The Mole

Calculating quantities

Learning Target

MMLT: Apply Avogadro's number in calculations of representative particles. This includes molar mass, volume of a gas at STP and percent composition calculations.

Be able to define, explain, identify or provide examples of each of the following:

- Mole
- Avogadro's Number
- Representative Particle
- Molar Mass
- STP
- Molar Volume
- Density
- Percent Composition
- Empirical Formula

Textbook Practice

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The Mole

- A mole is defined as 6.022×10^{23} representative particles.
  - Much like a dozen is 12, a mole is a very high number of particles because the particles are extremely small.
  - A representative particle is the smallest part of a compound. It can be atoms, molecules or formula units.
- 6.022×10^{23} is called **Avogadro's Number** (in honour of the Italian researcher Amedeo Avogadro di Quaregna)
- Defined as the number of atoms in exactly 12 grams of carbon-12)

The Mole Math

- 1 mole = 6.022×10^{23} particles, to use it in calculations it is written as a ratio:

When converting to moles: $\frac{1\ mol}{6.022 \times 10^{23}\ particles}$

When converting to number of particles: $\frac{6.022 \times 10^{23}\ particles}{1\ mol}$

The Mole Math

- How many moles is 7.31×10^{24} atoms of potassium?
- How many atoms is 8.55 mol of platinum?
- How many molecules of CO_2 are in 4.56 mol of CO_2?
- How many atoms of oxygen in 4.56 mol of CO_2?
- How many moles is 7.78×10^{24} formula units of $MgCl_2$?
- How many atoms of hydrogen in 1.23 mol of $C_6H_{12}O_6$?

Molar Mass

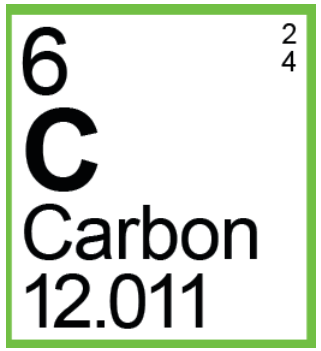
- The average atomic mass of an element is also the mass in grams of 1 mole of that element, called the ***molar mass***.
  - Both have the same reference quantity, carbon-12.
- 1 mole of H has a mass of 1.008 grams.
- 1 mole of Fe has a mass of 55.85 grams.
- We can count representative particles in a compound by measuring its mass.

Molar Mass Math

- Calculate the mass of 2.34 moles of carbon.
- How many moles of magnesium is 63.29 grams of Mg?
- How many atoms is 4.77 g of Li?
- Calculate the mass of 9.45×10^{22} atoms of U.

Molar Mass of Compounds

- To determine the molar mass of a compound, add up the molar mass of ***each atom*** in the compound.
- For example, $MgCO_3$



24.3050 g + 12.0107 g + 3 x (15.999 g) = 84.3139 g

Moles-to-Mass & Mass-to-Moles

- The molar mass of a compound acts as a conversion factor.
  - 1 mol $MgCO_3$ = 84.31 g $MgCO_3$ or 84.31 g/mol
- Calculate the mass of 4.31 mol of $MgCO_3$.

More Molar Mass Math

- How many moles is 285.45 g of PO_3?
- Calculate the number of molecules in 285.45 g of PO_3.
- Calculate the number of oxygen atoms in 285.45 g of PO_3.

Practice

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Mole-Volume Relationship for Gases

- It is difficult to directly measure the mass of a gas, with it being a gas and all.
- For a gas, its volume relates to how many particles are contained within.
- Two factors influence the volume of a gas: ***Temperature*** and ***Pressure***.
- To count particles, we need a reference volume with all gases at the same temperature and pressure.

STP

- The reference temperature and pressure is $0^{o}C$ and 1 atm (atmosphere) of pressure.
- This is referred to as Standard Temperature and Pressure, or **STP**.
- At STP, 1 mole of any gas occupies a volume of 22.4 L. Called the ***molar volume***.
- 1 mole = 22.4 L (for gases only)

Molar Volume Calculations

- Calculate the volume of 4.59 mol of CO_2 gas at STP.
- Calculate the amount of moles of 14.8 L of O_2 at STP.
- Calculate the volume of 9.75 g of methane, CH_4 at STP.

Density of a Gas

- Density for a substance is mass per unit volume (D = m/V), usually measured in g/L for gases.
- At STP all gases have a volume of 22.4 L.
- Use the molar mass to determine its density by assuming there is exactly 1 mole of the gas.
- Calculate the density of CO_2 at STP.
- Calculate the density of butane, C_4H_{10} at STP.

Percent Composition of a Compound

- Assume you have exactly one mole.
- Determine the mass of each of the elements in the compound and divide by the molar mass of the compound.
  - Multiply that answer by 100%.
- Calculate the percent composition of $Al_2(CO_3)_3$.

Practice Questions for Review

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Empirical Formulas

- An empirical formula is the lowest whole number ratio of atoms in a compound.
- A molecular formula is the true number of atoms of each element in the formula for a compound.
- For example, take benzene:
  - Molecular Formula: C_6H_6
  - Empirical Formula: CH
- It is possible for two different compounds to have the same empirical formula.
  - Acetylene: Molecular formula is C_2H_2, empirical is CH

Empirical Formulas

- Formula Units for ionic compounds are always empirical (it's the definition of a formula unit).
- A molecular compound can only have a different empirical formula if the number of all the atoms contain a common factor.

Molecular: (Correct formula)	H_2O	$C_6H_{12}O_6$	$C_{12}H_{22}O_{11}$
	↓	↓	↓
Empirical: (Lowest whole number ratio)	H_2O	CH_2O	$C_{12}H_{22}O_{11}$

Calculating Empirical Formulas

- Because empirical formulas are the lowest ratio of atoms, they are also the lowest ratio of moles.
  - C_3H_8O 3:8 carbon-hydrogen, 8:1 Hydrogen-Oxygen
- Step 1: Assume you have a 100g sample, then all of the % compositions can be written as a mass in grams.
- Step 2: Convert from grams to moles.
- Step 3: Find lowest whole number ratio by dividing each number of moles by the smallest value.

Calculating Empirical Formulas

- Calculate the empirical formula of a compound composed of:
  - 38.67 % C, 16.22 % H, and 45.11 % N
- Calculate the empirical formula of a compound composed of:
  - 43.64 % P and 56.36 % O
- Calculate the empirical formula for caffeine:
  - 49.48 % C, 5.15 % H, 28.87 % N and 16.49 % O

Unit Review

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