

**Formula Mass**

A formula mass is the sum of the atomic masses of all the atoms represented in the chemical formula of a substance. (The term “formula mass” can be used for both ionic and molecular compounds.) Formula masses are similar to the atomic masses from which they are calculated; both are relative masses based on the relative mass scaled to carbon-12. Formula masses are calculated by simply adding the atomic masses of the elements in the compound—count each atomic mass as many times as the symbol for the elements occurs in the chemical formula.

For example: What is the formula mass for **(a)** tin (II) fluoride,  $\text{SnF}_2$ , and **(b)** urea,  $(\text{NH}_2)_2\text{CO}$ ?

**(a)** One formula unit of  $\text{SnF}_2$  contains 1 Sn atom and 2 F atoms

$$1 \text{ atom Sn} \times \left( \frac{118.71 \text{ amu}}{1 \text{ atom Sn}} \right) = 118.71 \text{ amu}$$

$$2 \text{ atom F} \times \left( \frac{19.00 \text{ amu}}{1 \text{ atom F}} \right) = \underline{38.00 \text{ amu}}$$

$$\text{Formula mass} = 156.71 \text{ amu}$$

**(b)** The chemical formula for urea contains parentheses. In the formula  $(\text{NH}_2)_2\text{CO}$ , the subscript 2 outside the parentheses affects both of the symbols inside the parentheses. One molecule of urea has 2 N atoms, 4 H atoms, 1 C atom, and 1 O atom.

$$\text{N} \quad 2 \times 14.01 \text{ amu} = 28.02 \text{ amu}$$

$$\text{H} \quad 4 \times 1.01 \text{ amu} = 4.04 \text{ amu}$$

$$\text{C} \quad 1 \times 12.01 \text{ amu} = 12.01 \text{ amu}$$

$$\text{O} \quad 1 \times 16.00 \text{ amu} = \underline{16.00 \text{ amu}}$$

$$(\text{NH}_2)_2\text{CO} = 60.07 \text{ amu}$$

**Molar Mass**

Atoms and molecules are so small that we are seldom able to deal with one of them at a time. When we weight even a very small amount of an element or compound, we are dealing with huge numbers of atoms or molecules.

Chemist resolved this problem by determining the exact number of carbon-12 atoms in exactly 12 g of carbon-12. There are exactly  $6.022 \times 10^{23}$  atoms of carbon-12 in exactly 12 g of carbon-12.

The number  $6.022 \times 10^{23}$  is known as Avogadro's number. Avogadro's number is an extremely large number and is very inconvenient to use. The counting unit called the mole, abbreviated mol, is used to represent  $6.022 \times 10^{23}$  objects.

The molar mass of any substance is the mass of one mole of any substance expressed in grams.

Molar mass also may be written in units as grams per mole,  $\frac{g}{mol}$ , that is the mass of the substance per mole of the substance.

For example: What is the molar mass for **(a)** tin (II) fluoride,  $\text{SnF}_2$ , and **(b)** urea,  $(\text{NH}_2)_2\text{CO}$ ?

**(a)** One mole of  $\text{SnF}_2$  contains 1 mole of Sn atom and 2 moles of F atoms

$$1 \text{ mol Sn} \times \left( \frac{118.71 \text{ g}}{1 \text{ mol Sn}} \right) = 118.71 \text{ g}$$

$$2 \text{ mol F} \times \left( \frac{19.00 \text{ g}}{1 \text{ g F}} \right) = \underline{38.00 \text{ g}}$$

$$1 \text{ mol SnF}_2 = 156.71 \text{ g}$$

$$\text{Molar mass of SnF}_2 = 156.71 \frac{\text{g}}{\text{mol}}$$

**(b)** One mole of urea has 2 mol N atoms, 4 mol H atoms, 1 mol C atom, and 1 mol O atom.

$$\text{N} \quad 2 \times 14.01 = 28.02 \text{ g}$$

$$\text{H} \quad 4 \times 1.01 = 4.04 \text{ g}$$

$$\text{C} \quad 1 \times 12.01 = 12.01 \text{ g}$$

$$\text{O} \quad 1 \times 16.00 = \underline{16.00 \text{ g}}$$

$$1 \text{ mol } (\text{NH}_2)_2\text{CO} = 60.07 \text{ g}$$

$$\text{Molar mass of urea} = 60.07 \frac{\text{g}}{\text{mol}}$$

1. Determine the molar mass of the following compounds.
  - a. Methane,  $\text{CH}_4$

f. Methyl alcohol,  $\text{CH}_3\text{OH}$

j. Ammonium dichromate,  $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$

**Mole-Mass Conversions**

The molar mass of a substance is the conversion factor that allows us to convert between the mass of a substance (**in grams**) and the number of moles of that substance that are present. (Remember that one mole contains  $6.022 \times 10^{23}$  atoms, ions, molecules or formula units.)

**To convert from grams to moles**

Take the mass and divide by the molar mass of the substance.

For example: How many moles of  $H_2$  are present in 14.7 g of  $H_2$ ?

$$14.7g H_2 \left( \frac{1 mol H_2}{2.016g H_2} \right) = 7.29mol H_2$$

**To convert from moles to grams**

Take the number of moles and multiply by the molar mass of the substance.

