.

15.   Calculate:
   (i)   The volume of 0.1M HCl that reacts with 25cm^3 of 0.05M NaOH.
   (ii)   The molarity of HCl if 25 cm^3 react with 100cm^3 of 0.05M NaOH.

16.   25 cm^3 of 2M NaOH was diluted to 500cm$^{3.}$ Calculate the
   concentration in moles per litre of new solution.

17.   How can you prepare 30 cm^3 of 0.5 M HCl using 6M HCl that is
   on the laboratory bench.

18.   Calculate the volume of 0.2M Na_2CO_3 which will react exactly
   with 40 cm^3 of 0.3 M H_3PO_4

 19. In an experiment, 5.85g of Epsom salt (hydrated magnesium Sulphate –
    $MgSO_4.xH_2O$) was heated to a constant mass of 2.86g
    (a)What is responsible for the decrease in mass?
    (b)   Calculate the number of the water of crystallization.

ANSWERS TO PRACTICE QUESTIONS

1. This question is solved using Boyle's Law i.e.

    $P_1V_1 = P_2V_2$

    $P_1 = 740$ mm Hg

    $P_2 = ?$

    $V_1 = 600$ cm^3

    $V_2 = 300$ cm^3

    $P_1V_1 = P_2V_2$

    $P_2 = \dfrac{P_1V_1}{V_2}$

    $\therefore P_2 = \dfrac{740 \text{ mm Hg x } 600 \text{ cm}^3}{}$

$$300 \text{ cm}^3$$

$$= \underline{1480 \text{ mm Hg}}$$

2. This is an application of the Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_1 = 350 \text{ cm}^3$ $T_1 = 70 \,^0C = 343 \text{ K}$
$V_2 = 400 \text{ cm}^3$ $T_2 = \quad ?$
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_2 = \frac{V_2 \times T_1}{V_1}$$

$$= \frac{400 \text{ cm}^3 \times 343 \text{ K}}{350 \text{ cm}^3}$$

$$= \underline{392 \text{ K}} \text{ i.e. } \underline{119^0 C}$$

3. (a) This is an application of the ideal gas equation

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$P_1 = 570 \text{ mm Hg}, V_1 = 257 \text{ cm}^3, T_1 = -16^0C = 257K$
$P_2 = 760 \text{ mm Hg}, V_2 = \quad ?, T_2 = 0^0C = 273K$

$$\underline{P_1 V_1} \xrightarrow{} = \underline{P_2 V_2}$$

T_2 T_2

V_2 $= \dfrac{P_1V_1}{T_1} \times \dfrac{T_2}{P_2}$

          $= \dfrac{V_1 \times P_1 \times T_2}{P_2 \times T_1}$

          $= \dfrac{570 \text{ mm Hg} \times 257 \text{ cm}^3 \times 273 \text{ K}}{257\text{K} \times 760 \text{ mm Hg}}$

          $= 204.75 \text{ cm}^3$
          $= \underline{205 \text{ cm}^3}$

4. (a) This is first an application of the ideal gas equation

   $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$

   $V_2 = \dfrac{V_1 \times P_1 \times T_2}{P_2 \times T_1}$

        $= \dfrac{672 \text{ cm}^3 \times 760 \text{ mm Hg} \times 273 \text{ K}}{760 \text{ mmHg} \times 819 \text{ K}}$

        $= \underline{224 \text{ cm}^3}$

   $P_1 = 760 \text{mmHg}, \; P_2 = 760 \text{mm Hg}$
   $V_1 = 672 \text{ cm}^3$
   $T_1 = 273 + 540 = 819 \text{ K}$
   $T_2 = 273\text{K}$

   (b) The mass of 224 cm^3 of sulphur $= 2.56\text{g}$

The mass of 1 cm³ of sulphur   = $\underline{2.56g}$
$$\qquad\qquad\qquad\qquad\qquad 224\ cm^3$$

