Name:

Volumetric Analysis	**Objectives**
1. Concentrations of Solutions	-define solution -define concentration -define molarity -express concentration of solutions in mol/L(molarity), g/L and also in % (v/v) -appreciate the everyday use of % v/v e.g. in alcoholic beverages -calculate molarity from concentration in grams per litre and vice versa -calculate number of moles from molarity and volume -apply knowledge of concentrations of solutions to everyday examples -describe how colour intensity can be used as an indicator of concentration -Define a primary standard and a standard solution -prepare standard solution of sodium carbonate *(balanced equations will be given in all volumetric problems)*
3. Volumetric Analysis	-identify appropriate apparatus used in volumetric analysis -use correct titrimetric procedure when carrying out titrations -solve volumetric problems from first principles -carry out a titration between hydrochloric acid and sodium hydroxide solutions and use this titration to make a sample of sodium chloride (OL only) -standardise a hydrochloric acid solution using a standard solution of sodium carbonate

Def^n: A ***solution*** is a homogeneous mixture of a solute and a solvent.

Def^n: The ***concentration*** of a solution is the amount of solute dissolved in a given volume of the solution.

1. **<u>%(v/v)</u>**
   Means volume of solute per 100 cm^3 of solution, or $cm^3/100\ cm^3$.
   E.g. Alcoholic drinks – Vodka's alcohol (ethanol) concentration is 37.5% (v/v) = 37.5 cm^3 ethanol in 100 cm^3 vodka.

2. **<u>Parts per Million (ppm)</u>**
   Means the concentration in mg/L. This is calculated by multiplying the concentration in g/L by 1000.
   1000mg = 1g.

3. **<u>Molarity (M or mol/L)</u>**
   This is the main unit used in the chemistry course. This means the number of moles of solute in 1 litre of solution.
   E.g. A 0.125 M solution of $KMnO_4$ has 0.125 moles of $KMnO_4$ in 1 litre of litre solution.

   <u>Calculations</u>
   (a) mol/L to g/L

   1. How many grams of $FeSO_4$ are present in a solution marked 0.35 M $FeSO_4$?

   M_r of |$FeSO_4$ = (56) + (32) + 4(16) = 152
   We have 0.35 mol/L $FeSO_4$
   ×152 [mol to g → × M_r]
   =53.2 g/L

2. Calculate the concentration in grams per litre of bench hydrochloric acid whose concentration is 12 mol/L.

M_r of HCl = (1) + (35.5) = 36.5
We have 1.5 mol/L HCl
× 36.5 [mol to g → × M_r]
=54.75 g/L HCl

(b) g/L to mol/L

1. What is the molarity of a solution that contains 7.36 g of NaOH per litre of solution?

M_r of NaOH = (23) + (16) + (1) = 40
We have 7.36 g/L NaOH
÷ 40 [g to mol → ÷ M_r]
0.184 mol/L NaOH

2. Calculate the concentration of a solution containing 45 g of sulphuric acid in a litre of solution.

M_r of H_2SO_4 = 2(1) + (32) + 4(16) = 98
We have 45 g/L H_2SO_4
÷ 98 [g to mol → ÷ M_r]
0.4592 mol/L H_2SO_4

(c) Calculate moles per litre, given the mass of solute and volume of solution

1. Calculate the concentration in moles per litre of a solution containing 45 grams of sulphuric acid per 240 cm^3 of solution.

M_r of H_2SO_4 = 2(1) + (32) + 4(16) = 98
We have 45 g/240 cm^3 H_2SO_4
÷ 98 [g to mol → ÷ M_r]
=0.4592 mol/240 cm^3 H_2SO_4
$\frac{0.4592}{240} \times 1000$
=1.193 mol/L H_2SO_4

2. 7.6 g of anhydrous Na_2CO_3 is dissolved in deionised water and made up to 300 cm^3 of solution. Express the concentration of this solution in mol/L.

M_r of Na_2CO_3 = 2(23) + (12) + 3(16) = 106
We have 7.6 g/300 cm^3 Na_2CO_3
÷106 [g to mol → ÷ M_r]
=0.0717 mol/300 cm^3 Na_2CO_3
$\frac{0.0717}{300} \times 1000$
=0.239 mol/L Na_2CO_3

(d) Compound calculations (combinations of (a) to (c))

1. What mass of sodium hydroxide is contained in 25 cm^3 of a 1.5 M solution of sodium hydroxide?

M_r of NaOH = (23) + (16) + (1) = 40
We have 1.5 mol/L NaOH
× 40 [mol to g → × M_r]
= 60 g/L NaOH
$\frac{60}{1000} \times 25$
=1.5 g/25 cm^3 NaOH

