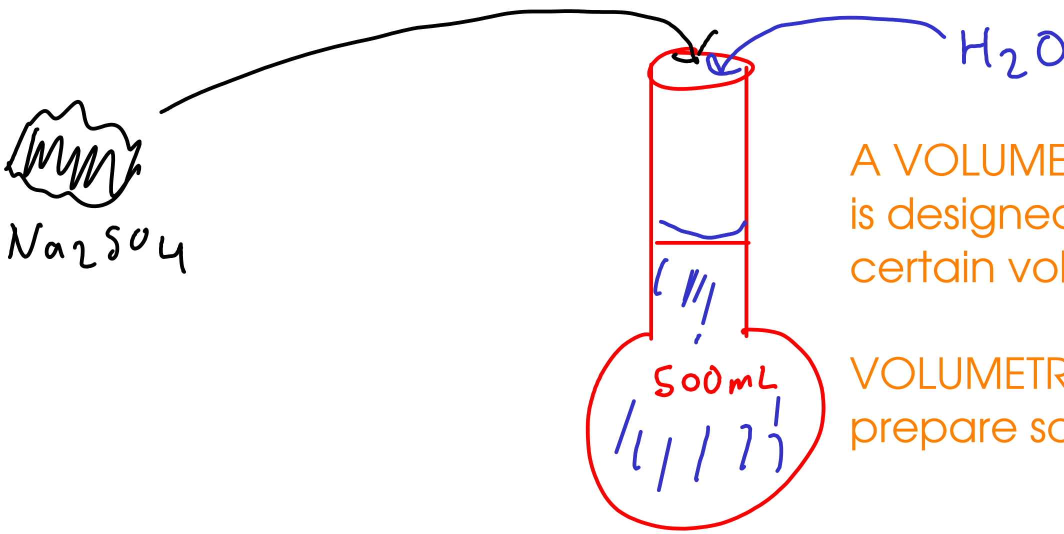
Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

Na_2SO_4 : 142.05 g/mol

Dissolve the appropriate amount of sodium sulfate into enough water to make 500. mL of solution.



A VOLUMETRIC FLASK is a flask that is designed to precisely contain a certain volume of liquid.

VOLUMETRIC FLASKS are used to prepare solutions.

volumetric flask

We know that we need 500. mL of solution, and we also know that the concentration should be 0.500 M. From that, we can calculate the moles of sodium sulfate we should dissolve. Then, we can convert that to mass using formula weight.

$0.500 \text{ mol } Na_2SO_4 = L$ | $mL = 10^{-3} L$ | $142.05 \text{ g } Na_2SO_4 = \text{mol } Na_2SO_4$

$$500. \text{ mL} \times \frac{10^{-3} L}{mL} \times \frac{0.500 \text{ mol } Na_2SO_4}{L} \times \frac{142.05 \text{ g } Na_2SO_4}{\text{mol } Na_2SO_4} = \boxed{35.5 \text{ g } Na_2SO_4}$$

To prepare this solution, take 35.5 grams of sodium sulfate, put into a 500. mL volumetric flask, and fill to the mark with distilled water.

More on MOLARITY

To prepare a solution of a given molarity, you generally have two options:

1. Weigh out the appropriate amount of solute, then dilute to the desired volume with solvent (usually water)

"stock solution"

2. Take a previously prepared solution of known concentration and DILUTE it with solvent to form a new solution

- Use DILUTION EQUATION

The dilution equation is easy to derive with simple algebra.

$$M \times V$$

$$\frac{\text{mol}}{\text{L}} \times \text{L} = \text{moles solute}$$

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1V_1 = M_2V_2$$

before diution | after dilution

Since the number of moles of solute stays the same, this equality must be true!

$$M_1V_1 = M_2V_2$$ ... the "DILUTION EQUATION"

M_1 = molarity of concentrated solution

V_1 = volume of concentrated solution

M_2 = molarity of dilute solution

V_2 = volume of dilute solution (total volume, not volume of added solvent!)

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both volumes!

Example: Take the 0.500 M sodium sulfate we discussed in the previous example and dilute it to make 150. mL of 0.333 M solution. How many mL of the original solution will we need to dilute?

$M_1V_1 = M_2V_2$

$M_1 = 0.500\,M$ $\quad M_2 = 0.333\,M$

$V_1 = ?$ $\quad V_2 = 150.\,mL$

$$(0.500\,M) \times V_1 = (0.333\,M) \times (150.\,mL)$$

$$V_1 = 99.9\text{ mL of } 0.500\,M\ Na_2SO_4$$

To prepare this solution, take 99.9 mL of 0.500 M sodium sulfate solution, and add enough water to make 150. mL of solution.

CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!

- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms

$$2\,Al(s) + 3\,Br_2(l) \rightarrow 2\,AlBr_3(s)$$

coefficients are in terms of atoms and molecules!

