The Mole

Chapter 7

Homework

Page 175 #'s 5 & 6

Page 179 #'s 7 & 8

6.02×10^{23}

The Mole

- A counting unit
- Similar to a dozen, except instead of 12, it's 602 billion trillion 602,000,000,000,000,000,000,000
- 6.02×10^{23} (in scientific notation)
- This number is named in honor of Amedeo Avogadro (1776 – 1856), who studied quantities of gases and discovered that no matter what the gas was, there were the same number of molecules present

Just How Big is a Mole?

- Enough soft drink cans to cover the surface of the earth to a depth of over 200 miles.
- If you had Avogadro's number of unpopped popcorn kernels, and spread them across the United States of America, the country would be covered in popcorn to a depth of over 9 miles.
- If we were able to count atoms at the rate of 10 million per second, it would take about 2 billion years to count the atoms in one mole.

Learning Check

Suppose we invented a new collection unit called a rapp. One rapp contains 8 objects.

1. How many paper clips in 1 rapp?

a) 1 b) 4 c) 8

2. How many oranges in 2.0 rapp?

a) 4 b) 8 c) 16

3. How many rapps contain 40 gummy bears?

a) 5 b) 10 c) 20

The Mole

- 1 dozen cookies = 12 cookies
- 1 mole of cookies = 6.02×10^{23} cookies

- 1 dozen cars = 12 cars
- 1 mole of cars = 6.02×10^{23} cars

- 1 dozen Al atoms = 12 Al atoms
- 1 mole of Al atoms = 6.02×10^{23} atoms

Note that the NUMBER is always the same, but the MASS is very different!

Mole is abbreviated mol (gee, that's a lot quicker to write, huh?)

A Mole of Particles

Contains 6.02×10^{23} particles

1 mole C = 6.02×10^{23} C atoms

1 mole H_2O = 6.02×10^{23} H_2O molecules

1 mole NaCl = 6.02×10^{23} NaCl "molecules"

(technically, ionics are compounds not molecules so they are called formula units)

6.02×10^{23} Na^+ ions and

6.02×10^{23} Cl^- ions

Avogadro's Number as a Conversion Factor (unit analysis)

$$\frac{6.02 \times 10^{23} \text{ particles}}{1 \text{ mole}}$$

or

$$\frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ particles}}$$

Note particles could be atom OR molecule OR ions!

Learning Check

1. Number of atoms in 0.500 mole of Al
   a) 500 Al atoms
   b) 6.02×10^{23} Al atoms
   c) 3.01×10^{23} Al atoms

2. Number of moles of S in 1.8×10^{24} S atoms
   a) 1.0 mole S atoms
   b) 3.0 mole S atoms
   c) 1.1×10^{48} mole S atoms

Answers

- $\frac{0.5 \text{ mol Al}}{1} \times \frac{6.02 \times 10^{23} \text{ Al}}{1 \text{ mol Al}} = 3.01 \times 10^{23}$

$\frac{1.8 \times 10^{24} \text{ S atoms}}{1} \times \frac{1 \text{ mol S}}{6.02 \times 10^{23} \text{ S atoms}} = 3.0 \text{ mol S}$

Molar Mass

- The Mass of 1 mole (in grams)
- Equal to the numerical value of the average atomic mass (get from periodic table)

1 mole of C atoms	=	12.0 g
1 mole of Mg atoms	=	24.3 g
1 mole of Cu atoms	=	63.5 g

Other Names Related to Molar Mass

- **Molecular Mass/Molecular Weight:** If you have a single molecule, mass is measured in amu's instead of grams. But, the molecular mass/weight is the same numerical value as 1 mole of molecules. Only the units are different. (This is the beauty of Avogadro's Number!)
- **Formula Mass/Formula Weight:** Same goes for compounds. But again, the numerical value is the same. Only the units are different.
- **THE POINT: You may hear all of these terms** which mean the *SAME NUMBER*… just different units

Learning Check!

Find the molar mass

(usually we round to the tenths place)

A.1 mole of Br atoms = 79.9 g/mole

B.1 mole of Sn atoms = 118.7 g/mole

Molar Mass of Molecules and Compounds

Mass in grams of 1 mole equal numerically to the sum of the atomic masses

1 mole of $CaCl_2$ = 111.1 g/mol

1 mole Ca x 40.1 g/mol

+ 2 moles Cl x 35.5 g/mol = 111.1 g/mol $CaCl_2$

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1 mole of N_2O_4 = 92.0 g/mol

Learning Check!

A. Molar Mass of K_2O = ? Grams/mole

K = 39.0 x 2 = 78 g

O = 16.0 g x 1 = 16 g total = 94 g

94g K_2O/mol K_2O

B. Molar Mass of antacid $Al(OH)_3$ = ? Grams/mole

Learning Check

Prozac, $C_{17}H_{18}F_3NO$, is a widely used antidepressant that inhibits the uptake of serotonin by the brain. Find its molar mass.

$$= \frac{309\ g\ C_{17}H_{18}F_3NO}{mol\ C_{17}H_{18}F_3NO}$$

Calculations with Molar Mass

molar mass

Grams ⟷ **Moles**

Converting Moles and Grams

Aluminum is often used for the structure of light-weight bicycle frames. How many grams of Al are in 3.00 moles of Al?

