CHEM 5 AQUEOUS SOLUTIONS, SOLVENTS/SOLUTES

(%w/v, %w/w, molarity, dilution, ppm, ppb, molality, p-notation)

[w = weight   m = mass,   but in Chemistry we use: % w/v = % m/v, and   % w/w = % m/m]

Preparation of a solution – a known mass (m gram) of the solute (eg 5.85 g NaCℓ, M_r = 58.5 g/mol) is dissolved in a solvent such as water to give a known volume (V mL or Litre) of the solution (eg 250 mL aqueous solution).

Concentration = c = mass (gram) / volume (mL or Litre)

= 5.85 g / 250 mL = 0.0234 g/mL = 5.85 g / 0.25 L = 23.4 g/L = 23.4 g/1000 mL

Then, **%w/v = gram solute in 100 mL of solution** = 2.34 g / 100 mL = **2.34 %w/v NaCℓ,**

= **2.34 %m/v NaCℓ.**

(This concentration is Temperature Dependent because liquids expand when heated)

Or, we can prepare a solution by dissolving a known mass of the solute in a solvent to give a known mass of solution;

Then, **% w/w = gram solute in 100 g solution**

So, if 2.34 g of NaCℓ is dissolved in 97.66 g of water to give 100 g of solution

Then % w/w = 2.34 g / 100 g solution

= 2.34 % w/w NaCℓ

(This concentration is Independent of Temperature because mass does not change with temperature)

(= 2.34 g in about 98 mL = 2.39 g / 100 mL)

Molarity = M = amount (mole) / solution volume (Litre) $\boxed{\mathbf{M = n / V}}$

So if 5.85 g NaCℓ, (M_r = 58.5 g/mol) is dissolved in 250 mL water the Molarity would be given by :

= {mass (gram)/molar mass (M_r) gram/mol }/volume(L)

= (5.85 g / 58.5 g mol^{-1}) / 0.25 L = 0.1 mol / 0.25 L = 0.4 mol/L

To calculate the number of mol of material in a given volume of a solution having a known concentration:

Number of mol = n = concentration (mol L^{-1}) x volume (L) $\boxed{\mathbf{n = C \times V}}$

ie, n = C × V   or   M(mol L^{-1}) × V(L)

or   n = M(mol L^{-1}) × V(mL)/1000

TASK: To prepare 500 mL of an approximately 0.05 M Na_2CO_3 solution with an exactly known concentration, from a solid sample of pure Na_2CO_3 (M_r = 106.0 g/mol).

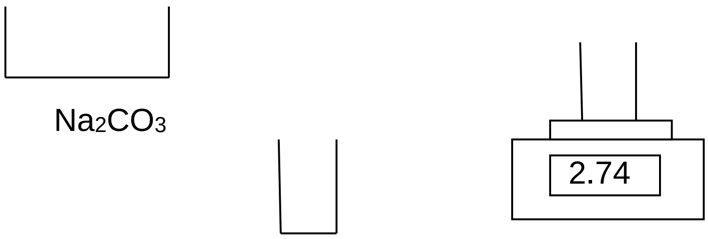
A. <u>Calculate approximate mass of solid Na_2CO_3 required</u>:

n= C x V n = 0.05 x 500/1000 = 0.025 mol

n = m/ M_rm = n x M_r = 0.025 x 106.0 = 2.65 g

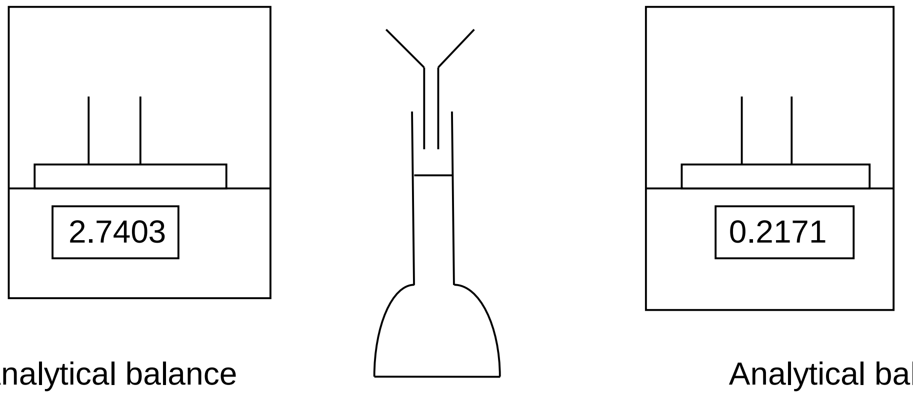
B. <u>Weigh out approximate mass of Na_2CO_3 :</u>

