Chapter 3 Part 1 (Extra)

Dr. Turner

Moles

- A mole is 6.022×10^{23} of something
  - Ex. A mole of ammonia is 6.022×10^{23} ammonia molecules
- The value 6.022×10^{23} is called Avogadro's number and is abbreviated N_A
- Moles are the SI (metric) unit for amount
- Moles can also have prefixes such as kmol, mmol, cmol, or μmol
- Avogadro’s number is used as a conversion factor between moles and formula units (molecules, atoms, ions)

Using N_A as a conversion factor

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$$17.5 \text{ kmol } NO_2 \left(\frac{1000 \text{ mol } NO_2}{1 \text{ kmol } NO_2}\right)\left(\frac{6.022 \times 10^{23} \text{ molec } NO_2}{1 \text{ mol } NO_2}\right)$$

$$= 1.05 \times 10^{23} \text{ molec } NO_2$$

Formula mass and Molar mass

Formula mass

- The mass of one formula unit of something
- Measured in units of amu
- Calculated using average atomic masses on the periodic table
- Ex. Water having a formula mass of 18.02 amu means that one water molecule has mass of 18.02 amu

Molar mass

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$$6.022 \times 10^{23} \text{ amu} = 1 \text{ g}$$

Calculating Formula Mass and Molar Mass

Calculate the (A) formula mass and (B) molar mass of $MgCl_2$.

(A)

$$\text{average atomic mass of Mg} + 2(\text{average atomic mass of Cl})$$
$$= 24.31 + 2(35.45)$$
$$= 95.21 \text{ amu}$$

(B)

$$\text{average atomic mass of Mg} + 2(\text{average atomic mass of Cl})$$
$$= 24.31 + 2(35.45)$$
$$= 95.21 \frac{\text{g}}{\text{mol}}$$

Mass

Which of the following contains the most mass?

A. 1 formula unit (molecule) of $MgCl_2$
B. 1 gram of $MgCl_2$
C. 1 mole of $MgCl_2$
D. 1 atomic mass unit of $MgCl_2$

Mass

Which of the following contains the most mass?

A. 1 formula unit (molecule) of $MgCl_2$

$$95.21\ \text{amu}\left(\frac{1\ \text{g}}{6.022 \times 10^{23}\ \text{amu}}\right) = 1.581 \times 10^{-23}\ \text{g}$$

B. 1 gram of $MgCl_2$ 1 g

C. 1 mole of $MgCl_2$ 95.21 g

D. 1 atomic mass unit of $MgCl_2$

$$1\ \text{amu}\left(\frac{1\ \text{g}}{6.022 \times 10^{23}\ \text{amu}}\right) = 1.661 \times 10^{-24}\ \text{g}$$

The correct answer is C

Using Molar Mass

- Molar mass is calculated the same way as formula mass, but molar mass has units of g/mol instead of amu.
- Since molar mass has units of g/mol, it can be used as a conversion factor between grams and moles.
- Since grams are a unit of mass (how much matter is in something) and moles are a unit of amount (how many of something there is), molar mass can be used as a conversion factor between mass and amount.

Amount vs. Mass

Amount

- How many of something there are
- Expressed in units of moles, dozens, pairs, etc.
- SI unit is moles

Mass

- How much matter is in something
- Expressed in units of grams, pounds, kilograms, short tons, etc.
- SI unit is kilograms

Atomic mass units

What is the mass (in amu) of 10.0 billion SO_2 molecules?

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$$10.0 \times 10^{9}\ \mathrm{SO_2\ molecules}\left(\frac{1\ \mathrm{mol\ SO_2}}{6.022 \times 10^{23}\ \mathrm{molecules\ SO_2}}\right)\left(\frac{64.058\ \mathrm{g\ SO_2}}{1\ \mathrm{mol\ SO_2}}\right)\left(\frac{6.022 \times 10^{23}\mathrm{amu\ SO_2}}{1\ \mathrm{g\ SO_2}}\right) = 6.41 \times 10^{11}\mathrm{amu\ SO_2}$$

Moles

An analytical balance can detect a mass of 0.1 mg. What is the total number of $MgCl_2$ molecules present in this minimally detectable quantity of $MgCl_2$?

