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

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

coefficients are in terms of atoms and molecules!

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

$$2 \text{ mol } Al = 3 \text{ mol } Br_2 = 2 \text{ mol } AlBr_3$$

- 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? 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.

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

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?

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

1 - Convert 25.0 grams 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. Use MOLAR CONCENTRATION (6.00 M)

(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

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

(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 grams 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. Use MOLAR CONCENTRATION (6.00 M)

(3) 6.00 mol HCl = L

$$0.471742612\,mol\ HCl \times \frac{L}{6.00\ mol\ HCl} = 0.0786\,L \text{ of } 6.00\,M\ HCl$$

Notice the problem specifically asks for an answer in MILLILITERS. So, we'll just convert liters to milliliters to get the answer in the desired units.

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

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

25.0 mL of acetic acid solution requires 37.3 mL of 0.150 M sodium hydroxide for complete reaction. The equation for this reaction is:

$$NaOH + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O$$

What is the molar concentration of the acetic acid?

$$\frac{\text{mol } HC_2H_3O_2}{\text{L solution}} \leftarrow = 25.0\text{ mL or } 0.0250\text{ L}$$

1 - Start with the NaOH ... Convert 37.3 mL of 0.150 M NaOH to moles using CONCENTRATION.
2 - Convert moles NaOH to moles acetic acid. Use CHEMICAL EQUATION
3 - Calculate molar concentration by dividing (mol acid / volume acid).

0.150 mol NaOH = L | mL = 10^{-3} L | mol NaOH = mol $HC_2H_3O_2$

$$37.3\text{ mL} \times \frac{10^{-3}\text{ L}}{\text{mL}} \times \underset{①}{\frac{0.150\text{ mol NaOH}}{\text{L}}} \times \underset{②}{\frac{\text{mol } HC_2H_3O_2}{\text{mol NaOH}}} = 0.005595\text{ mol } HC_2H_3O_2$$

③

$$M = \frac{\text{mol } HC_2H_3O_2}{\text{L solution}} = \frac{0.005595\text{ mol } HC_2H_3O_2}{0.0250\text{ L}} = \boxed{0.224\ M\ HC_2H_3O_2}$$

* See the calculations for experiment 4C... they're similar to this problem!

$$42.081\ g/mol \qquad\qquad\qquad 53.064\ g/mol$$

$$4\,C_3H_6 + 6\,NO \longrightarrow 4\,C_3H_3N + 6\,H_2O + N_2$$

propylene — acrylonitrile

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

1 - Convert mass propylene to moles. Use FORMULA WEIGHT of propylene (and kg->g conversion)
2 - Convert moles propylene to moles acrylonitrile. Use CHEMICAL EQUATION
3 - Convert moles acrylonitrile to mass acrylonitrile. Use FORMULA WEIGHT of acrylonitrile.

$42.081\ g\ C_3H_6 = mol\ C_3H_6$	$4\ mol\ C_3H_6 = 4\ mol\ C_3H_3N$
$53.064\ g\ C_3H_3N = mol\ C_3H_3N$	$kg = 10^3\ g$

$$651\ kg\ C_3H_6 \times \underbrace{\frac{10^3\ g}{kg} \times \frac{mol\ C_3H_6}{42.081\ g\ C_3H_6}}_{1} \times \underbrace{\frac{4\ mol\ C_3H_3N}{4\ mol\ C_3H_6}}_{2} \times \underbrace{\frac{53.064\ g\ C_3H_3N}{mol\ C_3H_3N}}_{3} =$$

$$= \boxed{821000\ g\ C_3H_3N} \quad (821\ kg)$$

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 grams iron(II) sulfate to moles using FORMULA WEIGHT.
2 - Convert moles iron(II) sulfate to moles potassium permangenate using CHEMICAL EQUATION
3 - Convert moles potassium permangenate to volume using MOLAR CONCENTRATION

151.90 g $FeSO_4$ = mol $FeSO_4$	10 mol $FeSO_4$ = 2 mol $KMnO_4$
0.250 mol $KMnO_4$ = L	mL = 10^{-3} L

$$3.36\,g\,FeSO_4 \times \frac{mol\,FeSO_4}{151.90\,g\,FeSO_4} \times \frac{2\,mol\,KMnO_4}{10\,mol\,FeSO_4} \times \frac{L}{0.250\,mol\,KMnO_4} \times \frac{mL}{10^{-3}\,L} =$$

(1) (2) (3)

= 17.7 mL of 0.250 M $KMnO_4$