∴ The mass of 22.4 x 10³ of sulphur = $\dfrac{2.56g \times 22.4\ \times 103\ cm^3}{224\ cm^3}$

$$= \underline{256\ g}$$

(c) The relative formula mass of sulphur = 256

(d) Molar mass of Sulphur = 256g

Atoms of sulphur molecule = $\dfrac{256g}{32g}$

$$= 8$$

∴ The formula of a sulphur molecule is:

$$= \underline{S_8}$$

5. This problem is solved by using the equation of state.

PV = nRT

P = 1 atm, V = ? R = 8.21 x 10⁻² atm mol⁻¹ K⁻¹ T = 0ᴼC

$KClO_3$ = 39 + 35.5 + 48

$$= 122.5g\ mol^{-1}$$

Moles of $KC\ell O_3$ = $\dfrac{12.25g}{122.5g\ mol^{-1}}$

$$= 0.1\ mol$$

∴ n = 0.1 mol.

From the equation: i.e.

2 $KClO_3$ ~~(s)~~ $\longrightarrow$ $2KC\ell$ (s) + 3 O_2 (g) gives   3 moles of O_2 (g)

It follows that:

2 moles of $KClO_3$ give 3 moles of O_2

1 mole of $KClO_3$ gives $\dfrac{3 \text{ moles of } O_2}{2 \text{ moles of } KClO_3}$

$\therefore$ 0.1 mole of $KClO_3$ will give $\dfrac{3 \text{ moles of } O_2 \text{ x } 0.1 \text{ mole of } KClO_3}{2 \text{ moles of } KClO_3}$

$\qquad\qquad\qquad\qquad\qquad = \underline{0.15 \text{ mole of } O_2}$

$\therefore$ Using the equation of state and substitute appropriately i.e.

$\qquad PV = RT$

$\qquad V = \dfrac{nRT}{P}$

$\qquad\qquad = \dfrac{0.15 \text{ mol x } 8.21 \text{ x } 10^{-2} \text{ atm. mol}^{-1} \text{ K}^{-1} \text{ x } 273K}{1 \text{ atm}}$

$\qquad\qquad \approx \quad \underline{3.36\, \ell}$

6. This problem is solved by applying Graham's Law of diffusion.

$\qquad$ Rate $\propto \dfrac{1}{\sqrt{d}}$

$\quad$ Note: Rate $= \dfrac{\text{Volume}}{\text{Time}}$

$\therefore \quad \dfrac{\text{Volume}}{\text{Time}} \quad \propto \quad \dfrac{1}{\sqrt{d}}$

$\qquad$ Hence: $\dfrac{R_1}{R_2} = \dfrac{\sqrt{d_2}}{\sqrt{d_1}}$

Rate of diffusion of oxygen $= \dfrac{60 \text{ cm}^3}{10s} = 6 \text{ cm}^3/s$

Rate of diffusion of Chlorine $= \dfrac{100 \text{cm}^3}{} = 4 \text{ cm}^3/s$

25s

It therefore follows that:

$$\frac{RO_2}{RCl_2} = \frac{\sqrt{d_{CL2}}}{\sqrt{do_2}}$$

$$\frac{6}{4}^2 = \frac{\sqrt{dCl_2}}{\sqrt{0_2}}$$

$$\left(\frac{6}{4}\right)^2 = \frac{\sqrt{dCl_2}}{\sqrt{d\,0_2}}$$

$$\frac{6^2}{4^2} = \frac{dCl_2}{16} \qquad\qquad 4 \qquad \sqrt{16}$$

$$dCl_2 = \frac{6^2 \times 16}{4^2}$$

$$= \frac{6 \times 6 \times 16}{4 \times 4}$$

$$= \underline{36}$$

7. (a) This part involves the ideal gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$V_1 = 306 \text{ cm}^3$ $T_1 = 293$ K $P_1 = 730$ mm Hg
$V_2 = $? $T_2 = 273$ K $P_2 = 760$ mm Hg

$$V_2 = \frac{V_1 \times P_1 \times T_2}{P_2 \times T_1}$$

$$= \frac{306 \text{ cm}^3 \times 273 \text{ K} \times 730 \text{ mm Hg}}{}$$

$$\frac{293 \times 760 \text{ mm Hg}}{}$$

$\approx$ <u>274 cm^3</u>

(b.)   Using the ideal gas equation i.e.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