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$$0.1\ \text{mg MgCl}_2 \left(\frac{1\ \text{g MgCl}_2}{1000\ \text{mg MgCl}_2}\right)\left(\frac{1\ \text{mol MgCl}_2}{95.21\ \text{g MgCl}_2}\right)\left(\frac{6.022 \times 10^{23}\ \text{molec MgCl}_2}{1\ \text{mol MgCl}_2}\right)$$

$$= 6 \times 10^{17}\ \text{molecules}$$

Moles

How many molecules of liquid ethyl mercaptan, C_2H_6S, are contained in a 1.0 μL sample? The density of ethyl mercaptan is 0.84 g/mL.

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$$1.0\ \mu\text{L}\left(\frac{1.0\times 10^{-6}\text{L}}{1\ \mu\text{L}}\right)\left(\frac{1000\ \text{mL}}{1\ \text{L}}\right)\left(\frac{0.84\ \text{g C}_2\text{H}_6\text{S}}{1\ \text{mL}}\right)\left(\frac{1\ \text{mol C}_2\text{H}_6\text{S}}{62.1\ \text{g C}_2\text{H}_6\text{S}}\right)$$

$$\left(\frac{6.022\times 10^{23}\text{molec C}_2\text{H}_6\text{S}}{1\ \text{mol C}_2\text{H}_6\text{S}}\right) = 8.1\times 10^{18}\text{molecules C}_2\text{H}_6\text{S}$$

Elemental Composition

- Elemental composition recognizes how many atoms are in a molecule of something and uses that as a conversion factor.
- It recognizes that PH_3 has 3 hydrogen atoms per 1 PH_3 molecule

How many atoms of hydrogen are present in 254 molecules of PH_3?

$$254\ \mathrm{PH_3\ molec}\left(\frac{3\ \mathrm{H\ atoms}}{1\ \mathrm{PH_3\ molec}}\right) = 762\ \mathrm{H\ atoms}$$

Elemental Composition

How many atoms of hydrogen are present in 2500 mmol of H_2SO_4?

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$$2500\ \text{mmol}\ H_2SO_4 \left(\frac{1\ \text{mol}}{1000\ \text{mmol}}\right)\left(\frac{6.022\times 10^{23}\ \text{molec}\ H_2SO_4}{1\ \text{mol}\ H_2SO_4}\right)\left(\frac{2\ \text{atoms H}}{1\ \text{molec}\ H_2SO_4}\right)$$

$$= 3.0\times 10^{24}\ \text{atoms H}$$

Percent Composition (Mass Percent)

- Percent composition is defined as the percentage by mass of each element in a compound

Find the percent composition of CH_4 to 2 sig figs?

$$\%C = \frac{\text{mass of C in } CH_4}{\text{mass of } CH_4} = \frac{12.01}{16.04} \times 100 = 75\%$$

$$\%H = \frac{\text{mass of H in } CH_4}{\text{mass of } CH_4} = \frac{4(1.008)}{16.04} \times 100 = 25\%$$

Percent Composition (Mass Percent)

Determine the percent composition of each element in HNO_3 to four significant figures?

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Determine the percent composition of each element in HNO_3 to four significant figures?

$$\%\mathrm{H} = \frac{1.008\ \mathrm{g}}{63.012\ \mathrm{g}} \times 100 = 1.600\ \%$$

$$\%\mathrm{N} = \frac{14.007\ \mathrm{g}}{63.012\ \mathrm{g}} \times 100 = 22.23\ \%$$

$$\%\mathrm{O} = \frac{3(15.999\ \mathrm{g})}{63.012\ \mathrm{g}} \times 100 = 76.17\%$$