The Mole:A Measurement of Matter

Mole/Mass Conversions

Percent Composition & Chemical Formulas

The Mole:A Measurement of Matter

What Is a Mole?

Name some things that we 'count' in groups, or that a specific number represents one unit?

Chemists use a specific number to represent things.

A '*mole*' of any substance contains **6.02×10^{23}** representative particles.

Converting Number of Particles to Moles

1 mol=6.02×10^{23} particles is the basis of the conversion factor

EXAMPLE:
How many moles of magnesium is 1.25×10^{23} atoms?

$$1 \text{ mol of Mg} \quad = \quad 6.02 \times 10^{23} \text{ particles}$$
$$x \text{ mol of Mg} \quad = \quad 1.25 \times 10^{23} \text{ particles}$$

$$\frac{1}{X} = \frac{6.02 \times 10^{23}}{1.25 \times 10^{23}}$$

$$(6.02 \times 10^{23}) X = 1.25 \times 10^{23}$$

$$x = \frac{1.25 \times 10^{23}}{6.02 \times 10^{23}} \longrightarrow 0.208 \text{ mol}$$

<u>Converting Moles to Number of Particles</u>

EXAMPLE:
Propane gas is used for heating and cooking. How many **atoms** are in 2.12mol of propane (C_3H_8)

$$1 \text{ mol of propane} = 6.02 \times 10^{23} \text{ particles}$$
$$2.12 \text{ mol of propane} = x \text{ particles}$$

$$\frac{1}{2.12} = \frac{6.02 \times 10^{23}}{x}$$

$$x = (6.02 \times 10^{23})(2.12)$$

$$1.27624 \times 10^{24} \text{ particles of propane}$$

but 1 particle of propane has 11 atoms therefore,

$$(1.27624 \times 10^{24})(11) \longrightarrow 1.40 \times 10^{25} \text{ atoms}$$

<u>Mass of A Mole of a Substance</u>

● The molar mass of a substance is the sum of the molar masses of each element in that substance.

The atomic mass in amu of any element is it's molar mass in grams.

EXAMPLE:

● molar mass of glucose $C_6H_{12}O_6$

6 x the molar mass of C = (6)(12amu)= 72g
12 x the molar mass of H = (12)(1amu)= 12g
6 x the molar mass of O = (6)(16amu)= 96g
_____
                                    Total=180g

∴ 1 mole of glucose has a mass of 180g

6.02×10^{23} particles glucose has a mass of 180g

Converting Moles to Mass

The aluminum satellite dishes in Figure 10.8 are resistant to corrosion because the aluminum reacts with oxygen in the air to form a coating of aluminum oxide (Al_2O_3). This tough, resistant coating prevents any further corrosion. What is the mass of 9.45 mol of aluminum oxide?

Known   1 mole of Al_2O_3

Al = 26.98 x 2 = 53.96g
O = 15.99 x 3 = 47.97g
           101.93g

$$\frac{9.45\ mol\ |\ 101.93\ g}{|\ 1\ mol} = ?\ g$$

therefore,

  1 mol = 101.93g
9.45 mol =   x g

$$= 963.24\ g$$

cross multiplying,

x g = (9.45)(101.93) = 963.24g

16. Find the mass, in grams, of 4.52×10^{-3} mol $C_{20}H_{42}$.

17. Calculate the mass, in grams, of 2.50 mol of iron(II) hydroxide.

Converting Mass to Moles

When iron is exposed to air, it corrodes to form red-brown rust. Rust is iron(III) oxide (Fe_2O_3). How many moles of iron(III) oxide are contained in 92.2 g of pure Fe_2O_3?

Known

1 mole of Fe_2O_3

Fe = 55.85 x 2 = 111.7g
O = 15.99 x 3 = 47.97g
                159.67g

Method 1

1 mol = 159.67g
x mol = 92.2g

Cross Multiply,

(92.2) = (159.67)(x)

$\dfrac{92.2}{159.67}$ = x = 0.58 mol

Method 2

$$\frac{92.2g\ |\ 1\ mol}{|\ 159.67g} =$$

$\dfrac{92.2}{159.67}$ = 0.58 mol

18. Find the number of moles in 3.70×10^{-1} g of boron.

19. Calculate the number of moles in 75.0 g of dinitrogen trioxide.
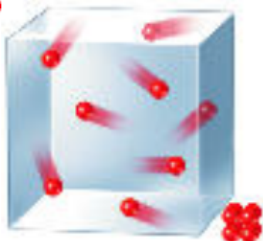
Moles/Volume Conversions