If among other factors the temperature is 0^0C for either T_1 or T_2 is zero the substitution would then be either:

$$\frac{P_1V_2}{0} = \frac{P_2V_2}{T_2} \quad \text{or} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{0}$$

The above equations would be undefined and thus the importance of the conversion from ^0C to K.

(c) Mass = Volume x density or m = v x d.

(d) Mass of hydrogen = 273 cm^3 x 9.0 $^{-5}$gcm^{-3}

= <u>0.02457g</u>

(d) 0.02457g H$_2$ (g) displace 0.2g metal

1g H$_2$(g) displaces $\frac{0.2g}{0.02457g}$

= <u>8.1</u>

Therefore equivalent of metal is 8.1

(e) Atomic mass = Valency x equivalent

= 8.1 x 3

= <u>24.3</u>

8. The formula that can be applied for both (a) and (b) is

K (Kelvin) = ^0C (degree Celsius) + 273

K = ^0C + 273

(a) (i) -13^0C to K

K = ^{0}C + 273

= -13^0C + 273

= <u>260K</u>

ii) 37^0c to K

K = ^{0}C + 273

= 37 + 273

= <u>310K</u>

(iii) 223^0C to K

K = ^{0}C + 273

= 223 + 273

= <u>496K</u>

(b) (i) 378K to ^{0}C

K = ^{0}C + 273

^{0}C = K – 273

= 378 – 273

= <u>105^{0}C</u>

(ii). 40K to ^{0}C

K = ^{0}C + 273

= ^{0}C = K - 273

= 40 – 273

= <u>-233^{0}C</u>

(iii) 8 78K to ^{0}C

$K = {}^0C + 273$

${}^0C = K - 273$

$= 878 - 273$

$= 605\,{}^0C$

9. $\Delta H = MC\,\Delta T \quad M = 50g$

$C = 4.2\ Jg^{-1}\ {}^0C^{-1}$

$T = 50^0$

$\Delta H = 50g \times 4.2\ Jg^{-1}\ {}^0C^{-1} \times 50\,{}^0C$

$= 10500\ J$

10.   Total volume $= (500 + 500)\ cm^3 = 1000cm^3$

∴ Mass of solution $= 1000\ cm^3 \times 1g\ cm^{-3}$

$= 1000g$

Rise in temperature $(\Delta T) = 13.7\,{}^0C$

$\Delta H = MC\,\Delta T$

$= 1000g\ 4.2Jg^{-1}\ {}^0C^{-1} \times 13.7\ {}^0C$

$= 57540J$

$= 57.54KJ$

Considering either NaOH or HCl and given that concentration is 2M of each.

$\underline{\text{Moles that reacted}}$

$1cm^3$ contains $= \dfrac{2\ moles}{1000\ cm^3}$

$= 0.002\ moles$

∴ $500\ cm^3$ contain $= \underline{0.002\ mol \times 500cm^3}$

$$\frac{}{1000cm^3}$$
$$= 0.001 \text{ moles}$$

$\therefore$ Heat liberated per mole either of HCl or NaOH is 57.54KJ

Heat Δ H (neutralization) = <u>- 57.54 KJ mol $^{-1}$</u>

11.   C = 1t

Where C = coulombs (quantity in amperes)

t = time in seconds

$\therefore$ C = 0.2A x 482s

= 965 As

i.e. 965 coulombs

12.   This can be solved by using the Faraday's first law of

electrolysis.

