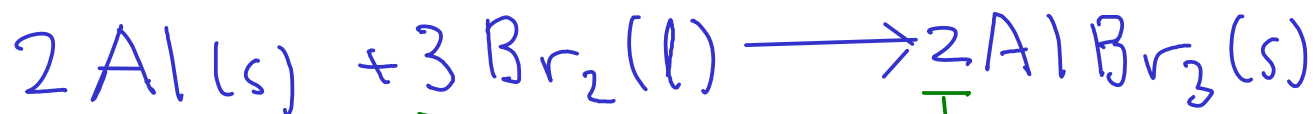


## CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- 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

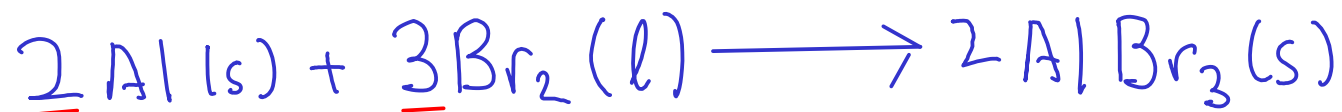


coefficients are in terms of atoms and molecules!

$$2 \text{ atoms Al} = 3 \text{ molecules Br}_2 = 2 \text{ formula units AlBr}_3$$

$$2 \text{ mol Al} = 3 \text{ mol Br}_2 = 2 \text{ mol AlBr}_3$$

- 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



\* 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  $\text{Br}_2$ :  $\frac{2 \times 79.90}{159.80}$

$$159.80 \text{ g Br}_2 = 1 \text{ mol Br}_2$$

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} = 0.15645 \text{ mol Br}_2$$

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

$$2 \text{ mol Al} = 3 \text{ mol Br}_2$$

$$0.15645 \text{ mol Br}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} = 0.10430 \text{ mol Al}$$

③ Convert moles aluminum to mass: Need formula weight  $\text{Al}$ : 26.98

$$26.98 \text{ g Al} = 1 \text{ mol Al}$$

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

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

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 2.81 \text{ g Al}$$

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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.

$$\begin{array}{r} 25.0 \text{ g Br}_2 \\ + 2.81 \text{ g Al} \\ \hline 27.8 \text{ g AlBr}_3 \end{array}$$

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?

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol AlBr}_3}{3 \text{ mol Br}_2} \times \frac{266.694 \text{ g AlBr}_3}{1 \text{ mol AlBr}_3} = 27.8 \text{ g AlBr}_3$$

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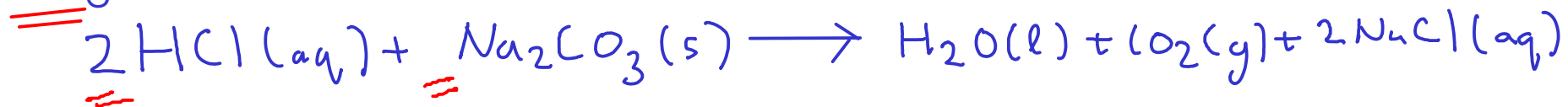
convert mass  
bromine  
to moles

convert moles  
bromine to  
moles aluminum  
bromide

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?



- 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)

$$\textcircled{1} \text{Na}_2\text{CO}_3 - \begin{array}{l} \text{Na: } 2 \times 22.99 \\ \text{C: } 1 \times 12.01 \\ \text{O: } 3 \times 16.00 \\ \hline 105.99 \text{ g Na}_2\text{CO}_3 = \text{mol Na}_2\text{CO}_3 \end{array}$$

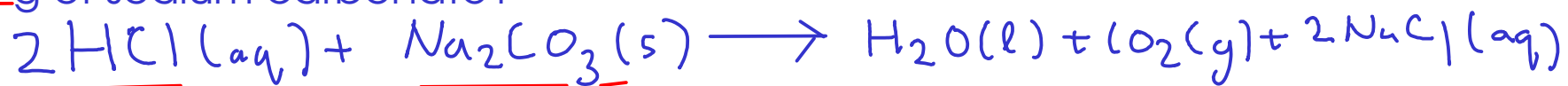
$$25.0 \text{ g Na}_2\text{CO}_3 \times \frac{\text{mol Na}_2\text{CO}_3}{105.99 \text{ g Na}_2\text{CO}_3} = 0.2358713086 \text{ mol Na}_2\text{CO}_3$$

$$\textcircled{2} 2 \text{ mol HCl} = \text{mol Na}_2\text{CO}_3$$

$$0.2358713086 \text{ mol Na}_2\text{CO}_3 \times \frac{2 \text{ mol HCl}}{\text{mol Na}_2\text{CO}_3} = 0.4717426172 \text{ mol HCl}$$

## 102 Example:

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



- 
- 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)
- 

$$\textcircled{3} \quad 6.00 \text{ mol HCl} = \text{L}$$

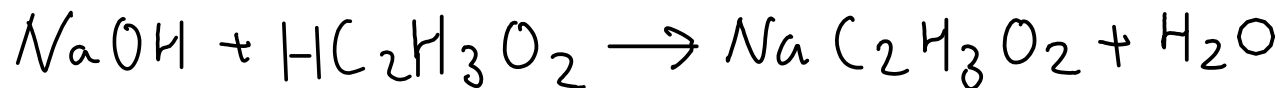
$$0.4717426172 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = 0.0786 \text{ L of } 6.00 \text{ M HCl}$$

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.