Avogadro's Hypothesis
- equal volumes of gases at the same temperature and pressure will contain equal number of particles
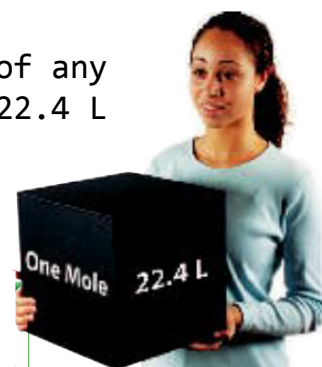
Standard Temperature & Pressure (STP)
- temperature of 0°C
- pressure of 101.3kPa (1 atmosphere=1atm)

At STP, 1 mol (6.02 x 10^{23}) representative particles, of any gas, occupies a volume of 22.4 L

Often called the 'molar volume' of a gas.

One Mole 22.4 L

Calculating the Volume of a Gas at STP

Sulfur dioxide (SO_2) is a gas produced by burning coal. It is an air pollutant and one of the causes of acid rain. Determine the volume, in liters, of 0.60 mol SO_2 gas at STP.

1mol = 22.4L
0.60mol = X L

$$\frac{0.60 \text{mol}}{} \times \frac{22.4\text{L}}{1\text{mol}} = 13\text{L}$$

X=(0.60)(22.4)= 13L

20. What is the volume of these gases at STP?
 a. 3.20×10^{-3} mol CO_2
 b. 3.70 mol N_2

21. At STP, what volume do these gases occupy?
 a. 1.25 mol He
 b. 0.335 mol C_2H_6

<u>Calculating Molar Mass from Density</u>

- the density of gases are usually measured in grams/L (g/L) at a specific temperature.

Calculating the Molar Mass of a Gas at STP

The density of a gaseous compound containing carbon and oxygen is found to be 1.964 g/L at STP. What is the molar mass of the compound?
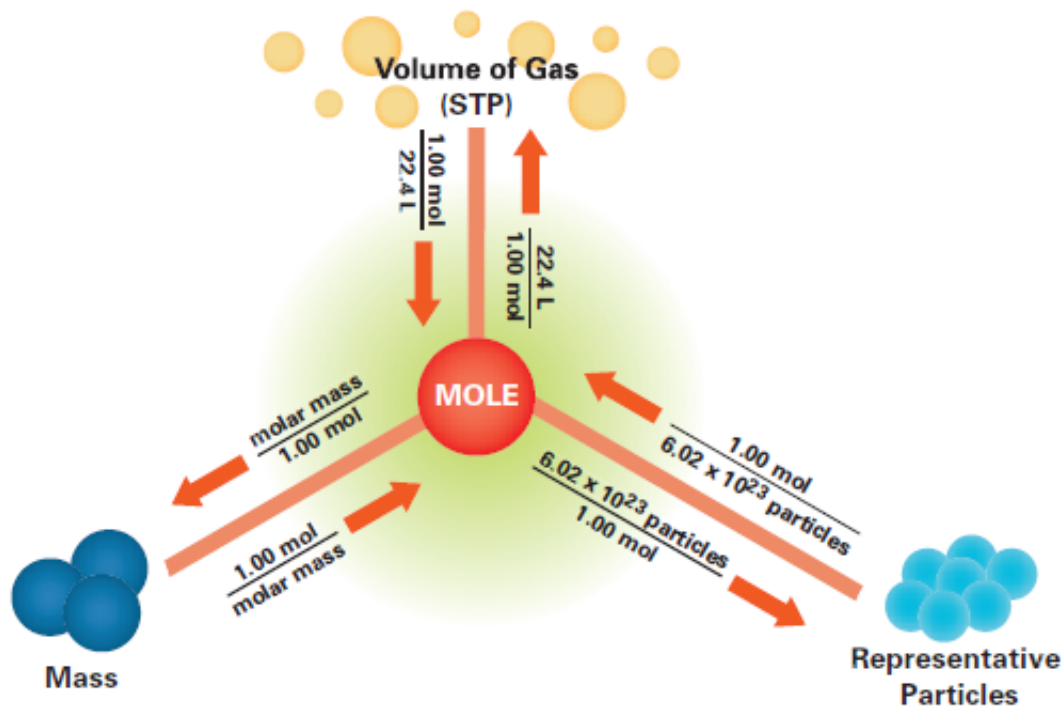
Knowns
- density = 1.964 g/L
- 1 mol (gas at STP) = 22.4 L

