The Mole:A Measurement of Matter

Mole/Mass Conversions

Percent Composition & Chemical Formulas

Chapter 10

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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 mol of Mg = 6.02×10^{23} particles

x mol of Mg = 1.25×10^{23} particles

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

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

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

Converting Moles to Number of Particles

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

1 mol of propane = 6.02×10^{23} particles
2.12 mol of propane = x particles

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

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

1.27624×10^{24} particles of propane

but 1 particle of propane has 11 atoms therefore,

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

Mass of A Mole of a Substance

- 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

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

therefore,

1 mol = 101.93g
9.45 mol = x g

$$= 963.24 \text{ g}$$

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)

$$\frac{92.2}{159.67} = x = 0.58 \text{ mol}$$

Method 2

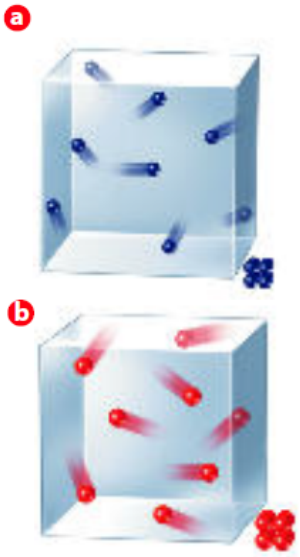
$$\frac{92.2\text{g} \mid 1 \text{ mol}}{159.67\text{g}} =$$

$$\frac{92.2}{159.67} = 0.58 \text{ mol}$$

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.

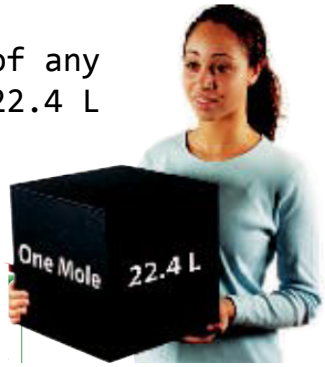
Moles/Volume Conversions



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℃
- pressure of 101.3kPa (1 atmosphere=1atm)

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



Often called the 'molar volume' of a gas.

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

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

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

Calculating Molar Mass from Density

- 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

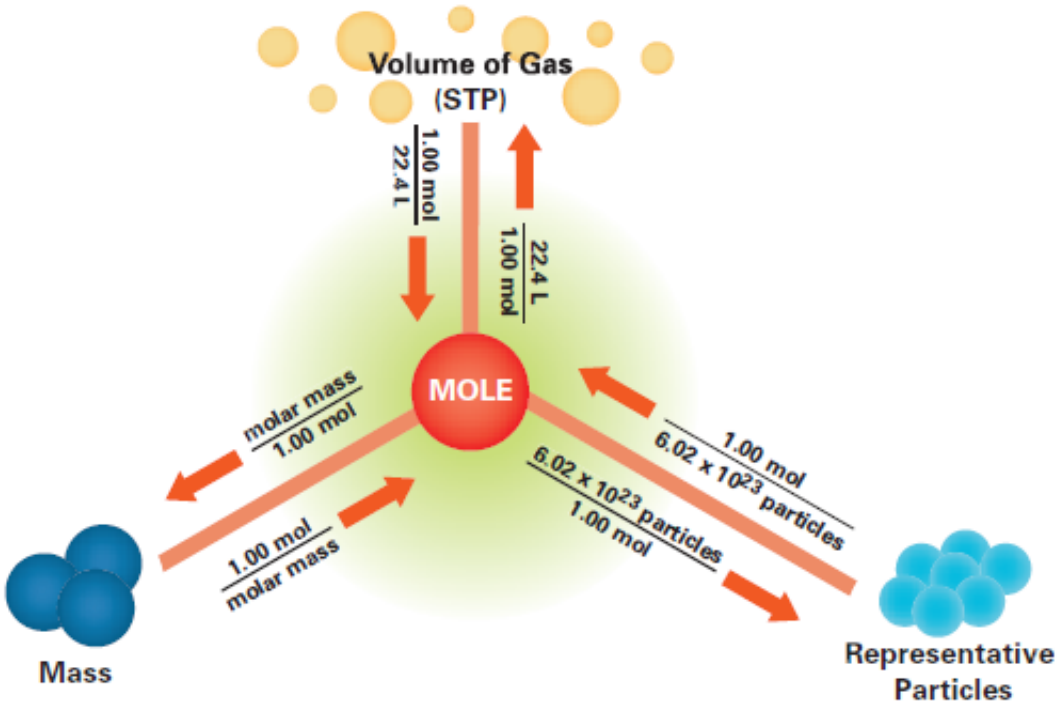
- density = 1.964 g/L
- 1 mol (gas at STP) = 22.4 L

