COEFFICIENTS

- Experimentally, we can usually determine the reactants and products of a reaction

- We can determine the proper ratios of reactants and products WITHOUT further experiments, using a process called BALANCING

  - BALANCING a chemical equation is making sure the same number of atoms of each element go into a reaction as come out of it.

- A properly balanced chemical equation has the smallest whole number ratio of reactants and products.

- There are several ways to do this, but we will use a modified trial-and-error procedure.

BALANCING

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

~~2~~ 10   1   6 + 4 = 10

1. Pick an element. Avoid (if possible) elements that appear in more than one substance on each side of the equation.

2. Change the coefficients on substances containing this element so that the same number of atoms of the element are present on each side. CHANGE AS LITTLE AS POSSIBLE!

3. Repeat 1-2 until all elements are done.

4. Go back and quickly VERIFY that you have the same number of atoms of each element on each side, If you used any fractional coefficients, multiply each coefficient by the DENOMIMATOR of your fraction.

Use SMALLEST WHOLE NUMBER RATIOS!

BALANCING

$$3MgCl_2 + 2Na_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 6NaCl \quad ✓$$

$$C_2H_2 + 2\tfrac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O$$

$$\not{4}\;5 \quad | \quad 4 + 1 = 5$$

We used a fraction to make five oxygen atoms come in. Since we can't have a fractional coefficient, we can multiply it out by multiplying ALL the coefficients by the denominator of the fraction (here, 2). We can do this because the coefficents form a RATIO.

$$\boxed{2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O} \quad ✓$$

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O \quad ✓$$

1 - Avoid H, balance S (H shows up twice on left)
2 - Avoid O, balance Na (O shows up in all four compounds)
3 - Balance H (shows up less than O)
4 - Balance O (it's already correct!)

CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$\_\; Na_2CO_3 + \underline{2}\,HCl \rightarrow \_\; H_2O + \_\; CO_2 + \underline{2}\,NaCl$$

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!

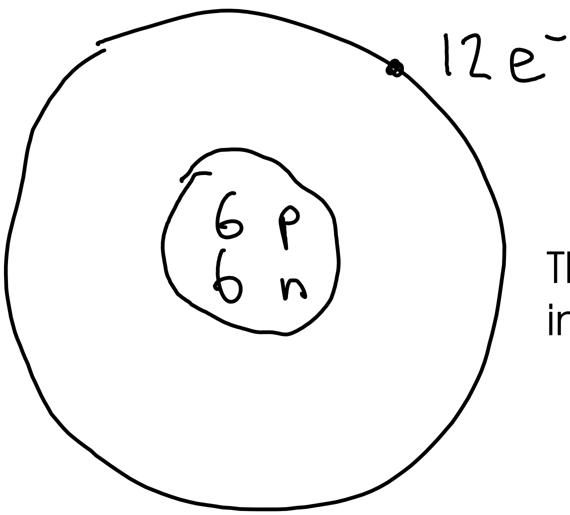
- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

THE MOLE CONCEPT

- A "mole" of atoms is 6.022×10^{23} atoms

Why so big? Because atoms are so small!

- Why - in the metric dominated world of science - do we use such a strange number for quantity of atoms?



carbon-12

The mole is also defined as the number of carbon-12 atoms in exactly 12 g of carbon-12

THE MOLE CONCEPT

- Why define the mole based on an experimentally-measured number?

- The atomic weight of an element (if you put the number in front of the unit GRAMS) is equal to the mass of ONE MOLE of atoms of that element!

Carbon (C): Atomic mass 12.01 ~~amu~~ → 12.01 g

12.01 g → the mass of ONE MOLE of naturally-occurring carbon atoms

Magnesium (Mg): 24.31 g = the mass of ONE MOLE OF MAGNESIUM ATOMS

- So, using the MOLE, we can directly relate a mass and a certain number of atoms!

RELATING MASS AND MOLES

- Use DIMENSIONAL ANALYSIS (a.k.a "drag and drop")

- Need CONVERSION FACTORS - where do they come from?

- We use ATOMIC WEIGHT as a conversion factor.

Mg : 24.31 (Atomic mass) | 24.31 g Mg = $\underline{\text{mol}}$ Mg

"mol" is the abbreviation for "mole"

Example: How many moles of atoms are there in 250. g of magnesium metal?

24.31 g Mg = mol Mg

$$250.\,g\,Mg \times \frac{mol\,Mg}{24.31\,g\,Mg} = \boxed{10.3\,mol\,Mg}$$

Example: You need 1.75 moles of iron. What mass of iron do you need to weigh out on the balance?

Fe: 55.85

55.85 g Fe = mol Fe

$$1.75 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{\text{mol Fe}} = 97.7 \text{ g Fe}$$

WHAT ABOUT COMPOUNDS? FORMULA WEIGHT

Example: 25.0 g of WATER contain how many MOLES of water molecules?

H_2O: H : 2 x 1.008 = 2.016

O : 1 x 16.00 = 16.00

18.016 ← FORMULA WEIGHT of water

FORMULA WEIGHT is the mass of one mole of either an element OR a compound.

$18.016\ g\ H_2O = mol\ H_2O$

$$25.0\ g\ H_2O \times \frac{mol\ H_2O}{18.016\ g\ H_2O} = 1.39\ mol\ H_2O$$

Formula weight goes by several names:

- For atoms, it's the same thing as ATOMIC WEIGHT
- For molecules, it's called MOLECULAR WEIGHT
- Also called "MOLAR MASS"

Example: How many grams of barium chloride do we need to weigh out to get 3.65 moles of barium chloride?

First, let's figure out the FORMULA of barium chloride. The name starts with the metal BARIUM, so it's ionic.

Ba^{2+} Cl^{-}

Cl^{-}

$BaCl_2$

Second, find the formula weight.

$BaCl_2$

Ba: 1 x 137.3

Cl: 2 x 35.45

208.2 g $BaCl_2$ = mol $BaCl_2$

Finally, calculate the mass barium chloride required...

$$3.65 \text{ mol } BaCl_2 \times \frac{208.2 \text{ g } BaCl_2}{\text{mol } BaCl_2} = 760. \text{ g } BaCl_2$$