Molecular Mass

Molecular Mass

synonymous with molar mass and molecular weight

is the sum of the atomic masses of all the atoms in a molecule

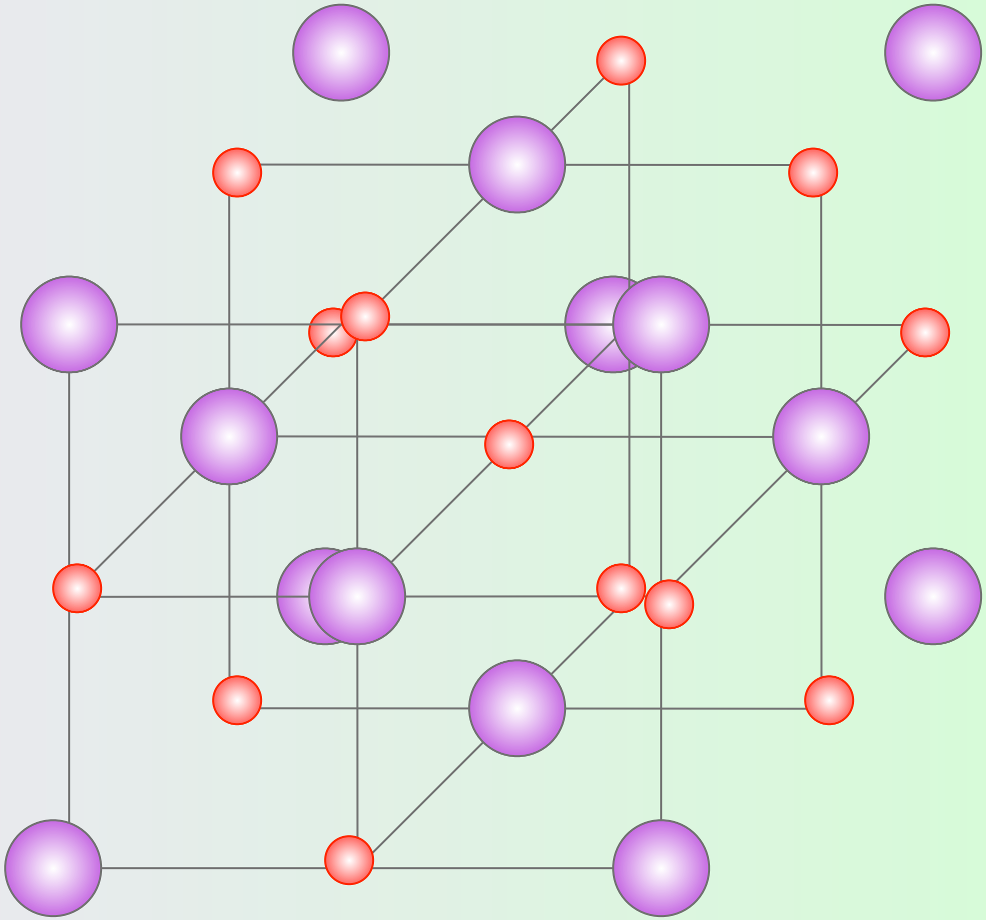
the mass in grams of one mole of a compound

Formula Mass

not all compounds are molecular

calculated exactly the same way as molecular mass

Solid structure of NaCl



pg. 322 problem 25

Determine the molar mass of $Sr(NO_3)_2$.

1 mol Sr = 87.62g

2 mol N = 2(14.00 g)

6 mol O = 6(16.00 g)

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1 mol $Sr(NO_3)_2$ = 211.62 g

pg. 323 problem 27

What is the mass in grams of 3.25 mol sulfuric acid (H_2SO_4).

1 mol S = 32.07g

2 mol H = 2(1.00 g)

4 mol O = 4(16.00 g)

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1 mol H_2SO_4 = 98.07 g

$$3.25\ \cancel{\text{m}}\text{ol } H_2SO_4 \times \frac{98.07\text{ g } H_2SO_4}{1\ \cancel{\text{m}}\text{ol } H_2SO_4} = 319\text{ g } H_2SO_4$$

pg. 324 problem 30a

Determine the number of moles present in 22.6 g $AgNO_3$.

