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)

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

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!

$$\frac{2 \text{ atoms } Al = 3 \text{ molecules } Br_2 = 2 \text{ formula units } AlBr_3}{2 \text{ mol } Al = 3 \text{ mol } Br_2 = 2 \text{ mol } AlBr_3}$$

- 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?

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

$159.80\,g\ Br_2 = mol\ Br_2$

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

(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

$26.98\,g\ Al = mol\ Al$

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

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

(1) $154.80\,g\ Br_2 = mol\ Br_2$ (2) $2\ mol\ Al = 3\ mol\ Br_2$ (3) $26.98\,g\ Al = mol\ Al$

$$25.0\,g\ Br_2 \times \frac{mol\ Br_2}{154.80\,g\ Br_2} \times \frac{2\ mol\ Al}{3\ mol\ Br_2} \times \frac{26.98\,g\ Al}{mol\ Al} = \boxed{2.81\,g\ Al}$$

(1) (2) (3)

Things we can do:

If we have ...	... and we need ...	Use ...
MASS	MOLES	FORMULA WEIGHT
SOLUTION VOLUME	MOLES	MOLAR CONCETRATION (MOLARITY)
MOLES OF A	MOLES OF B	BALANCED CHEMICAL EQUATION

101 Example:

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

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

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

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

3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00 M HCl)

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(1) Na_2CO_3 - Na: 2 x 22.99

C: 1 x 12.01

O: 3 x 16.00

$105.99\,g\ Na_2CO_3 = mol\ Na_2CO_3$

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

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(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 sodium carbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00 M HCl)

(3) 6.00 mol HCl = L

$$0.4717426172 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = 0.0786 \text{ L of } 6.00 \text{ M HCl}$$

The problem statement asks us for mL instead of L. Not a big problem ... we can just convert from L -> mL.

$$\text{mL} = 10^{-3} \text{ L}$$

$$0.0786 \text{ L} \times \frac{\text{mL}}{10^{-3} \text{ L}} = \boxed{78.6 \text{ mL of } 6.00 \text{ M HCl}}$$

$$\underset{\text{propylene}}{\overset{42.081\ \text{g/mol}}{4\,C_3H_6}} + 6\,NO \longrightarrow \underset{\text{acrylonitrile}}{\overset{53.064\ \text{g/mol}}{4\,C_3H_3N}} + 6\,H_2O + N_2$$

Calculate how many grams of acrylonitrile could be obtained from 651 g of propylene, assuming there is excess NO present.

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1 - Convert 651 g propylene to moles. Use FORMULA WEIGHT.
2 - Convert moles propylene to moles acrylonitrile. Use CHEMICAL EQUATION.
3 - Convert moles acrylonitrile to mass acrylonitrile. Use FORMULA WEIGHT.

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(1) $42.081\ g\ C_3H_6 = mol\ C_3H_6$ (2) $4\ mol\ C_3H_6 = 4\ mol\ C_3H_3N$

(3) $53.064\ g\ C_3H_3N = mol\ C_3H_3N$

$$651\ g\ C_3H_6 \times \frac{mol\ C_3H_6}{42.081\ g\ C_3H_6} \times \frac{4\ mol\ C_3H_3N}{4\ mol\ C_3H_6} \times \frac{53.064\ g\ C_3H_3N}{mol\ C_3H_3N} =$$

(1) (2) (3)

$$= \boxed{821\ g\ C_3H_3N}$$

151.90 g/mol

$$10\,FeSO_4 + 2\,KMnO_4 + 8\,H_2SO_4 \rightarrow 5\,Fe_2(SO_4)_3 + 2\,MnSO_4 + K_2SO_4 + 8\,H_2O$$

How many mL of 0.250M potassium permangenate are needed to react with 3.36 g of iron(II) sulfate?

1 - Convert 3.36 g iron(II) sulfate to moles. Use FORMULA WEIGHT.
2 - Convert moles iron(II) sulfate to moles potassium permangenate. Use CHEMICAL EQUATION.
3 - Convert moles potassium permangenate to volume potassium permangenate solution. Use MOLARITY. (0.250 M)

(1) 151.90 g $FeSO_4$ = mol $FeSO_4$ (2) 10 mol $FeSO_4$ = 2 mol $KMnO_4$

(3) 0.250 mol $KMnO_4$ = L

$$3.36\text{ g }FeSO_4 \times \frac{\text{mol }FeSO_4}{151.90\text{ g }FeSO_4} \times \frac{2\text{ mol }KMnO_4}{10\text{ mol }FeSO_4} \times \frac{\text{L}}{0.250\text{ mol }KMnO_4} =$$

(1) (2) (3)

= 0.0177 L <-- We need answer in mL, so convert it!

mL = 10^{-3} L

$$0.0177\text{ L} \times \frac{\text{mL}}{10^{-3}\text{ L}} = 17.7\text{ mL of }0.250\text{M }KMnO_4$$