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 sodium carbonate to moles using FORMULA WEIGHT.
2 - Convert moles sodium carbonate to moles hydrochloric acid using CHEMICAL EQUATION.
3 - Convert moles HCl to volume using CONCENTRATION (and a L -> mL conversion)

(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 g sodium carbonate to moles using FORMULA WEIGHT.
2 - Convert moles sodium carbonate to moles hydrochloric acid using CHEMICAL EQUATION.
3 - Convert moles HCl to volume using CONCENTRATION (and a L -> mL conversion)

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

$$0.471742 6172 \text{ mol HCl} \times \frac{L}{6.00 \text{ mol HCl}} \times \frac{mL}{10^{-3} L} = 78.6 \text{ mL of } 6.00 \text{ M HCl}$$

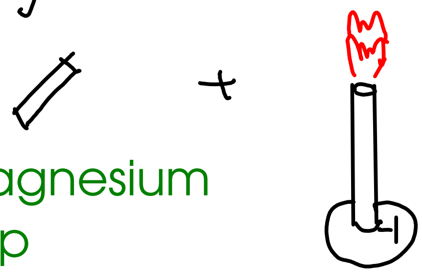
Done because the problem asks for an answer in mL

Tip: When starting a chemical calculation, try to start with an AMOUNT (like a volume or a mass) instead of a ratio/conversion factor (like a concentration or a formula weight)

CONCEPT OF LIMITING REACTANT

- When does a chemical reaction STOP?

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



- 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"

LIMITING REACTANT CALCULATIONS

- To find the limiting reactant, calculate how much product would be produced from ALL given reactants. Whichever produces the SMALLEST amouht of product is the limiting reactant, and the smallest anount of product is the actual amount of product produced.

Example:

56.08   12.01   64.10 <- Formula weights

$$CaO(s) + 3C(s) \xrightarrow{\Delta} CaC_2(s) + CO(g)$$

If you start with 100. g of each reactant, how much calcium carbide would be produced?

CaO: 56.08 g CaO = mol CaO | mol CaO = mol CaC_2 | 64.10 g CaC_2 = mol CaC_2

$$100.\,g\ CaO \times \frac{mol\ CaO}{56.08\,g\ CaO} \times \frac{mol\ CaC_2}{mol\ CaO} \times \frac{64.10\,g\ CaC_2}{mol\ CaC_2} = \boxed{114\,g\ CaC_2}$$

C: 12.01 g C = mol C | 3 mol C = mol CaC_2 | 64.10 g CaC_2 = mol CaC_2

$$100.\,g\ C \times \frac{mol\ C}{12.01\,g\ C} \times \frac{mol\ CaC_2}{3\ mol\ C} \times \frac{64.10\,g\ CaC_2}{mol\ CaC_2} = 178\,g\ CaC_2$$

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114 grams of calcium carbide should be produced. Calcium oxide runs out when this amount of product is made, and there's nothing left for the remaining carbon to react with! No further product can be made!

Calcium oxide is limiting.