

# Quantitative Composition of Compounds

## Chapter 7

# Avogadro's Number

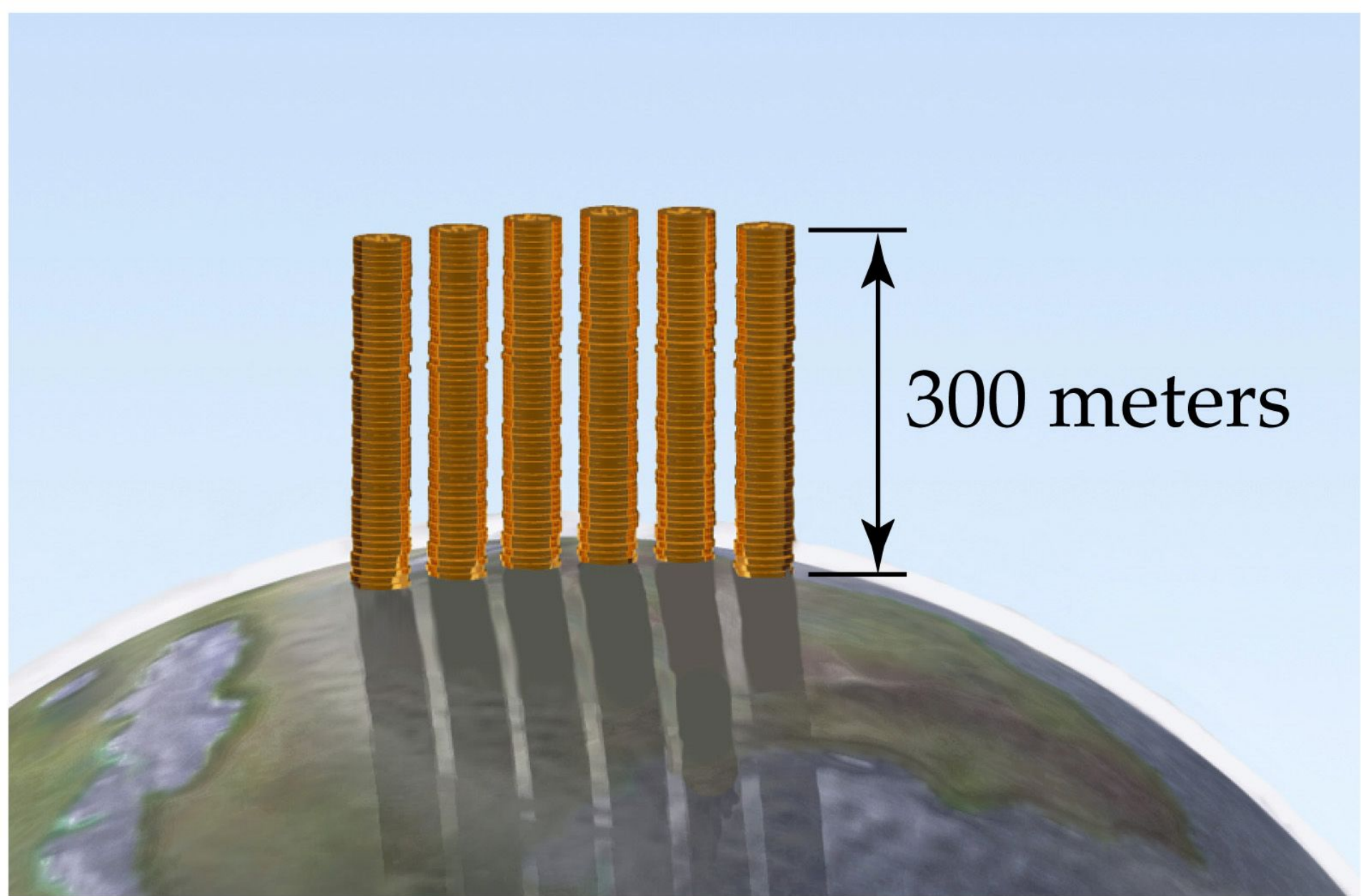
- How do we count atoms?
  - Dozens? Reams?

