

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)

$$M_1 V_1 = M_2 V_2$$

before
dilution

after
dilution

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

$$M_1 V_1 = M_2 V_2 \quad \dots \text{the "DILUTION EQUATION"}$$

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?

$$M_1 V_1 = M_2 V_2 \quad \left| \quad \begin{array}{l} M_1 = 0.500 \text{ M} \\ V_1 = ? \end{array} \quad \begin{array}{l} M_2 = 0.333 \text{ M} \\ V_2 = 150. \text{ mL} \end{array} \right.$$

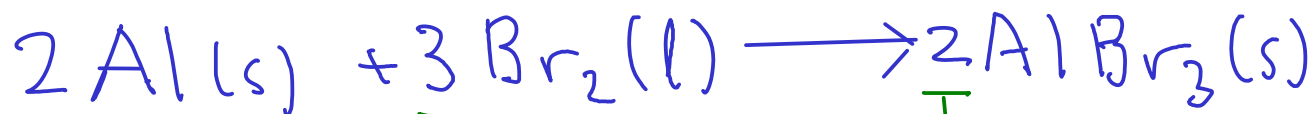
$$(0.500 \text{ M})(V_1) = (0.333 \text{ M})(150. \text{ mL})$$

$$V_1 = \boxed{99.9 \text{ mL}} \quad (\text{of } 0.500 \text{ M Na}_2\text{SO}_4)$$

Take 99.9 mL of 0.500 M sodium sulfate, and add enough water to make the total volume 150. mL.

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

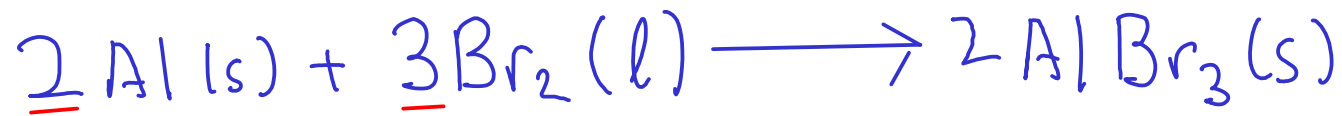


coefficients are in terms of atoms and molecules!

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

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

- 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?

① Convert grams of bromine to moles: Need formula weight $\text{Br}_2 : \frac{2 \times 79.90}{159.80}$

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

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

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

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

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

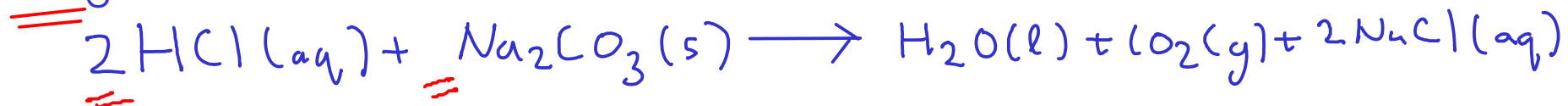
③ Convert moles aluminum to mass: Need formula weight $\text{Al} : 26.98$

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

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

Example:

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



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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 solution. Use MOLARITY
-

$$\textcircled{1} \text{Na}_2\text{CO}_3 - \text{Na}: 2 \times 22.99$$

$$\text{C}: 1 \times 12.01$$

$$\text{O}: 3 \times 16.00$$

$$\underline{\underline{105.99 \text{ g Na}_2\text{CO}_3 = 1 \text{ mol Na}_2\text{CO}_3}}$$

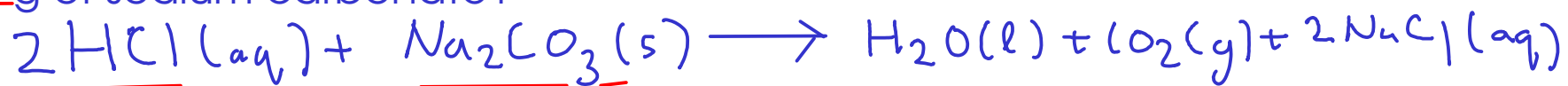
$$25.0 \text{ g Na}_2\text{CO}_3 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{105.99 \text{ g Na}_2\text{CO}_3} = 0.2358713086 \text{ mol Na}_2\text{CO}_3$$

$$\textcircled{2} 2 \text{ mol HCl} = 1 \text{ mol Na}_2\text{CO}_3$$

$$0.2358713086 \text{ mol Na}_2\text{CO}_3 \times \frac{2 \text{ mol HCl}}{1 \text{ mol Na}_2\text{CO}_3} = 0.4717426172 \text{ mol HCl}$$

