

STOICHIOMETRY

Lecture 6



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INTRODUCTION

- Mole
- Balancing equations
- Calculations using the equations (STOICHIOMETRY)
- Limiting reactant and % yield

stoichiometry - the relationship between the relative quantities of substances taking part in a reaction or forming a compound, typically a ratio of whole integers.



THE MOLE

the fundamental unit of measurement in chemistry

Dozen = 12

used to count eggs easily

Mole = 6.02×10^{23}

used to count subatomic particles easily

$$N = n \times 6.02 \times 10^{23}$$

N – number of particles (molecules, atoms)

n – number of moles

unit used to deal with large
numbers of atom/molecules



THE MOLE - DEFINITIONS

mole - the amount of substance that contains the same number of particles (atoms/ ions/ molecules/ formula units etc.) as there are atoms in exactly 12 g of carbon-12.

Why use 12 grams? This is the theoretical atomic mass of the Carbon-12 isotope (6 protons and 6 neutrons). This means that the atomic mass or atomic weight (12 grams) of carbon is equal to exactly 1 mole of carbon. Using carbon as a reference, the atomic weights you see in the periodic table are also equal to one mole of those substances

Avogadro's number - number of particles in one mole of any substance, equal to $6.02214076 \times 10^{23}$



ATOMIC MASS UNIT AND MOLAR MASS

atomic mass unit (amu; dalton) - a unit of mass equal to exactly $1/12$ the mass of one ^{12}C atom, or $1.660538921 \times 10^{-24}$ g. This is the approximate mass of one proton or one neutron. It is the basis of atomic weights.

while a carbon atom weighs 12 AMU, the mass shown in the periodic table is:

$$12 \text{ atoms} \times 1.66 \times 10^{-24} \text{g} \times 6.022 \times 10^{23} \text{ atoms/mol} = 12 \text{ g/mol}$$

a single carbon atom weighs 12 amu while a mole of carbon atoms weighs 12.01g/mol.

molar mass (MM) – (molecular weight) mass of 1 mole of a substance in g/mol calculated as a sum of all individual masses of the elements it contains



WHY IS MOLE IMPORTANT?

Compare reactions (e.g. fuels)

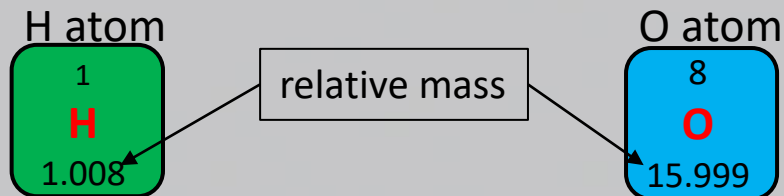
Work out concentrations (e.g. acids)

Work out how much material is needed (e.g. mass balance)



MOLAR MASS (MM)

1 mole of a pure substance weighs the relative mass in grams



1 mole of H atoms weighs 1.0 g
Molar mass = 1.0 g/mol
 6.02×10^{23} H atoms weigh 1.0 g

1 mole of O atoms weighs 16.0 g
Molar mass = 16.0 g/mol
 6.02×10^{23} O atoms weigh 16.0 g

H_2O molecule $2 \times 1.0 + 1 \times 16.0 = 18.0$

molar mass of $\text{H}_2\text{O} = 18.0 \text{ g/mol}$

1 mole of H_2O weighs 18.0 g

6.02×10^{23} H_2O molecules weigh 18.0 g



MASS TO MOLES

Once you know the molar mass of a compound, you can use that mass to determine the amount of moles in a gram amount of the substance or conversely, you can calculate the number of grams in a mole amount of the substance.

EXAMPLE:

1 mole of water weighs 18.0 g

4 moles of water weigh $4 \times 18.0 = 72.0$ g of water

45.0 g of water ???

$45.0 \text{ g} / 18.0 \text{ g/mol} = 2.5$ moles of water

$$\text{grams} = \text{moles} \times \text{Molar Mass}$$

$$g = n \quad MM$$



COUNTING BY WEIGHT

How many water molecules are in 36.0 g of water?

$$g = n \times MM \longrightarrow n = \frac{g}{MM}$$

$$N = n \times 6.02 \times 10^{23}$$

$$g = 36.0 \text{ g}$$
$$MM = 18.0 \text{ g/mol}$$

$$N = 2.00 \text{ mol} \times 6.02 \times 10^{23} \text{ molecules/mol}$$

$$n = \frac{36.0 \text{ g}}{18.0 \text{ g/mol}}$$

$$n = 2.00 \text{ mol H}_2\text{O}$$

$$N = 1.20 \times 10^{24} \text{ molecules H}_2\text{O}$$



Practice problem 1: How many moles of AlCl_3 is equivalent to 3.45×10^{22} AlCl_3 "molecules" (formula units)? Answer using 3 decimal places.