- 1.0079 amu = 1 atom hydrogen
- 40.078 amu = 1 atom calcium
- 55.847 amu = 1 atom iron
  
- 1.0079 g H = ????? Hydrogen atoms
- 40.078 g Ca = ??? Calcium atoms
- 55.847 g Fe = ??? Iron atoms

# Mole

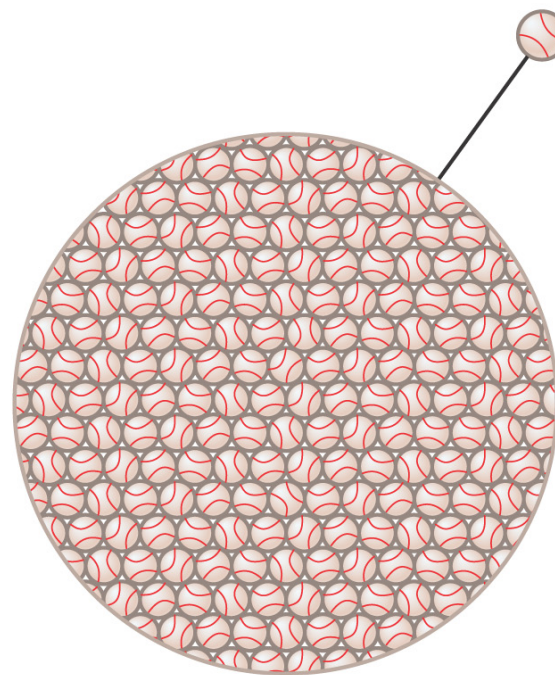
- The number of particles in the atomic mass in grams of an element (molecular mass for a compound)
- $6.022 \times 10^{23}$  particles

- An orange truck contains 5 dozen oranges, how many oranges are in the truck?
- A sand truck contains 5 moles of sand, how grains of sand are in the truck?
- An orange truck contains  $5.62 \times 10^7$  oranges. How many moles of oranges are in the truck?
- A bug truck contains 5 moles of spiders. How many moles of spider legs are in the truck?





Earth



$6.02 \times 10^{23}$

- How many atoms of platinum are in 4.21 mol of platinum?
- How many molecules of methane ( $\text{CH}_4$ ) are in 0.286 mol of methane?
- How many formula units of potassium bromide are in 0.50 mol of potassium bromide?



- Molecule - The simplest representative particle in a compound composed of nonmetals
- Formula unit - The simplest representative particle in a compound composed of ions.

- Helium (He) is a valuable gas used in industry, low temperature research, deep sea diving, and balloons. How many moles of He are in 6.46 g of He?
- Zinc (Zn) is a silvery metal that is used to form brass (with copper) and to plate iron to prevent corrosion. How many grams of Zn are there in 0.356 mol of Zn?
- Silver (Ag) is a precious metal used mainly in jewelry. What is the mass of one silver atom?

- Atomic mass – mass of an element
- Molar mass – mass of a compound  
=  $\Sigma$  atomic masses of constituent elements

(Also known as molecular mass, formula mass, molecular weight, formula weight, etc.)

# Calculating molecular (formula) masses

- KCl

- $39.09 + 35.45 = 74.54$  amu

- $C_2H_6$

- $2(12.01) + 6(1.008) = 30.08$  amu

- $Ca_3(PO_4)_2$

- $3(40.08) + 2(30.97) + 8(16.00) = 310.18$  amu

- Calculate the number of moles of carbon in 3.54 moles of methane.
- Calculate the number of moles of hydrogen in 3.54 moles of methane.
- Calculate the number of moles of methane gas( $\text{CH}_4$ ) in 3.29 grams of methane.
- Calculate the number of grams of methane in 2.54 mole of methane.

- How many atoms of oxygen are in 12 formula units of  $\text{Ca}_3(\text{PO}_4)_2$ ?
- How many formula units of calcium phosphate contain 27 atoms of Ca?
- How many phosphorous atoms will be in a sample of calcium phosphate containing 33 atoms of Ca?

Lead(II)chromate,  $\text{PbCrO}_4$ , is a yellow pigment used in paint known as chrome yellow.