3.00 moles Al ⟶ ? g Al

1. Molar mass of Al 1 mole Al = 27.0 g Al

2. Conversion factors for Al

$$\frac{27.0\text{g Al}}{1\text{ mol Al}} \quad \text{or} \quad \frac{1\text{ mol Al}}{27.0\text{ g Al}}$$

3. Setup $3.00\text{ moles Al} \times \frac{27.0\text{ g Al}}{1\text{ mole Al}}$

Answer = 81.0 g Al

Learning Check!

The artificial sweetener aspartame (Nutra-Sweet) formula $C_{14}H_{18}N_2O_5$ is used to sweeten diet foods, coffee and soft drinks. How many moles of aspartame are present in 225 g of aspartame?

Atoms/Molecules and Grams

- Since 6.02×10^{23} particles = 1 mole
  AND
  1 mole = molar mass (grams)
- You can convert atoms/molecules to moles and then moles to grams! (Two step process)
- You can't go directly from atoms to grams!!!! You MUST go thru MOLES.
- That's like asking 2 dozen cookies weigh how many ounces if 1 cookie weighs 4 oz? You have to convert to dozen first!

Calculations

Everything must go through Moles!!!

Atoms/Molecules and Grams

How many atoms of Cu are present in 35.4 g of Cu?

$$35.4\ \text{g}\ \cancel{\text{Cu}} \times \frac{1\ \cancel{\text{mol Cu}}}{63.5\ \cancel{\text{g Cu}}} \times \frac{6.02 \times 10^{23}\ \text{atoms Cu}}{1\ \cancel{\text{mol Cu}}}$$

= 3.4 X 10^{23} atoms Cu

Learning Check!

How many atoms of K are present in 78.4 g of K?

Learning Check!

What is the mass (in grams) of 1.20 X 10^{24} molecules of glucose ($C_6H_{12}O_6$)?

Learning Check!

How many **atoms** of O are present in 78.1 g of oxygen?

$$\frac{78.1\ \text{g } O_2}{} \left| \frac{1\ \text{mol } O_2}{32.0\ \text{g } O_2} \right| \frac{6.02 \times 10^{23}\ \text{molecules } O_2}{1\ \text{mol } O_2} \left| \frac{2\ \text{atoms O}}{1\ \text{molecule } O_2} \right.$$

Percent Composition

What is the percent carbon in $C_5H_8NO_4$ (the glutamic acid used to make MSG monosodium glutamate), a compound used to flavor foods and tenderize meats?

a) 8.22 %C
b) 24.3 %C
c) 41.1 %C

Chemical Formulas of Compounds

- **Formulas give the relative numbers of atoms or moles of each element in a formula unit - always a whole number ratio (the law of definite proportions).**

  NO_2 2 atoms of O for every 1 atom of N

  1 mole of NO_2 : 2 moles of O atoms to every 1 mole of N atoms

- **If we know or can determine the relative number of moles of each element in a compound, we can determine a formula for the compound.**

Types of Formulas

- **Empirical Formula**

  The formula of a compound that expresses the *smallest whole number ratio* of the atoms present.

  Ionic formula are always empirical formula

- **Molecular Formula**

  The formula that states the *actual* number of each kind of atom found in *one molecule* of the compound.

To obtain an *Empirical Formula*

1. Determine the mass in grams of each element present, if necessary.
2. Calculate the number of *moles* of each element.
3. Divide each by the smallest number of moles to obtain the *simplest whole number ratio.*
4. If whole numbers are not obtained* in step 3), multiply through by the smallest number that will give all whole numbers

* Be careful! Do not round off numbers prematurely

A sample of a brown gas, a major air pollutant, is found to contain 2.34 g N and 5.34g O. Determine a formula for this substance.

moles of N = $\frac{\text{2.34g of N}}{\text{14.01 g/mole}}$ = 0.167 moles of N

moles of O = $\frac{\text{5.34 g}}{\text{16.00 g/mole}}$ = 0.334 moles of O

Formula:

$N_{0.167}O_{0.334}$

Calculation of the Molecular Formula

A compound has an empirical formula of NO_2. The colourless liquid, used in rocket engines has a molar mass of 92.0 g/mole. What is the *molecular formula* of this substance?

Empirical Formula from % Composition

A substance has the following composition by mass: 60.80 % Na ; 28.60 % B ; 10.60 % H

What is the empirical formula of the substance?

Consider a sample size of 100 grams
This will contain 28.60 grams of B and
60.8 g Na and 10.60 grams H
Determine the number of moles of each
Determine the simplest whole number ratio