M $\propto$ It

M = KIt   K = E (electrochemical equivalent)

M = KIt

M = EIt

N.B.   It = C i.e. coulombs or quantity of electricity.

M = EC

C = <u>M</u>

E

= <u>108g mol $^{-1}$</u>

1.118 X 10^{-3}gC^{-1}

$\approx$ <u>96600 C</u>

13 (a) $CH_3CH_2CH_3$

(b) (i) $Q \xrightarrow{\quad H_2/Ni \quad} CH_3CH_2CH_3$

Then Q must be $CH_3CH = CH_2$

.(ii) C_3H_6

(c)

$P \xrightarrow[\text{Hot}]{\text{Conc. } H_2SO_4} CH_3CH = CH_2$

Then P must be an alcohol $CH_3CH_2CH_2OH$

Dehydration - Removal of hydrogen and oxygen from a compound and when the two recombine water is formed.

(d). (i) P, molecular formula $CH_3CH_2CH_2$ then general formula is:
$C_nH_{2n+2}O$ or $C_nH_{2n+1}OH$

(ii) Q, molecular formula is : C_3H_6
Then general formula is: C_nH_{2n}

(iii) R, molecular formula is $CH_3CH_2CH_3$
Then general formula C_nH_{2n+2}

14.   R.F.M. of Na_2CO_3 = (2 x 23) + 12 + (3 x 16)
= 106
∴ Molar mass of Na_2CO_3 = 106 g mol^{-1}

Moles of Na_2CO_3 = $\dfrac{10.6 \text{ g}}{106 \text{ g mol}^{-1}}$

$$= \underline{0.1 \text{ mol}}$$

$$Na_2CO_3 \text{ (aq)} \rightarrow \qquad 2Na^+ \text{ (aq)} + CO_3^{2-} \text{ (aq)}$$
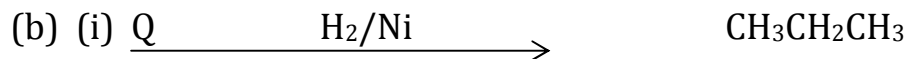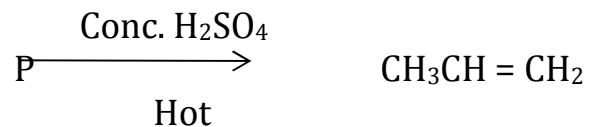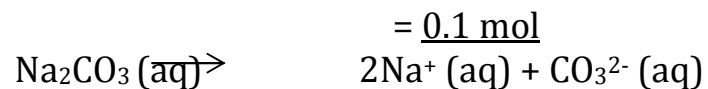
From the equation:

∴ Molarity $= \dfrac{\text{mol}}{\ell}$

Moles of Na^+ (aq) $= \underline{2 \text{ x } 0.1 \text{mol}}$

$= 0.2$ mol

$= 0.2$m

∴ molarity $= \dfrac{0.2 \text{ mol}}{1\ell}$

$= 0.2$ M

15. The formula that can be applied is:-

$M_aV_a = M_bV_b$

(i) M_a = molarity of HCl = 0.1M

V_a = volume of HCl = ?

M_b = molarity of NaOH = 0.05M cm³

$\underline{V_b}$ = Volume of NaOH = 25 cm³

$M_aV_a = M_bV_b$

$V_a = \dfrac{M_bV_b}{M_a}$

$= \dfrac{0.05 \text{ M x } 25 \text{ cm}^3}{0.1} \qquad\qquad\qquad\qquad M$

$\underline{12.5 \text{cm}^3}$

(ii) M_a = molarity of HCl = ?