- If you precipitate 45.6g of lead(II)chromate, how many moles do you precipitate?
- How many formula units of lead(II)chromate precipitate?
- How many moles of lead are there in the sample?
- How many atoms of lead are there in the sample?
- How many moles of oxygen atoms are there in the sample?
- How many atoms of oxygen are there in the sample?

- Nitric acid,  $\text{HNO}_3$ , is a colorless, corrosive liquid used in the manufacture of nitrogen fertilizers and explosives. How many atoms of O are in a 28.5 g sample of nitric acid?
- Hydrogen cyanide (HCN) is a volatile, colorless liquid with the odor of certain fruit pits (peach and cherry). The compound is highly toxic. What is the mass of  $3.14 \times 10^{19}$  molecules of HCN?



# For glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) calculate

- Molecular mass
- Number of molecules in 8.35 mol glucose.
- Number of atoms oxygen in 9.43 mol glucose.
- Number of molecules in 29.4 g glucose.
- Number of atoms of carbon in 29.4 g glucose.
- Moles of carbon in a glucose sample containing 4.22 mol hydrogen.
- Mass of hydrogen in  $3.59 \times 10^{25}$  molecules glucose.

Mass percent of Cl in  $\text{CCl}_2\text{F}_2 =$



mass of 2 mole Cl

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mass of one mole  $\text{CCl}_2\text{F}_2$   $\times 100\%$



- Sodium nitrite ( $\text{NaNO}_2$ ) is a food preservative that is added to ham, hot dogs, and bologna. In recent years its use has come under attack because it has been shown to lead to cancer in certain animals. Calculate the percent composition by mass of Na, N and O in  $\text{NaNO}_2$ .

- Calculate the percent composition of stearic acid,  $C_{18}H_{36}O_2$ , a principle component of saturated fat.

# Empirical Formula

- The formula for a compound that is determined experimentally.
- A formula that represents the lowest integral ration of atoms of the elements in a compound.
- The simplest formula for a compound.

compound	molecular formula	empirical formula
hydrazine	$\text{N}_2\text{H}_4$	$\text{NH}_2$
peroxide	$\text{H}_2\text{O}_2$	$\text{HO}$
water	$\text{H}_2\text{O}$	$\text{H}_2\text{O}$
glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	$\text{CH}_2\text{O}$

- The major air pollutant in coal burning countries is a colorless, pungent gaseous compound containing only sulfur and oxygen. Chemical analysis of a 1.078 g sample of this gas showed that it contained 0.540 g of S and 0.538 g of O. What is the empirical formula of this compound?

# Empirical Formula from % Composition

- Polystyrene, a well-known plastic, is composed of 92.26% carbon and 7.74% hydrogen.
  - How many grams of each element are in 100 grams of polystyrene?
  - How many moles of each element are in 100 g of polystyrene?
  - What is the mole ratio in integers?
  - What is the empirical formula?



- What is the empirical formula? Ascorbic acid (vitamin C) cures scurvy and may help prevent the common cold. It is composed of 40.92% C, 4.58% H, and 54.50% O. Determine the empirical formula of vitamin C.

- TNT, trinitrotoluene, is composed of 37.01% carbon, 2.22% hydrogen, 18.50% nitrogen, and 42.26% oxygen. Determine its empirical formula.

# Converting Empirical Formulas to Molecular Formulas

- Determine the molar mass of empirical formula
- Determine ratio of molar mass compound to molar mass empirical formula.
  - $(MM \text{ actual} / MM \text{ empirical formula})$
- Determine number of units of empirical formula in overall compound.

# Converting Empirical Formulas to Molecular Formulas

- The empirical formula of acetic acid (the important ingredient of vinegar) is  $\text{CH}_2\text{O}$ . What is the molecular formula of the compound, given that its Molar mass is around 60 g/mol?

- A compound containing only sulfur and nitrogen is 69.6% S by mass; the molar mass is 184 g/mol. What are the empirical and molecular formulas of the compound?

- Fluorocarbonyl hypofluorite was recently isolated, and analysis showed it to be 14.6% C, 39.0% O, and 46.3% F. If the molar mass of the compound is 82 g/mol determine the empirical and the molecular formula for the compound.