Practice problem 2: To the nearest whole number, what is the molar mass of K_2Se ?

Practice problem 3: How many moles of H_3PO_4 are contained in 0.352 grams of H_3PO_4 . Enter your answer to 5 decimal places.

Practice problem 4: How many grams (to the nearest whole number) of $\text{C}_7\text{H}_{11}\text{O}_2$ are contained in 4.45 moles of $\text{C}_7\text{H}_{11}\text{O}_2$.



BALANCING EQUATIONS



CHEMICAL REACTIONS AND EQUATIONS

A **chemical reaction** is a process that leads to the chemical transformation of one set of chemical substances to another.

Stuff $\longrightarrow$ Different stuff

Reactants $\longrightarrow$ Products

Consider sodium placed in water

https://www.youtube.com/watch?v=ODf_sPexS2Q

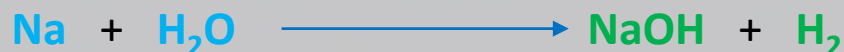
The **solid sodium** is reacting with the **liquid water** to produce **sodium hydroxide** (in aqueous solution) and **hydrogen gas**

This is **MACROSCOPIC** description

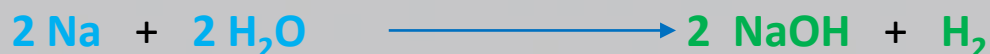


SUBMISROSCOPIC DESCRIPTION

We can write this using our chemical knowledge:



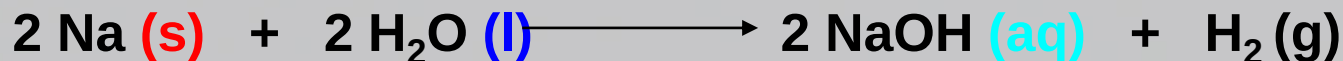
Even more – relative numbers of species involved:



Na	2	2
H	4	4
O	2	2

law of **conservation of mass** - matter cannot be created or destroyed in a chemical reaction.

MACRO: The **solid** sodium is reacting with the **liquid** water to produce sodium hydroxide (in an **aqueous solution**) and hydrogen **gas**.

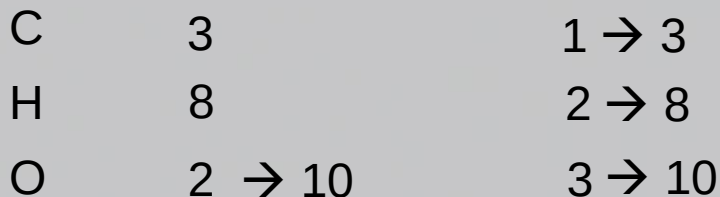
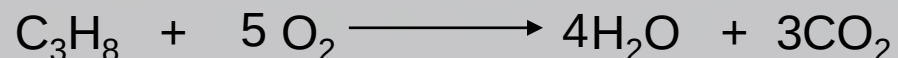


ANOTHER EXAMPLE

Propane burns in oxygen gas to give water vapor and carbon dioxide gas.

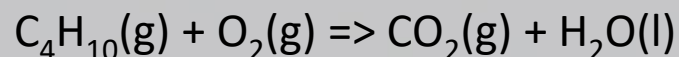
This is a **MACROSCOPIC** description

At the submicroscopic level:

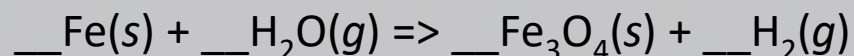


PRACTICE PROBLEMS

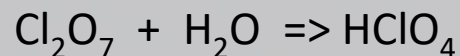
Practice Problem 1: When the following equation is balanced with lowest ratio whole number coefficients, what is the coefficient of CO_2 ?