2. What volume of 0.01 M $KMnO_4$ solution will contain 5 g of $KMnO_4$?

M_r of $KMnO_4$ = (39) + (55) + 4(16) = 158
We have 0.01 mol/L $KMnO_4$
× 158 [mol to g → × M_r]
= 1.58 g/L $KMnO_4$. This can be rewritten as 1.58 g/1000 cm^3 $KMnO_4$
÷1.58
= 1 g/632.9 cm^3 $KMnO_4$
×5
= 5 g/3164.6 cm^3 $KMnO_4$

Standard Solutions

Def^n: A **standard solution** is one whose concentration is accurately known.
Def^n: A **primary standard** is a substance that can be directly weighed and used to make a standard solution. It must:

- Be available in a pure and stable solid state
- Be soluble in water
- Have a high molecular mass
- Be anhydrous (no water of crystallisation)

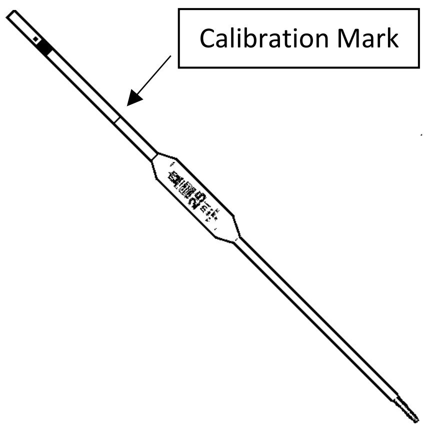
Primary Standards: Na_2CO_3, NaCl

Not Primary Standards:
HCl – it is a gas
I_2 – it sublimes
H_2SO_4 – it absorbs moisture from air
NaOH – it absorbs CO_2 and moisture from air
$KMnO_4$ – it is reduced by sunlight

Equipment used in Titrations

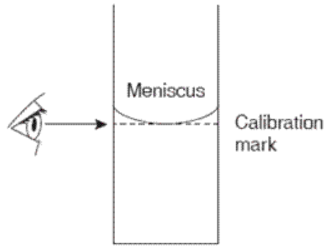
1. Pipette:

Used to accurately measure a known volume of liquids/solutions.



Procedure for cleaning, filling and transferring solutions using a pipette:

- Rinse with dionised water.
- Rinse with the solution it is to contain (name this solution if you know). *[This is done to remove the water, so the solution in the pipette doesn't get diluted.]*
- Using a pipette filler, fill pipette with solution until the bottom of the meniscus
- reaches the graduation mark, at eye level.
- Let the pipette drain under gravity, touching the tip of the pipette against the flask to remove the last drop stuck to the tip.

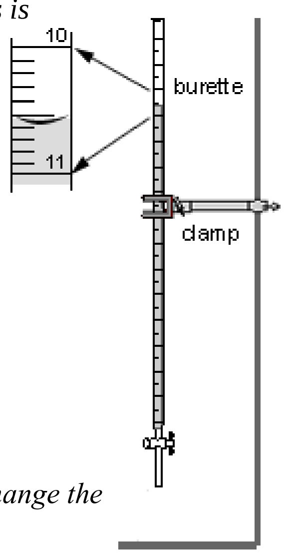


2. Burette:

Used to accurately measure the volume of liquid/solution added.

Procedure for cleaning and filling a burette:

- Rinse with deionised water.
- Rinse with the solution it is to contain (name this solution if you know). *[This is done to remove the water, so the solution in the burette doesn't get diluted.]*
- Clamp vertically.
- Using a funnel, fill the burette above the zero mark.
- Remove the funnel.
- Open the tap to bring the bottom of the meniscus to the zero mark, and to fill the jet below the tap.



3. Conical Flask:

A specially shaped flask that allows swirling without spilling the contents.

Procedure for cleaning the conical flask:

- Clean with deionised water only. *[Any water droplets remaining won't change the number of moles of reactant you add].*

<u>Acid/Base Titrations:</u>

1. To standardise a solution of HCl using a standard solution of Na_2CO_3.

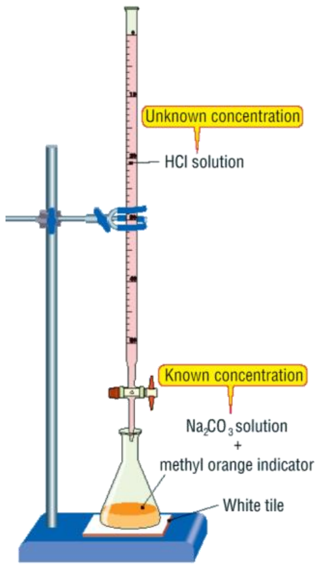
Acid: HCl – strong acid *Base:* Na_2CO_3 – weak base

Indicator: Methyl Orange

Colour change: Yellow to Red

Equation: $2HCl + Na_2CO_3 \rightarrow NaCl + H_2O + CO_2$

Ratio: 2 HCl : 1 Na_2CO_3



Sample calculation: (2012 HL Q1)

A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a 0.05 M primary standard solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25 cm^3 pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8 cm^3.