2 atoms Al = 3 molecules Br_2 = 2 formula units $AlBr_3$

2 mol Al = 3 mol Br_2 = 2 mol $AlBr_3$

- To do chemical calculations, we need to:
  - Relate the amount of substance we know (mass or volume) to a number of moles
  - Relate the moles of one substance to the moles of another using the equation
  - Convert the moles of the new substance to mass or volume as desired

$$2\,Al(s) + 3\,Br_2(l) \longrightarrow 2\,AlBr_3(s)$$

* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine? How many grams of aluminum bromide would be produced?

(1) Convert grams of bromine to moles: Need formula weight Br_2: $2 \times 79.90 = 159.80$

$159.80\ g\ Br_2 = 1\ mol\ Br_2$

$$25.0\ g\ Br_2 \times \frac{1\ mol\ Br_2}{159.80\ g\ Br_2} = 0.15645\ mol\ Br_2$$

(2) Use the chemical equation to relate moles of bromine to moles of aluminum

$2\ mol\ Al = 3\ mol\ Br_2$

$$0.15645\ mol\ Br_2 \times \frac{2\ mol\ Al}{3\ mol\ Br_2} = 0.10430\ mol\ Al$$

(3) Convert moles aluminum to mass: Need formula weight Al: 26.98

$26.98\ g\ Al = 1\ mol\ Al$

$$0.10430\ mol\ Al \times \frac{26.98\ g\ Al}{1\ mol\ Al} = \boxed{2.81\ g\ Al}$$

You can combine all three steps on one line if you like!

$$25.0\,g\,Br_2 \times \frac{1\,mol\,Br_2}{159.80\,g\,Br_2} \times \frac{2\,mol\,Al}{3\,mol\,Br_2} \times \frac{26.98\,g\,Al}{1\,mol\,Al} = \boxed{2.81\,g\,Al}$$

(1) (2) (3)

You can solve the second part of the question using CONSERVATION OF MASS - since there's only a single product and you already know the mass of all reactants.

$$\begin{array}{r} 25.0\,g\,Br_2 \\ +\;\; 2.81\,g\,Al \\ \hline 27.8\,g\,AlBr_3 \end{array}$$

But ...

...what would you have done to calculate the mass of aluminum bromide IF you had NOT been asked to calculate the mass of aluminum FIRST?

$$25.0\,g\,Br_2 \times \frac{1\,mol\,Br_2}{159.80\,g\,Br_2} \times \frac{2\,mol\,AlBr_3}{3\,mol\,Br_2} \times \frac{266.694\,g\,AlBr_3}{1\,mol\,AlBr_3} = 27.8\,g\,AlBr_3$$

(1) convert mass bromine to moles

(2) convert moles bromine to moles aluminum bromide

(3) convert moles aluminum bromide to mass

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

---

1 - Convert 25.0 g of sodium carbonate to moles. Use FORMULA WEIGHT of sodium carbonate.

2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.

3 - Convert moles HCl to volume. Use MOLAR CONCENTRATION of HCl.

---

(1) Na_2CO_3

Na : 2 x 22.99

C : 1 x 12.01

O : 3 x 16.00

105.99 g Na_2CO_3 = mol Na_2CO_3

Formula weight of sodium carbonate

$$25.0\,g\,Na_2CO_3 \times \frac{mol\,Na_2CO_3}{105.99\,g\,Na_2CO_3} = 0.2358713086\,mol\,Na_2CO_3$$

---

(2) 2 mol HCl = mol Na_2CO_3

$$0.2358713086\,mol\,Na_2CO_3 \times \frac{2\,mol\,HCl}{mol\,Na_2CO_3} = 0.4717426172\,mol\,HCl$$

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 g of sodium carbonate to moles. Use FORMULA WEIGHT of sodium carbonate.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to volume. Use MOLAR CONCENTRATION of HCl.

(3) 6.00 mol HCl = L | mL = 10^{-3} L

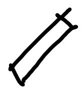
$$0.4717426172 \text{ mol HCl} \times \frac{L}{6.00 \text{ mol HCl}} \times \frac{mL}{10^{-3} L} = 78.6 \text{ mL of } 6.00\,\underline{M} \text{ HCl}$$

This step was added because the problem specifically asked for an answer in MILLILITERS.

CONCEPT OF LIMITING REACTANT

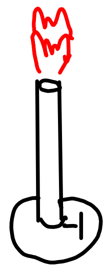
- When does a chemical reaction STOP?

$$2Mg(s) + O_2(g) \xrightarrow{\Delta} 2MgO(s)$$



Magnesium strip

+



Flame, oxygen from air

Magnesium oxide powder

- When does this reaction stop? When burned in open air, this reaction stops when all the MAGNESIUM STRIP is gone. We say that the magnesium is LIMITING.

- This reaction is controlled by the amount of available magnesium

- At the end of a chemical reaction, the LIMITING REACTANT will be completely consumed, but there may be amount of OTHER reactants remaining. We do chemical calculations in part to minimize these "leftovers".

These are often called "excess" reactants, or reactants present "in excess"