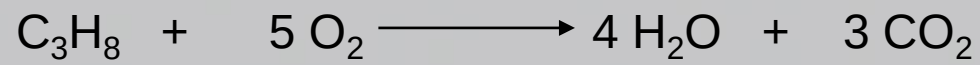
Practice Problem 2: Write a balanced equation (with smallest set of coefficients) for the following:



Practice Problem 3: Balance the following equation using the lowest possible integer coefficients and give the coefficient of HClO_4 .



SUBMISROSCOPIC DESCRIPTION



1 molecule	5 molecules	4 molecules	3 molecules
3 molecule	15 molecules	12 molecules	9 molecules
10 molecule	50 molecules	40 molecules	30 molecules
x molecule	5x molecules	4x molecules	3x molecules
x moles	5x moles	4x moles	3x moles

moles of B

moles of A

=

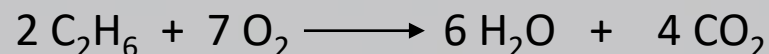
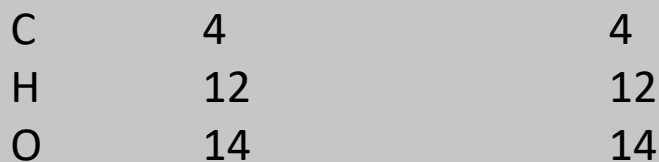
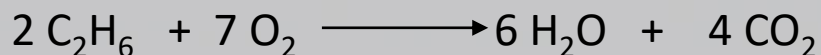
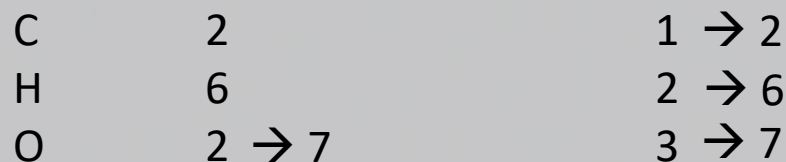
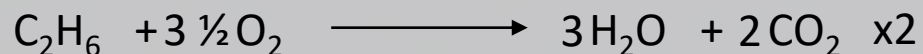
coefficient of B

coefficient of A



ANOTHER EXAMPLE

Ethane burns in oxygen gas to give water vapor and carbon dioxide gas. How many moles of oxygen gas are needed to completely burn 5.0 mol of ethane?



$$\frac{\text{moles of B}}{\text{moles of A}} = \frac{\text{coefficient of B}}{\text{coefficient of A}}$$

$$\frac{\text{moles of O}_2}{\text{moles of C}_2\text{H}_6} = \frac{\text{coefficient of O}_2}{\text{coefficient of C}_2\text{H}_6}$$

$$\frac{\text{moles of O}_2}{5.0 \text{ moles of C}_2\text{H}_6} = \frac{7}{2}$$

moles of O₂ = 17.5 mol



EXAMPLE

Consider the reaction $\text{N}_2 (\text{g}) + \text{H}_2 (\text{g}) \rightarrow 2 \text{NH}_3 (\text{g})$. How many molecules of NH_3 will be made from the reaction of 42.0 g N_2 ?

Step 1: Find the moles of N_2 from its mass and molar mass

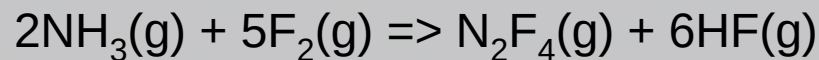
Step 2: Find the moles of NH_3 that form from this quantity of N_2

Step 3: Convert moles of NH_3 to number of molecules of NH_3 using Avogadro's number



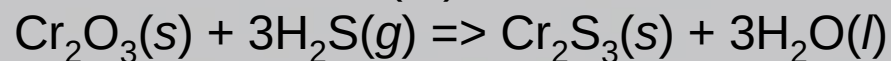
PRACTICE PROBLEMS

Practice Problem 1: Ammonia will react with fluorine to produce dinitrogen tetrafluoride and hydrogen fluoride.



How many moles of NH_3 are needed to react completely with 27.2 mol of F_2 ?

Practice Problem 2: Chromium(III) oxide reacts with hydrogen sulfide (H_2S) gas to form chromium(III) sulfide and water:



To produce 237.5 g Cr_2S_3 , how many moles of Cr_2O_3 are required?

Practice Problem 3: Consider the following reaction:



How many molecules of O_2 are needed to make 110.5 g of H_2O ?