   V_a = volume of HCl   = 25 cm^3
   M_b = molarity of NaOH = 0.05M

   M_b = Volume of NaOH = 100 cm^3

   M_aV_a = M_bV_b
     M_a = $\dfrac{M_bV_b}{V_a}$

       = $\dfrac{0.05\ M \times 100\ cm^3}{25\ cm^3}$

       = 0.2 M

16. The formula that can be used is:

   Molarity x Volume = molarity x volume
    (original)   (diluted)

   M_1 Original molarity = 2M
   M_2 diluted molarity = ?
   V_1 original volume = 25 cm^3
   V_2 diluted volume = 500 cm^3
   $M_1V_1 = M_2V_2$
     $M_2 = \dfrac{M_1V_1}{V_2}$
       = $\dfrac{2M \times 25\ cm^3}{}$

500 cm^3

$= \underline{0.1 \text{ M}}$

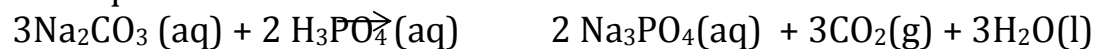17. The formula used is:

$M_1V_1 = M_1V_2$

$M_1 = 6M$

$V_1 = ?$

$M_2 = 0.5M$

$V_2 = 30 \text{ cm}^3$

$V_1 = \dfrac{M_2V_2}{M_1}$

$= \dfrac{0.5M \times 30 \text{ cm}^3}{6M}$

$= \underline{2.5 \text{ cm}^3}$

$\therefore$ This is done by diluting 2.5 cm³ of 6M HCl to final volume of 30cm³ and required molarity of 0.5M is obtained.

18. The equation for the reaction is :-

$3Na_2CO_3 \text{ (aq)} + 2 H_3PO_4 \text{(aq)} \longrightarrow 2 Na_3PO_4\text{(aq)} + 3CO_2\text{(g)} + 3H_2O\text{(l)}$

The formula $\dfrac{M_aV_a}{M_bV_b} = \dfrac{2}{3}$ will be applicable

$M_a = 0.3 \text{ M} = $ molarity of H_3PO_4

$V_a = 40 \text{ cm}^3 = $ Volume of H_3PO_4

$M_b = 0.2M = $ molarity of Na_2CO_3

V_b = ?   = Volume of Na_2CO_3

$3M_aV_a$ = $\underline{2M_b\,V_b}$

V_b = $\dfrac{3M_aV_a}{2M_b}$

= $\underline{3 \times 0.3M \times 40cm^3}$
      $2 \times 0.2\ M$

= $\underline{90\ cm^3}$

i.e. Volume of 0.2M $Na_2\ CO_3$ required is $90cm^3$

19. (a) The decrease is due to removal of water of crystallization.

(b) $MgSO_4 . xH_2O(s)$ $MgSO_4\ (s)\ +\ xH_2O(\ell)$

The formula that can be applied for finding the value of x is:

$\underline{\text{Mass of water of crystallization}}$ = $\dfrac{xH_2O}{\text{R.F.M. of } MgSO_4}$
       Mass of anhydrous $MgSO_4$

(Mg = 24, S = 32, O = 16, H = 1)
Mass of hydrated salt 5.85g
Mass of anhydrous salt =   2.86g

∴ Mass of water of crystallization = 5.85 - 2.86
                                    = 2.99g

R.F.M. of $MgSO_4$ = 24 + 32 + 64
                   =$\underline{120}$
                      x

x (R.F.M. of H_2O) = [(2 x 1) + 16]

$\qquad\qquad$ = x (18)

$\qquad\qquad$ = 18x

$\therefore$ $\underline{2.99}$ $\qquad$ = $\underline{18x}$

2.86 $\qquad$ 120

2.99 x 120 = 18x X 2.86

$\qquad$ 18x = $\underline{2.99 \text{ x } 120}$

$\qquad\qquad\qquad$ 2.86

$\qquad\qquad$ x = $\underline{2.99 \text{ x } 120}$

$\qquad\qquad\qquad$ 2.86 x 18

$\qquad\qquad$ = 6.96

$\qquad\qquad$ = 7

Thus $\underline{MgSO_4.7H_2O}$