The balanced equation for the titration reaction was:

$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + H_2O + CO_2$$

(*e*) Calculate, correct to two decimal places, the concentration of the hydrochloric acid solution in
(*i*) moles per litre,
(*ii*) grams per litre. (12)

(i) $$\frac{m_1 v_1}{n_1} = \frac{m_2 v_2}{n_2}$$

HCl	Na_2CO_3
m_1 = ?	m_2 = 0.05 M
v_1 = 20.8 cm^3	v_2 = 25 cm^3
n_1 = 2 (from eq^n)	n_2 = 1 (from eq^n)

$$\frac{m_1 \times 20.8}{2} = \frac{0.05 \times 25}{1}$$

Cross multiply

$$m_1 \times 20.8 \times 1 = 0.05 \times 25 \times 2$$

$$m_1 \times 20.8 = 2.5$$

$$m_1 = \frac{2.5}{20.8}$$

$$m_1 = 0.12\ mol/L$$

(ii) M_r of HCl = (1) + (35.5) = 36.5
0.12 x 36.5 [mol/L to g/L → x M_r]
= 4.38 g/L

2. To standardise a solution of NaOH using a standard solution of HCl.

Acid: HCl – strong acid *Base:* NaOH – strong base

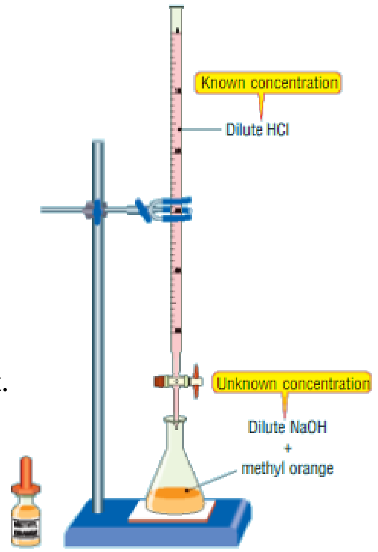
Indicator: Methyl Orange

Colour change: Yellow to Red

Equation: $HCl + NaOH \rightarrow NaCl + H_2O$

Ratio: 1 HCl : 1 NaOH

After doing titration, carry out again using no indicator and your average HCl amount. Evaporate your solution to isolate a sample of pure NaCl.



G. Galvin

Sample calculation: (2017 OL Q2)

Hydrochloric acid (HCl) of known concentration was added from a burette to neutralise 25.0 cm^3 portions of sodium hydroxide (NaOH) solution of unknown concentration in a concical flask. Each portion of sodium hydroxide solution had been measured out using a pipette. One rough titration and a number of accurate titrations were carried out.

The burette readings noted in this experiment were:

19.9 cm^3 HCl for the rough titration and 19.6 cm^3 and 19.5 cm^3 for the following two accurate titrations.

(d) (ii) What average hydrochloric acid volume should be used in calculations?

(e) The equation for the titration reaction is:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The concentration of the hydrochloric acid solution was 0.10 M.

Calculate the concentration of the sodium hydroxide solution

(i) in moles per litre,

(ii) in grams per litre.

(d) (ii) $\frac{19.6+19.5}{2} = 19.55\ cm^3$

(e) (i) $\frac{m_1 v_1}{n_1} = \frac{m_2 v_2}{n_2}$

HCl	NaOH
m_1 = 0.10 M	m_2 = ?
v_1 = 19.55 cm^3	v_2 = 25 cm^3
n_1 = 1 (from eq^n)	n_2 = 1 (from eq^n)

$$\frac{0.10 \times 19.55}{1} = \frac{m_2 \times 25}{1}$$

Cross multiply

$$0.10 \times 19.55 \times 1 = m_2 \times 25 \times 1$$

$$m_2 \times 25 = 1.955$$

$$m_2 = \frac{1.955}{25}$$

$$m_2 = 0.0782\ mol/L$$

(iii) (ii) M_r of NaOH = (23) + (16) + (1) = 40
0.0782 x 40 [mol/L to g/L → x M_r]
= 3.128 g/L

G. Galvin