6.4: Molar Mass

Learning Objectives

- Calculate the molar mass of an element or compound.
- Determine the number of atoms, formula units, or molecules in one mole of a substance.

Molar Mass of an Element

According to the periodic table, the atomic mass of aluminum is 26.98 amu, copper is 63.55 amu, and carbon is 12.01 amu. Since 1 amu is only 1.674×10^{-24} g, these masses would be way too small to measure on ordinary laboratory equipment. However, if we have 6.022×10^{23} atoms, or 1 mole of each of these elements, we would have 26.98 g Al, 63.55 g Cu, and 12.01 g C. In other words, one mole of any element will have a mass that is numerically equal to its atomic mass and expressed in units of grams. This mass is called the **molar mass**.

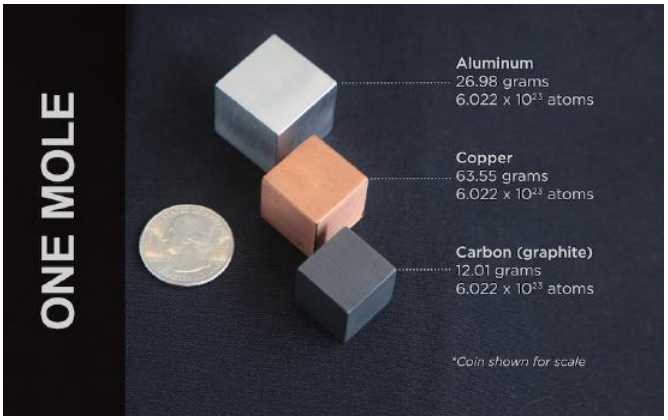

Figure 6.4.1: One mole of aluminum, copper, and carbon. (R. Press/N. Hanacek/NIST)

We might find these easier to use if the relationships are written out like this (recall that mole is abbreviated as mol):

- 1 mol Al = 26.98 g Al = 6.022×10^{23} atoms Al
- 1 mol Cu = 63.55 g Cu = 6.022×10^{23} atoms Cu
- 1 mol C = 12.01 g C = 6.022×10^{23} atoms C

Molar Mass of a Compound

One mole of any compound will have a mass that is numerically equal to its molecular mass or formula mass and expressed in units of grams. This mass is also called the **molar mass**.

In Section 6.2, the formula mass for NaCl was calculated to be 58.44 amu. This means that the molar mass of NaCl is 58.44 g and it will contain 6.022×10^{23} formula units of NaCl, or one mole of NaCl. We also calculated the molecular mass for $C_{12}H_{22}O_{11}$ to be 342.3 amu. This means that the molar mass of $C_{12}H_{22}O_{11}$ is 342.3 g and it will contain 6.022×10^{23} molecules of $C_{12}H_{22}O_{11}$, or one mole of $C_{12}H_{22}O_{11}$.

We might find these easier to use if the relationships are written out like this (recall that mole is abbreviated as mol):

- 1 mol NaCl = 58.44 g NaCl = 6.022×10^{23} formula units NaCl
- 1 mol $C_{12}H_{22}O_{11}$ = 342.3 g $C_{12}H_{22}O_{11}$ = 6.022×10^{23} molecules $C_{12}H_{22}O_{11}$

Figure 6.4.2: One mole table salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$). (Lance S. Lund)

Summary of Relevant Terminology

Keeping the terminology straight (see Table 6.4.1) is essential to understanding the mole concept and correctly performing mole calculations.

Table 6.4.1: Relevant Terminology

Substance	Fundamental Unit	Atomic, Molecular, or Formula Mass	Molar Mass
aluminum (Al)	atom	atomic mass = 26.98 amu	molar mass = 26.98 g
sucrose ($C_{12}H_{22}O_{11}$)	molecule	molecular mass = 342.3 amu	molar mass = 342.3 g
sodium chloride (NaCl)	formula unit	formula mass = 58.44 amu	molar mass = 58.44 g

✅ Example 6.4.1

Find the molar mass of each element. Then determine how many atoms are contained in the calculated molar mass. (Periodic Table)

A. K
B. Pb

Solution

A. Since the atomic mass of K is 39.10 amu, it has a molar mass of 39.10 g. There are 6.022×10^{23} atoms K, which is also 1 mole of K, in 39.10 g K.
B. Since the atomic mass of Pb is 207.2 amu, it has a molar mass of 207.2 g. There are 6.022×10^{23} atoms Pb, which is also 1 mole of Pb, in 207.2 g Pb.

✅ Example 6.4.2

Calculate the molar mass for each compound. Then determine how many formula units or molecules are contained in the calculated molar mass. (Periodic Table)

A. H_2O
B. $Ca(NO_3)_2$

Solution

	H_2O	$Ca(NO_3)_2$
1. Determine how many atoms of each element are present in the compound. Multiply the number of atoms of each element by its atomic mass and express in units of grams.	2 H = 2(1.008) = 2.016 g H 1 O = 1(16.00) = 16.00 g O	1 Ca = 1(40.08) = 40.08 g Ca 2 N = 2(14.01) = 28.02 g N 6 O = 6(16.00) = 96.00 g O
2. Sum the masses to find the molar mass.	molar mass = 18.02 g	molar mass = 164.10 g
3. Determine whether the compound is ionic or molecular.	H_2O is a molecular compound.	$Ca(NO_3)_2$ is an ionic compound.
4. Formula units or molecules contained in the molar mass.	6.022×10^{23} molecules H_2O, which is also 1 mol H_2O, are in 18.02 g H_2O.	6.022×10^{23} formula units $Ca(NO_3)_2$, which is also 1 mol $Ca(NO_3)_2$, are in 164.10 g $Ca(NO_3)_2$.

Exercise 6.4.1

Calculate the molar mass for each substance. Then show the number of grams in 1 mol of the substance, as well as the number of atoms, molecules, or formula units that are contained 1 mol of the substance. (Periodic Table)

A. Na
B. Na_2S
C. N_2O

Answer A

molar mass = 22.99 g; Therefore, 1 mol Na = 22.99 g Na = 6.022×10^{23} atoms Na.

Answer B

molar mass = 78.05 g; Therefore, 1 mol Na_2S = 78.05 g Na_2S = 6.022×10^{23} formula units Na_2S.

Answer C

molar mass = 44.02 g; Therefore, 1 mol N_2O = 44.02 g N_2O = 6.022×10^{23} molecules N_2O.

Summary

- A mole is defined as exactly $6.02214076 \times 10^{23}$ particles, e.g., atoms, molecules, ions or electrons.
- There are $6.02214076 \times 10^{23}$ particles in 1 mole. This number is called Avogadro's number.
- The molar mass of an element can be found by referring to the atomic mass on a periodic table with units of grams.
- The molar mass of compounds can be determined by the molar masses of the atoms in their formulas.