For example: How many mg of  $O_2$  are present in 0.22 mol of  $O_2$ ?

$$0.22mol O_2 \left( \frac{32.00g O_2}{1 mol O_2} \right) \left( \frac{1000mg}{1g} \right) = 7.0 \times 10^3 mg O_2$$

1. Find the mass in grams for each of the following:
  - a. 4.86 moles of  $B_2O_3$

d. 19.2 mol ammonium dichromate (use answer to 1j on A32)

e. 0.136 mol of  $C_6H_{12}O_6$

2. Find the number of moles in each of the following (make sure your formula is correct):
- 3.75 g of aluminum hydroxide

b. 0.272 kg of magnesium nitride

c. 42.42 g of argon

3. Find the number of atoms, formula units, or molecules in each of the following:
- molecules of glucose,  $C_6H_{12}O_6$ , in 0.136 mol of  $C_6H_{12}O_6$

c. atoms of helium in 7.85 g of He

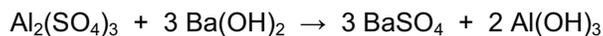
d. atoms of iodine in 229.6 mg of iodine,  $I_2$ , molecules (tricky)



**Stoichiometry**

Just as the subscripts in the formula of a compound tell us how the quantities of atoms are related within a molecule, the stoichiometric coefficients in a balanced reaction tell us about how the quantities of reactant and product molecules (or formula units) are related to each other. These can also be setup as ratios or equalities to allow us to solve chemical calculations.

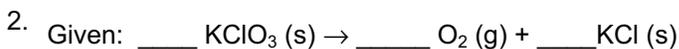
For example, in the reaction:



The following 12 mole-mole relationships can be established:

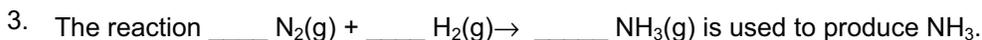
$$\frac{1 \text{ mol Al}_2(\text{SO}_4)_3}{3 \text{ mol Ba}(\text{OH})_2} \quad \frac{1 \text{ mol Al}_2(\text{SO}_4)_3}{3 \text{ mol BaSO}_4} \quad \frac{1 \text{ mol Al}_2(\text{SO}_4)_3}{2 \text{ mol Al}(\text{OH})_3} \quad \frac{3 \text{ mol Ba}(\text{OH})_2}{3 \text{ mol BaSO}_4} \quad \frac{3 \text{ mol Ba}(\text{OH})_2}{2 \text{ mol Al}(\text{OH})_3} \quad \frac{3 \text{ mol BaSO}_4}{2 \text{ mol Al}(\text{OH})_3}$$

Plus the 6  
reciprocals



How many moles of KCl is produced when 12.5 mol  $\text{KClO}_3$  is decomposed?

How many moles of  $\text{O}_2$  is produced when 12.5 mol  $\text{KClO}_3$  is decomposed?



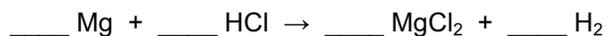
How many moles of  $\text{H}_2(\text{g})$  are required to produce 2.50 g of  $\text{NH}_3(\text{g})$ ?

How many grams of  $\text{N}_2(\text{g})$  are required to produce 2.50 g of  $\text{NH}_3(\text{g})$ ?

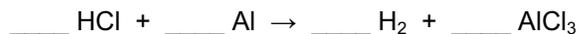
5. Given:  $\underline{\hspace{1cm}} \text{C}_5\text{H}_{12}(\text{l}) + \underline{\hspace{1cm}} \text{O}_2(\text{g}) \rightarrow \underline{\hspace{1cm}} \text{CO}_2(\text{g}) + \underline{\hspace{1cm}} \text{H}_2\text{O}(\text{g})$  Calculate the grams of  $\text{O}_2(\text{g})$  gas needed to react with 2.00 mol of  $\text{C}_5\text{H}_{12}$ ?

6. Given:  $\underline{\hspace{1cm}} \text{N}_2(\text{g}) + \underline{\hspace{1cm}} \text{O}_2(\text{g}) \rightarrow \underline{\hspace{1cm}} \text{N}_2\text{O}_5(\text{g})$  How many moles of  $\text{O}_2(\text{g})$  are needed to react with 1.250 moles of  $\text{N}_2(\text{g})$ .

7. How many moles of  $\text{MgCl}_2$  can be produced from 16.2 moles of  $\text{HCl}$  based on the following reaction?



8. How many moles of  $\text{Al}$  would be required to produce 18.0 mol of  $\text{H}_2$  according to the following unbalanced equation?



9. Consider the reaction:  $\underline{\hspace{1cm}} \text{S}(\text{s}) + \underline{\hspace{1cm}} \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \underline{\hspace{1cm}} \text{SO}_2(\text{g}) + \underline{\hspace{1cm}} \text{H}_2\text{O}(\text{l})$   
4.80 g of sulfur reacts with excess sulfuric acid, what mass of water will be produced?