1 mol Ag = 107.87g

1 mol N = 14.00 g

3 mol O = 3(16.00 g)

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1 mol $AgNO_3$ = 169.87 g

$$22.6\ \cancel{g}\ AgNO_3 \times \frac{1\ mol\ AgNO_3}{169.87\ \cancel{g}\ AgNO_3} = 0.133\ mol\ AgNO_3$$

pg. 326 problem 31a

A sample of silver chromate (Ag_2CrO_4) has a mass of 25.8 g.

a. How many Ag^+ ions are present?

2 mol Ag	= 107.87g
1 mol Cr	= 52.00 g
4 mol O	= 4(16.00 g)
1 mol Ag_2CrO_4	= 331.74 g

$$25.8\ \cancel{g}\ Ag_2CrO_4 \times \frac{1\ \cancel{mol}\ Ag_2CrO_4}{331.74\ \cancel{g}\ Ag_2CrO_4} \times \frac{2\ \cancel{mol}\ Ag^+}{1\ \cancel{mol}\ Ag_2CrO_4}$$

$$\times \frac{6.02 \times 10^{23}\ \text{ions}\ Ag^+}{1\ \cancel{mol}\ Ag^+} = 9.36 \times 10^{22}\ \text{ions}\ Ag^+$$

pg. 326 problem 31b

A sample of silver chromate (Ag_2CrO_4) has a mass of 25.8 g.

b. How many CrO_4^{2-} ions are present?

2 mol Ag =	107.87g
1 mol Cr =	52.00 g
4 mol O =	4(16.00 g)
1 mol Ag_2CrO_4 =	331.74 g

$$25.8\ \cancel{g}\ Ag_2CrO_4 \times \frac{1\ \cancel{mol}\ Ag_2CrO_4}{331.74\ \cancel{g}\ Ag_2CrO_4} \times \frac{1\ \cancel{mol}\ CrO_4^{2-}}{1\ \cancel{mol}\ Ag_2CrO_4}$$

$$\times \frac{6.02 \times 10^{23}\ \text{ions}\ CrO_4^{2-}}{1\ \cancel{mol}\ CrO_4^{2-}} = 4.68 \times 10^{22}\ \text{atoms}\ CrO_4^{2-}$$

pg. 326 problem 31c

c. What is the mass in grams of one formula unit of silver chromate (Ag_2CrO_4).

2 mol Ag =	107.87g
1 mol Cr =	52.00 g
4 mol O =	4(16.00 g)
1 mol Ag_2CrO_4 =	331.74 g

$$\frac{331.74 \text{ g } Ag_2CrO_4}{1 \cancel{\text{mol}} \ Ag_2CrO_4} \times \frac{1 \cancel{\text{mol}} \ Ag_2CrO_4}{6.02 \times 10^{23} \text{ f.u. } Ag_2CrO_4} = \frac{5.51 \times 10^{-22} \text{ g } Ag_2CrO_4}{\text{f.u. } Ag_2CrO_4}$$

Percent Composition of Compounds

Percent composition is the percent by mass of each element the compound contains.

Obtained by dividing the mass of each element in one mole of the compound by the molar mass of the compound and multiplying by 100%

Example 45

Calculate the percent composition by mass of H,P and O for one mole of phosphoric acid (H_3PO_4)

Molar mass = 3(1.008g) + 30.97g + 4(16.00) = 97.99

Molar mass = 3(1.008g) + 30.97g + 4(16.00) = 97.99

$$\%H = \frac{3(1.008g)}{97.99g} \times 100\% = 3.086\%$$

$$\%P = \frac{30.97g}{97.99g} \times 100\% = 31.61\%$$

$$\%O = \frac{4(16.00)}{97.99g} \times 100\% = 65.31\%$$

Example

A sample of a compound containing carbon and oxygen had a mass of 88g. Of this sample 24g was carbon, 64g was oxygen. What is the percent composition of this compound.

$$\%\text{carbon} = \frac{24\text{g}}{88\text{g}} \times 100\% = 27\%$$

$$\%\text{oxygen} = \frac{64\text{g}}{88\text{g}} \times 100\% = 73\%$$

Determining Formula

Levels of Structure

Elemental Composition

Empirical Formula

Molecular Formula

Constitution

Configuration

Conformation

Elemental Composition

Examples:

Formaldehyde	Glucose
C: 40.00%	C: 40.00%
H: 6.73%	H: 6.73%
O: 53.27%	O: 53.27%

Levels of Structure

Elemental Composition √

Empirical Formula

Molecular Formula

Constitution

Configuration

Conformation

Empirical Formula

The empirical formula tells us which elements are present and the simplest whole-number ratio of their atoms.