$$\frac{1.964g}{x} = \frac{1L}{22.4L}$$

∴ x = (22.4)(1.964)
   = 43.994g/mol

$$\frac{1.964g}{1\cancel{L}} \left| \frac{22.4\cancel{L}}{1mol} \right. = 43.994g/mol$$

22. A gaseous compound composed of sulfur and oxygen, which is linked to the formation of acid rain, has a density of 3.58 g/L at STP. What is the molar mass of this gas?

23. What is the density of krypton gas at STP?

Percent Composition and Chemical Formula

● the percent by mass of an element in a compound is the number of grams of the element divided by the mass in grams of the compound multiplied by 100%

$$\% \text{ mass of element} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100\%$$

Calculating Percent Composition from Mass Data

When a 13.60-g sample of a compound containing only magnesium and oxygen is decomposed, 5.40 g of oxygen is obtained. What is the percent composition of this compound?

Knowns
● mass of compound = 13.60 g
● mass of oxygen = 5.40 g O
● mass of magnesium =
    13.60 g − 5.40 g = 8.20 g Mg

Unknowns
● percent Mg = ? % Mg
● percent O = ? % O

$$\% \text{ Mg} = \frac{\text{mass of Mg}}{\text{mass of compound}} \times 100\% = \frac{8.20 \ \cancel{g}}{13.60 \ \cancel{g}} \times 100\%$$

$$= 60.3\%$$

$$\% \text{ O} = \frac{\text{mass of O}}{\text{mass of compound}} \times 100\% = \frac{5.40 \ \cancel{g}}{13.60 \ \cancel{g}} \times 100\%$$

$$= 39.7\%$$

Practice

32. A compound is formed when 9.03 g Mg combines completely with 3.48 g N. What is the percent composition of this compound?

33. When a 14.2-g sample of mercury(II) oxide is decomposed into its elements by heating, 13.2 g Hg is obtained. What is the percent composition of the compound?

Percent Composition from the Chemical Formula

• using the masses of the individual elements in 1 mol of a compound, you can determine the %composition

$$\% \text{ mass} = \frac{\text{mass of element in 1 mol compound}}{\text{molar mass of compound}} \times 100\%$$

Calculating Percent Composition from a Formula

Propane (C_3H_8), the fuel commonly used in gas grills, is one of the compounds obtained from petroleum. Calculate the percent composition of propane.

Knowns
- mass of C in 1 mol C_3H_8 = 36.0 g
- mass of H in 1 mol C_3H_8 = 8.0 g
- molar mass of C_3H_8 = 44.0 g/mol

Unknowns
- percent C = ? % C
- percent H = ? % H

$$\% \, C = \frac{\text{mass of C}}{\text{mass of propane}} \times 100\% = \frac{36.0 \, \cancel{g}}{44.0 \, \cancel{g}} \times 100\% = 81.8\%$$

$$\% \, H = \frac{\text{mass of H}}{\text{mass of propane}} \times 100\% = \frac{8.0 \, \cancel{g}}{44.0 \, \cancel{g}} \times 100\% = 18\%$$

Practice

34. Calculate the percent composition of these compounds.
   a. ethane (C_2H_6)
   b. sodium hydrogen sulfate $(NaHSO_4)$

35. Calculate the percent nitrogen in these common fertilizers.
   a. NH_3
   b. NH_4NO_3

• recall in a previous problem that a sample of propane
consisted of 82% C and 18% H
• this means that in any 100g sample, there is 82g of C
and 18g of H

<u>EXAMPLE</u>

How many grams of C is there in a 73g
sample of propane? How many grams of H is
there?

<u>SOLUTION</u>

82% of the 73g sample is C

∴

$$\frac{82}{100} \times 73 = 59.9g\ C$$

If there is 59.9g of C the remainder must be H and
therefore there is

73-59.9= 13.1g H