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

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

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:



What is the molar concentration of the acetic acid?

$$\frac{\text{L mol HC}_2\text{H}_3\text{O}_2}{\text{L Solution}} \leftarrow = 25.0 \text{ mL or } 0.0250 \text{ L}$$

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$$\text{L Solution} \leftarrow = 25.0 \text{ mL or } 0.0250 \text{ L}$$

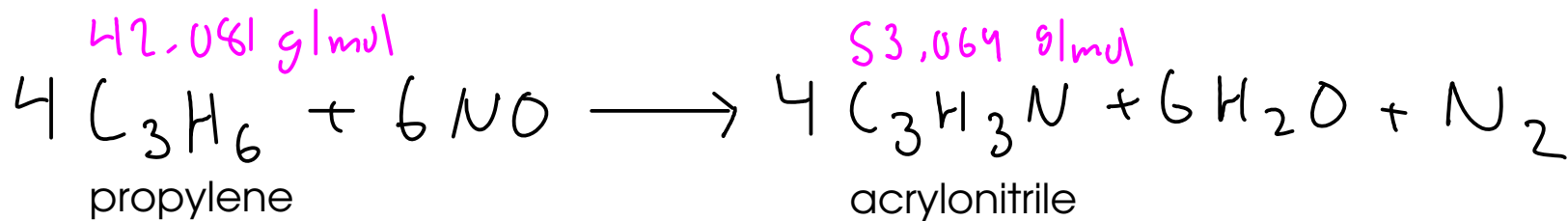
- 1 - Start with the NaOH ... Convert 37.3 mL of 0.150 M NaOH to moles using CONCENTRATION.
- 2 - Convert moles NaOH to moles acetic acid. Use CHEMICAL EQUATION
- 3 - Calculate molar concentration by dividing (mol acid / volume acid).

$$0.150 \text{ mol NaOH} = \frac{\text{L}}{\text{mL}} \times 10^{-3} \text{ L} \mid \text{mol NaOH} = \text{mol HC}_2\text{H}_3\text{O}_2$$

$$37.3 \text{ mL} \times \frac{10^{-3} \text{ L}}{\text{mL}} \times \frac{0.150 \text{ mol NaOH}}{\text{L}} \times \frac{\text{mol HC}_2\text{H}_3\text{O}_2}{\text{mol NaOH}} = 0.005595 \text{ mol HC}_2\text{H}_3\text{O}_2$$

$$\text{M} = \frac{\text{mol HC}_2\text{H}_3\text{O}_2}{\text{L Solution}} = \frac{0.005595 \text{ mol HC}_2\text{H}_3\text{O}_2}{0.0250 \text{ L}} = \boxed{0.224 \text{ M HC}_2\text{H}_3\text{O}_2}$$

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



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.

$$42.081 \text{ g C}_3\text{H}_6 = \text{mol C}_3\text{H}_6 \quad | \quad 4 \text{ mol C}_3\text{H}_6 = 4 \text{ mol C}_3\text{H}_3\text{N}$$

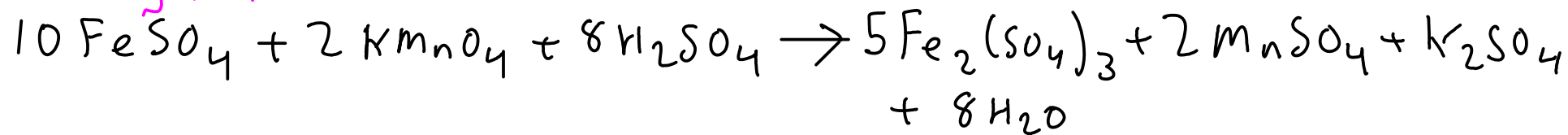
$$53.064 \text{ g C}_3\text{H}_3\text{N} = \text{mol C}_3\text{H}_3\text{N} \quad | \quad \text{Kg} = 10^3 \text{ g}$$

$$651 \text{ kg C}_3\text{H}_6 \times \frac{10^3 \text{ g}}{\text{Kg}} \times \frac{\text{mol C}_3\text{H}_6}{42.081 \text{ g C}_3\text{H}_6} \times \frac{4 \text{ mol C}_3\text{H}_3\text{N}}{4 \text{ mol C}_3\text{H}_6} \times \frac{53.064 \text{ g C}_3\text{H}_3\text{N}}{\text{mol C}_3\text{H}_3\text{N}} =$$

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②
③

$$= \boxed{821000 \text{ g C}_3\text{H}_3\text{N}} \quad (821 \text{ kg})$$

151.90 g/mol



How many mL of 0.250M potassium permanganate 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 permanganate using CHEMICAL EQUATION
- 3 - Convert moles potassium permanganate to volume using MOLAR CONCENTRATION

$$151.90 \text{ g FeSO}_4 = \text{mol FeSO}_4 \quad | \quad 10 \text{ mol FeSO}_4 = 2 \text{ mol KMnO}_4$$

$$0.250 \text{ mol KMnO}_4 = \text{L} \quad | \quad \text{mL} = 10^{-3} \text{L}$$

$$3.36 \text{ g FeSO}_4 \times \frac{\text{mol FeSO}_4}{151.90 \text{ g FeSO}_4} \times \frac{2 \text{ mol KMnO}_4}{10 \text{ mol FeSO}_4} \times \frac{\text{L}}{0.250 \text{ mol KMnO}_4} \times \frac{\text{mL}}{10^{-3} \text{L}} =$$

①
②
③

$$= 17.7 \text{ mL of } 0.250 \text{ M KMnO}_4$$