$$1.964\text{g} = 1\text{L}$$
$$x = 22.4\text{L}$$
$$\therefore x = (22.4)(1.964)$$
$$= 43.994\text{g/mol}$$

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

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

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

$$= 60.3\%$$

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

$$= 39.7\%$$

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

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

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

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

Using % Composition as a Conversion Factor

Previous Problem

- 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

EXAMPLE

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

SOLUTION

82% of the 73g sample is C

$\therefore$

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

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

$73 - 59.9 =$ 13.1g H

Determining the Empirical Formula of a Compound

The empirical formula of a compound shows the smallest whole number ratio of the atoms in the compound.

A compound is analyzed and found to contain 25.9% nitrogen and 74.1% oxygen. What is the empirical formula of the compound?

Knowns
- percent of nitrogen = 25.9% N
- percent of oxygen = 74.1% O

Unknown
- Empirical formula = $N_?O_?$

Step 1: Assume a 100g sample.
Therefore, it would have 25.9g of N and 74.1g of O

Step 2: Convert this number of grams to moles

$25.9\text{g N} \times \frac{1\text{mol}}{14\text{g}} = 1.85\text{mol}$ $\qquad$ $74.1\text{g O} \times \frac{1\text{mol}}{16\text{g}} = 4.63\text{mol O}$

Step 3: The mole ratio is therefore $N_{1.85}O_{4.63}$ but element ratios must be whole numbers. Divide EACH ratio by the smallest.

$\frac{1.85}{1.85} : \frac{4.53}{1.85} \longrightarrow 1:2.5$

The smallest whole number ratio is therefore 2:5 which gives the formula

$$N_2O_5$$

36. Calculate the empirical formula of each compound.

a. 94.1% O, 5.9% H

b. 67.6% Hg, 10.8% S, 21.6% O

37. 1,6-diaminohexane is used to make nylon. What is the empirical formula of this compound if it is 62.1% C, 13.8% H, and 24.1% N?

Finding the Molecular Formula of a Compound

The molecular formula of a compound is either the same as its experimentally determined empirical formula, or a whole number multiple of its empirical formula.

- The empirical formula represents the smallest 'possible' ratio of the elements involved in the compound.
- it may not be an 'actual' substance
- the 'molecular' formula is the formula of the actual substance created when the specific elements combine.

Calculate the molecular formula of a compound whose molar mass is 60.0 g/mol and empirical formula is CH_4N.

Knowns

- empirical formula = CH_4N
- molar mass = 60.0 g/mol

Unknown

- molecular formula = ?

Empirical Formula has a mass of

C= 1x12=12g
H= 4x1 =4g
N= 1x14=14g
30g

60g molar mass represents 2X this, therefore the molecular formula is

2 x CH_4N or $C_2H_8N_2$

38. Find the molecular formula of ethylene glycol, which is used as antifreeze. The molar mass is 62 g/mol and the empirical formula is CH_3O.

39. Which pair of molecules has the same empirical formula?

a. $C_2H_4O_2$, $C_6H_{12}O_6$

b. $NaCrO_4$, $Na_2Cr_2O_7$