Empirical Formula

Examples: Formaldehyde and Glucose

Elemental Composition

C:	**40.00%**	**40.00 g**
H:	**6.73%**	**6.73 g**
O:	**53.27%**	**53.27 g**

assume a 100g sample

calculate atom ratios by dividing by atomic weight

Calculating Empirical Formula

$$\textbf{C:}\quad 40.00\ \cancel{g} \times \frac{1\ \text{mol}}{12.01\ \cancel{g}} = 3.33\ \text{mol}$$

$$\textbf{H:}\quad 6.73\ \cancel{g} \times \frac{1\ \text{mol}}{1.00\ \cancel{g}} = 6.73\ \text{mol}$$

$$\textbf{O:}\quad 53.27\ \cancel{g} \times \frac{1\ \text{mol}}{16.0\ \cancel{g}} = 3.33\ \text{mol}$$

100 g

Empirical Formula

Examples: Formaldehyde and Glucose

Elemental Composition

C:	40.00%	40.00 g	3.33 mol
H:	6.73%	6.73 g	6.73 mol
O:	53.27%	53.27 g	3.33 mol

assume a 100g sample

calculate atom ratios by dividing by atomic weight

determine the smallest whole number ratio by dividing by the smallest molar value

Calculating Empirical Formula

$$\text{C: } 40.00\,\cancel{g} \times \frac{1\text{ mol}}{12.01\,\cancel{g}} = \frac{3.33\text{ mol}}{3.33\text{ mol}} = 1.00$$

$$\text{H: } 6.73\,\cancel{g} \times \frac{1\text{ mol}}{1.00\,\cancel{g}} = \frac{6.73\text{ mol}}{3.33\text{ mol}} = 2.02$$

$$\text{O: } \frac{53.27\,\cancel{g}}{100\text{ g}} \times \frac{1\text{ mol}}{16.0\,\cancel{g}} = \frac{3.33\text{ mol}}{3.33\text{ mol}} = 1.00$$

Empirical Formula

Examples: Formaldehyde and Glucose

Elemental Composition

C:	**40.00%**	**40.00 g**	**3.33 mol**	**1**
H:	**6.73%**	**6.73 g**	**6.73 mol**	**2**
O:	**53.27%**	**53.27 g**	**3.33 mol**	**1**

Empirical Formula: CH_2O

Example

A 1.723 g sample of aluminum oxide (which consists of aluminum and oxygen only) contains 0.912g of Al. Determine the empirical formula of the compound.

1.723 g sample - 0.912 g Al = 0.811 g O

$$\boxed{Al_2O_3}$$

$$0.912 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = \frac{0.0338 \text{ mol}}{0.0338 \text{ mol}} = 1.0 \times 2 = \boxed{2}$$

$$0.811 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = \frac{0.0507 \text{ mol}}{0.0338 \text{ mol}} = 1.5 \times 2 = \boxed{3}$$

Levels of Structure

Elemental Composition √

Empirical Formula √

Molecular Formula

Constitution

Configuration

Conformation

Molecular Formula

determined from empirical formula and experimentally determined molecular mass

Compound	Empirical Formula	Molar mass
formaldehyde	CH_2O	30
glucose	CH_2O	180

Calculation of empirical mass

1 mol C = 12.01 g

2 mol H = 2 x 1.016 g

1 mol O = 16.00g

30.026g

Molecular mass

glucose $\frac{180g}{30g}$ **= 6**

Empirical mass

formaldehyde $\frac{30g}{30g}$ **= 1**

Molecular Formula

determined from empirical formula and experimentally determined molecular mass

Compound	Empirical Formula	Molar mass	Molecular formula
formaldehyde	CH_2O	30	CH_2O
glucose	CH_2O	180	$C_6H_{12}O_6$

Elemental Composition

Example:

Lysine

C: 49.20%

H: 9.66%

N: 19.20%

O: 21.94%

Levels of Structure

Elemental Composition √

Empirical Formula

Molecular Formula

Constitution

Configuration

Conformation

Elemental Formula

Example:

Lysine

C:	**49.20%**	**49.20 g**
H:	**9.66%**	**9.66 g**
N:	**19.20%**	**19.20 g**
O:	**21.94%**	**21.94 g**

assume a 100-g sample

calculate atom ratios by dividing by atomic weight

determine smallest whole-number ratio by dividing by smallest number

$$49.20\text{ g C} \times \frac{1\text{ mol}}{12\text{g}} = \frac{4.10\text{ mol}}{1.37\text{ mol}} = 3$$

$$9.66\text{ g H} \times \frac{1\text{ mol}}{1.0\text{g}} = \frac{9.58\text{ mol}}{1.37\text{ mol}} = 7$$

$$19.20\text{ g N} \times \frac{1\text{ mol}}{14.0\text{g}} = \frac{1.37\text{ mol}}{1.37\text{ mol}} = 1$$

$$21.94\text{ g O} \times \frac{1\text{ mol}}{16.0\text{g}} = \frac{1.37\text{ mol}}{1.37\text{ mol}} = 1$$

Elemental Formula (cont'd)

Example:

Lysine

C:	**4.10 mol C atoms**	**3**
H:	**9.58 mol H atoms**	**7**
N:	**1.37 mol N atoms**	**1**
O:	**1.37 mol O atoms**	**1**

determine smallest whole-number ratio by dividing by smallest number (1.37 mol)

$\mathbf{C_3H_7ON}$

Levels of Structure

Elemental Composition √

Empirical Formula √

Molecular Formula

Constitution

Configuration

Conformation

Molecular Formula

determined from empirical formula and molar mass

Compound	Empirical Formula	Molar mass	Molecular formula
lysine	C_3H_7ON	~150	$C_6H_{14}O_2N_2$

$$\frac{150\text{g}}{73\text{g}} = 2$$

Example

Write the empirical formulas for the following molecules: (a) acetylene (C_2H_2), (b) dinitrogen tetroxide (N_2O_4), (c) glucose ($C_6H_{12}O_6$), diiodine pentoxide (I_2O_5).

This problem is not realistic. Molecular formulas are derived from empirical formulas, not vice versa. Empirical formulas come from experiment.

Example

Calculate the number of moles of chloroform ($CHCl_3$) in 198 g of chloroform.

Molecular mass of chloroform:

1 mol C = 12.01 g

1 mol H = 1.008 g

3 mol Cl = 3(35.46 g) = 106.38 g

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1 mol $CHCl_3$ = 119.4 g

$$198\ \cancel{g}\ CHCl_3 \times \frac{1\ \text{mol}\ CHCl_3}{119.4\ \cancel{g}\ CHCl_3} = 1.66\ \text{mol}\ CHCl_3$$

Example

Caffeine contains 49.48% carbon, 5.15% hydrogen, 28.87% nitrogen, and 16.49% oxygen by mass and has a molar mass of 194.2g. Determine the molecular formula formula of caffeine

Example

First determine the mass of each element in one mole of caffeine

$$\frac{49.48\text{g C}}{100\text{g caffeine}} \times \frac{194.2\text{g caffeine}}{1\text{ mol}} = \frac{96.09\text{g C}}{1\text{ mol caffeine}}$$

$$\frac{5.15\text{g H}}{100\text{g caffeine}} \times \frac{194.2\text{g caffeine}}{1\text{ mol}} = \frac{10.0\text{g H}}{1\text{ mol caffeine}}$$

$$\frac{28.87\text{g N}}{100\text{g caffeine}} \times \frac{194.2\text{g caffeine}}{1\text{ mol}} = \frac{56.07\text{g N}}{1\text{ mol caffeine}}$$

$$\frac{16.49\text{g O}}{100\text{g caffeine}} \times \frac{194.2\text{g caffeine}}{1\text{ mol}} = \frac{32.02\text{g O}}{1\text{ mol caffeine}}$$

Example

$C_8H_{10}N_4O_2$

then convert to moles

$$\frac{96.09\text{g C}}{1\text{ mol caffeine}} \times \frac{1\text{ mol C}}{12.011\text{g C}} = \frac{8.00\text{ mol C}}{1\text{ mol caffeine}}$$

$$\frac{10.0\text{g H}}{1\text{ mol caffeine}} \times \frac{1\text{ mol H}}{1.008\text{g H}} = \frac{9.92\text{ mol H}}{1\text{ mol caffeine}}$$

$$\frac{56.07\text{g N}}{1\text{ mol caffeine}} \times \frac{1\text{ mol N}}{14.01\text{g N}} = \frac{4.00\text{ mol N}}{1\text{ mol caffeine}}$$

$$\frac{32.02\text{g O}}{1\text{ mol caffeine}} \times \frac{1\text{ mol O}}{16.00\text{g O}} = \frac{2.00\text{ mol O}}{1\text{ mol caffeine}}$$