# Additional mole practice

- What is the mass of  $3.554 \times 10^{25}$  atoms of selenium? (4660. g Se)
- How many atoms are in 2.500 g of platinum? ( $7.717 \times 10^{21}$  atom Pt)
- What is the mass of one atom of lead(Pb)? ( $3.44 \times 10^{-22}$  g Pb)

# Additional mole practice

- Calculate the number of moles in 200 mg of a (1 carat) diamond (C). (0.0167 mol C)
- How many moles of formaldehyde (CH<sub>2</sub>O MM=30.03) are present in 65.0 g of formaldehyde? (2.16 mol CH<sub>2</sub>O)
- What is the mass of 1 atom of gold?  
(3.27 x 10<sup>-22</sup> g Au)



- Methane ( $\text{CH}_4$ ) is the principle component of natural gas. How many moles of  $\text{CH}_4$  have a mass of 6.07 g? (0.378 mol  $\text{CH}_4$ )
- Boron(B) is a rare nonmetallic element. It is almost as hard as diamond, which is the hardest substance known. How many atoms are in 0.500g of B? ( $2.79 \times 10^{22}$  atom B)
- Hydrogen peroxide,  $\text{H}_2\text{O}_2$ , is a colorless liquid. A concentrated solution of it is used as a source as oxygen for rocket propellant fuels. What is the mass of 0.909 mol of  $\text{H}_2\text{O}_2$ ? (29.9 g  $\text{H}_2\text{O}_2$ )

# Additional mole practice

- The artificial sweetener Nutrasweet is the compound aspartame, with the molecular formula  $C_{14}H_{18}N_2O_5$ . What is the molecular mass of aspartame? (294.30 amu)
- What is the mass of 0.362 mol of aspartame? (107 g)
- How many molecules of aspartame are there in 2.55 grams of aspartame? ( $5.22 \times 10^{21}$  molecules)
- How many atoms of oxygen are there in 2.55 grams of aspartame? ( $2.61 \times 10^{22}$  atom O)

- Male silkworm moths are attracted to an organic sex attractant with a molecular mass of 238. If  $4.10 \times 10^{-6}$  g of this attractant is released into a room, how many molecules of attractant are in the room? (1.04 x 10<sup>16</sup> molecules)
- How many atoms of carbon are present in 1.00 g of CH<sub>4</sub>O? (1.88 x 10<sup>22</sup> atoms C)

- How many moles of water contain  $5.23 \times 10^{24}$  molecules of water? (8.68 mol water)
- Aluminum (Al) is the third most abundant element in the earth's crust. It is used in transmission lines, aircraft, and beverage cans. What is the mass in grams of  $1.000 \times 10^{12}$  (one trillion) Al atoms? ( $4.48 \times 10^{-11}$  g Al)
- How many moles of nitrogen are in a sample of oxalamide ( $\text{C}_2\text{H}_4\text{N}_2\text{O}_2$ ) that contains 6.4 moles of hydrogen? (3.2 mol  $\text{N}_2$ )

- Adipic acid is used in the manufacture of nylon. The composition of the acid is 49.3% C, 6.9% H, and 43.8% O (by mass), and the molecular weight is 146 amu. What is the molecular formula?

- Empirical formula ( $\text{C}_3\text{H}_5\text{O}_2$ )
- Molecular formula ( $\text{C}_6\text{H}_{10}\text{O}_4$ )

- What is the empirical formula for ibuprofen, a headache remedy?  
Ibuprofen contains 75.69% C, 15.51% O and 8.80% H.

- $(C_{13}H_{18}O_2)$

- Phenol, commonly known as carbolic acid, was used by Joseph Lister as an antiseptic for surgery in 1865. Its principal use today is in the manufacture of phenolic resins and plastics. Combustion of 5.23 g of phenol yields 14.7 g CO<sub>2</sub> and 3.01 g H<sub>2</sub>O. Phenol contains only C, H, and O. What is the empirical formula of phenol?

- (76.5% C, 6.44% H, 17.1% O, C<sub>6</sub>H<sub>6</sub>O)