CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$Na_2CO_3 + 2HCl \longrightarrow H_2O + CO_2 + 2NaCl$$
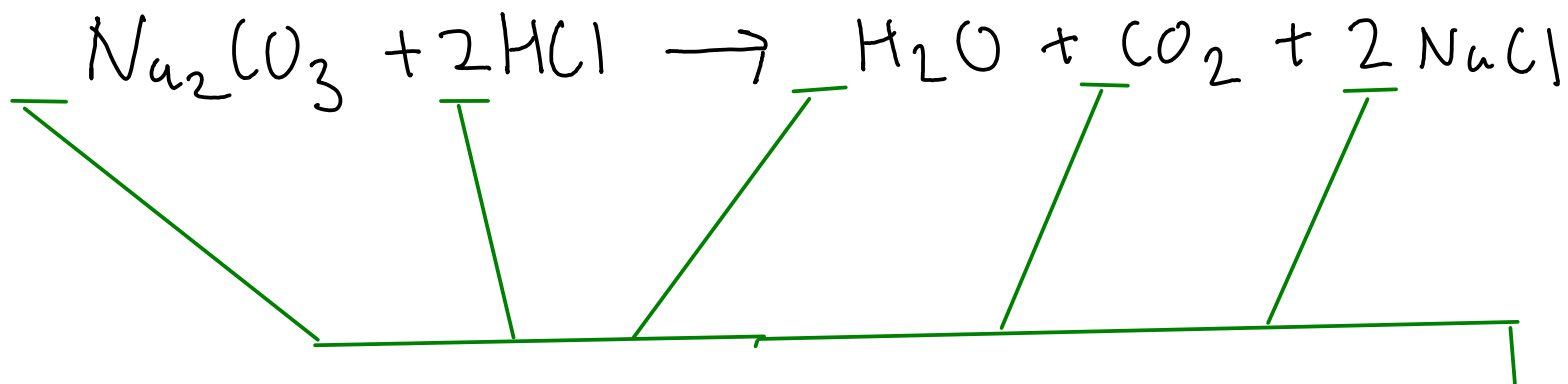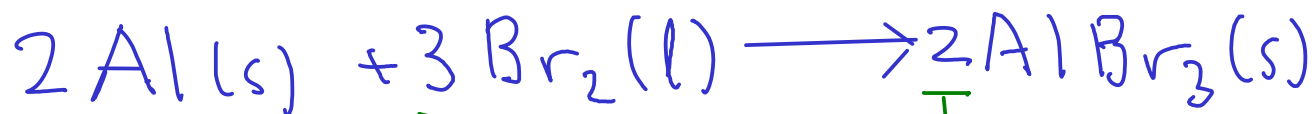
Chemical equations are written and balanced in terms of ATOMS and MOLECULES

- While chemical equations are written in terms of ATOMS and MOLECULES, that's NOT how we often measure substances in lab!

- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

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

$$2 \, Al \, (s) + 3 \, Br_2 \, (l) \longrightarrow 2 \, Al \, Br_3 \, (s)$$
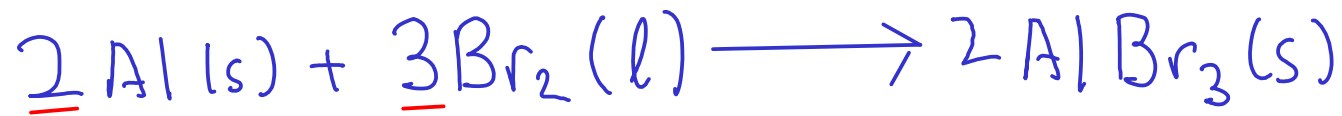
* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine?

① Convert grams of bromine to moles: Need formula weight $Br_2 : \dfrac{2 \times 79.90}{159.80}$

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

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

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

$$2 \, mol \, Al = 3 \, mol \, Br_2$$

$$0.15645 \, mol \, Br_2 \times \dfrac{2 \, mol \, Al}{3 \, mol \, Br_2} = 0.10430 \, mol \, Al$$

③ Convert moles aluminum to mass: Need formula weight $Al : 26.98$

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

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

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

① $159.80 \text{ g } Br_2 = \text{mol } Br_2$ ② $2 \text{ mol } Al = 3 \text{ mol } Br_2$ ③ $26.98 \text{ g } Al = \text{mol } Al$

$$25.0 \text{ g } Br_2 \times \frac{\text{mol } Br_2}{159.80 \text{ g } Br_2} \times \frac{2 \text{ mol } Al}{3 \text{ mol } Br_2} \times \frac{26.98 \text{ g } Al}{\text{mol } Al} = \boxed{2.81 \text{ g } Al}$$

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

Example:

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

$$2 HCl (aq) + Na_2CO_3 (s) \longrightarrow H_2O (\ell) + CO_2 (g) + 2 NaCl (aq)$$
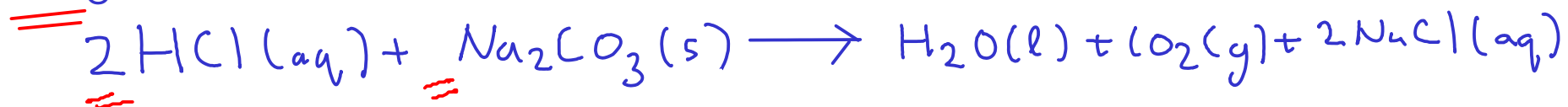
1 - Convert 25.0 grams of sodium carbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00M)

① Na_2CO_3

$Na = 2 \times 22.99$
$C = 1 \times 12.01$
$O = \dfrac{3 \times 16.00}{105.99 \text{ g } Na_2CO_3 = mol \ Na_2CO_3}$

$$25.0 \text{ g } Na_2CO_3 \times \frac{mol \ Na_2CO_3}{105.99 \text{ g } Na_2CO_3} = 0.235871308 6 \ mol \ Na_2CO_3$$

② $2 \ mol \ HCl = mol \ Na_2CO_3$

$$0.235871308 6 \ mol \ Na_2CO_3 \times \frac{2 \ mol \ HCl}{mol \ Na_2CO_3} = 0.4717426172 \ mol \ HCl$$

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

$$2 HCl\,(aq) + Na_2CO_3\,(s) \longrightarrow H_2O\,(l) + CO_2\,(g) + 2\,NaCl\,(aq)$$
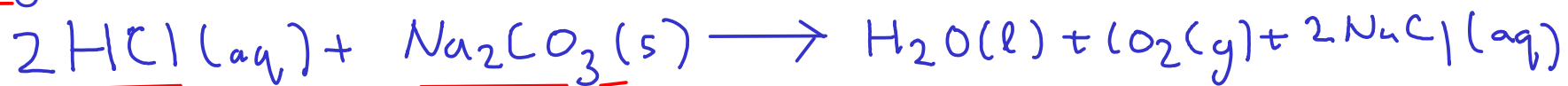
1 - Convert 25.0 grams of sodium carbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
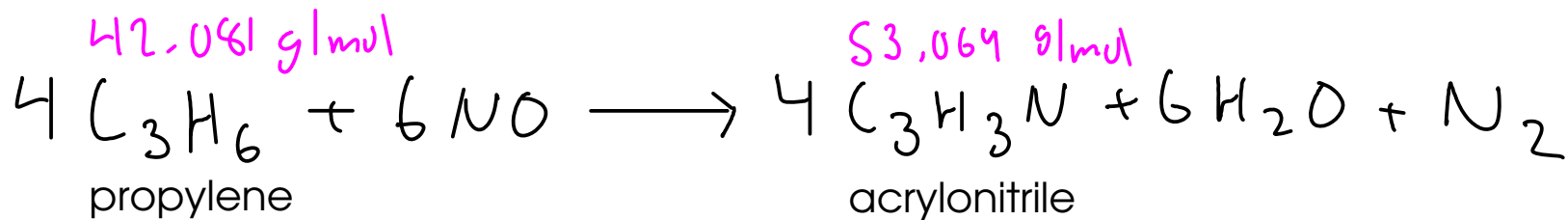3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00M)

③ $6.00\text{ mol }HCl = L$

$$0.4717426172 \text{ mol } HCl \times \frac{L}{6.00 \text{ mol } HCl} = 0.0786237695 \text{ L solution}$$

We've calculated the volume (0.0786 L), but we need to convert to mL because the problem
specifically requested those units.

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

$$0.0786237695 \text{ L} \times \frac{mL}{10^{-3} L} = \boxed{78.6 \text{ mL of } 6.00 M \text{ HCl}}$$

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

42.081 g/mol — over C_3H_6

53.064 g/mol — over C_3H_3N

propylene   acrylonitrile

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

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

① $42.081 \, g \, C_3H_6 = mol \, C_3H_6$ ② $4 \, mol \, C_3H_6 = 4 \, mol \, C_3H_3N$

③ $53.064 \, g \, C_3H_3N = mol \, C_3H_3N$

$$651 \, g \, C_3H_6 \times \underbrace{\frac{mol \, C_3H_6}{42.081 \, g \, C_3H_6}}_{①} \times \underbrace{\frac{4 \, mol \, C_3H_3N}{4 \, mol \, C_3H_6}}_{②} \times \underbrace{\frac{53.064 \, g \, C_3H_3N}{mol \, C_3H_3N}}_{③} = \boxed{821 \, g \, C_3H_3N}$$