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 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 solution. Use MOLARITY

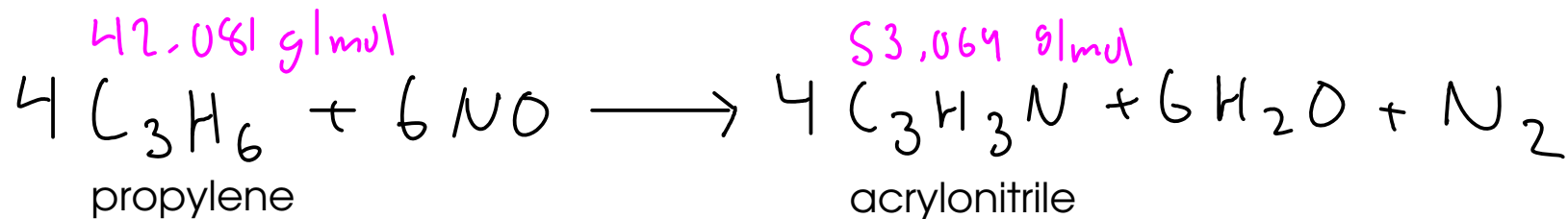
$$\textcircled{3} \quad 6.00 \text{ mol HCl} = \text{L}$$

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

... but since the problem statement wants the answer in mL ...

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

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



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

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

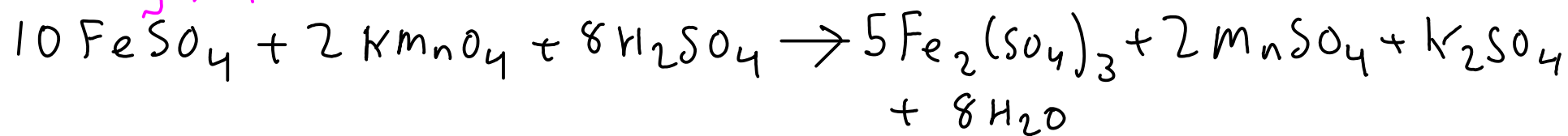
$$\textcircled{1} \quad 42.081 \text{ g C}_3\text{H}_6 = \text{mol C}_3\text{H}_6$$

$$\textcircled{2} \quad 4 \text{ mol C}_3\text{H}_6 = 4 \text{ mol C}_3\text{H}_3\text{N}$$

$$\textcircled{3} \quad 53.064 \text{ g C}_3\text{H}_3\text{N} = \text{mol C}_3\text{H}_3\text{N}$$

$$\begin{aligned}
 & 651 \text{ g C}_3\text{H}_6 \times \frac{\text{mol C}_3\text{H}_6}{42.081 \text{ g C}_3\text{H}_6} \times \frac{4 \text{ mol C}_3\text{H}_3\text{N}}{4 \text{ mol C}_3\text{H}_6} \times \frac{53.064 \text{ g C}_3\text{H}_3\text{N}}{\text{mol C}_3\text{H}_3\text{N}} \\
 & \qquad \qquad \qquad \textcircled{1} \qquad \qquad \qquad \textcircled{2} \qquad \qquad \qquad \textcircled{3} \\
 & = \boxed{821 \text{ g C}_3\text{H}_3\text{N}}
 \end{aligned}$$

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. Use FORMULA WEIGHT.
- 2 - Convert moles iron(II) sulfate to moles potassium permanganate. Use CHEMICAL EQUATION.
- 3 - Convert moles potassium permanganate to volume. Use MOLARITY.

$$\textcircled{1} 151.90 \text{ g FeSO}_4 = \text{mol FeSO}_4$$

$$\textcircled{2} 10 \text{ mol FeSO}_4 = 2 \text{ mol KMnO}_4$$

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

$$3.36 \text{ g FeSO}_4 \times \frac{\textcircled{1} \text{ mol FeSO}_4}{151.90 \text{ g FeSO}_4} \times \frac{\textcircled{2} 2 \text{ mol KMnO}_4}{10 \text{ mol FeSO}_4} \times \frac{\textcircled{3} \text{ L}}{0.250 \text{ mol KMnO}_4} \times \frac{\text{mL}}{10^{-3} \text{ L}} =$$

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