Add solid Na_2CO_3 until ≈2.7 g has been added to weighing bottle (approximate mass)



Weighing bottle top loading balance

<u>Using “weighing by difference” transfer solid Na_2CO_3 sample to standard (volumetric) flask</u>

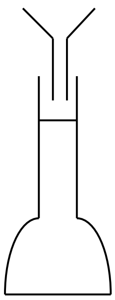


Exact mass of solid Na_2CO_3 in flask = 2.7403 – 0.2171 g = 2.5232 g

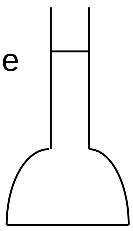
Analytical balance (weigh accurately) 500.0 mL standard flask Analytical balance (weigh accurately)

C. <u>Dissolve exact mass in water to give an exact volume (500.0 mL) of solution :</u>

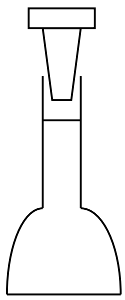
Rinse funnel and 2/3 rds fill flask with water. Swirl until all solid dissolves



Dilute exactly to volume



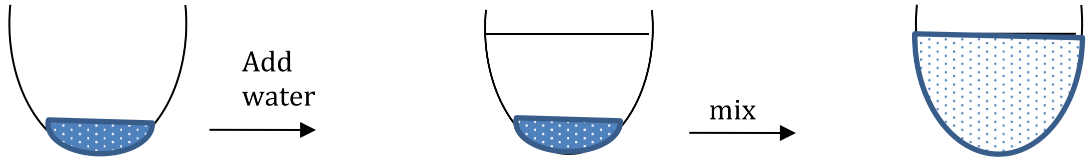
Stopper flask and shake to give uniform mixing.



D. <u>Calculate exact concentration of Na_2CO_3solution :</u>

C_{Na2CO3} = n/V = (m / M_r) / V = (2.5232 / 106.0) / 0.500 = 0.04761 mol/L

DILUTION –adding further pure solvent to a solution



Original solution vol = V_o , conc = C_o

Final solution vol = V_f , conc = C_f

$$n_o = C_o \, x \, V_o$$

$$n_f = C_f \, x \, V_f$$

Only pure solvent is added, so no extra moles of solute are added , **so** $n_f = n_o$

thus, $\boxed{C_f \, x \, V_f = C_o \, x \, V_o}$

eg, if 10 mL of a 0.4 mol/L solution is diluted to 50 mL, the final concentration can be calculated thus :

50 mL x C_f = 10 mL x 0.4 mol/L so, $C_f = \dfrac{10 \, \cancel{\text{mL}} \, x \, 0.4 \text{ mol/L}}{50 \, \cancel{\text{mL}}} = 0.08$ mol/L

Parts per million

ppm = g solute in 1 million g solution

= g solute in 10^6 g solution ie., g per tonne (1 000 kg) [used in mining industry]

= milligram in 10^3 g solution [The prefix "milli" means one-thousandth of = 1/1000 = 10^{-3}]

= **mg per Litre** (1 mg = 0.001 g = 10^{-3} g ; so 1 gram = 1000 mg)

Parts per Billion

ppb = g solute in 1 billion g solution

= g solute in 10^9 g solution = milligram in 10^6 g solution = mg in 10^3 Litre

= microgram in one Litre [The prefix "micro" means one-millionth of = 1/1 000 000 = 10^{-6}]

= **µg per Litre** (1 µg = 0.000 001 g = 10^{-6} g ; so 1 gram = 1 000 000 µg)

Molality

m = mol solute per kilogram of solvent (a temperature independent concentration)

eg, if a solution contains 4.38 g of KCℓ solute (M_r = 74.6 g mol^{-1}) in 100 g of solvent water.

Molality = $\dfrac{4.38 \text{ g}/74.6 \text{ g mol}^{-1}}{100\text{g} / 1000\text{g kg}^{-1}} = \dfrac{0.0587 \text{ mol}}{0.1 \text{ kg}} = 0.587$ molal (**m**)