Chemistry 11

The Mole V

Name:
Date:
Block:

1. **Empirical Formula**
2. **Percent Composition**

Empirical Formula

Molecular Formula: Identifies the # of each type of atom

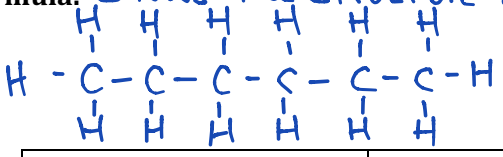
Ex: hexane C_6H_{14}

Empirical Formula: the simplest whole # ratio of atoms of each element

Ex: hexane C_3H_7

Structural Formula: Shows the structure of the molecule

Ex:



Molecular Formula	Empirical Formula
P_4O_{10} ÷2	P_2O_5
$C_{10}H_{22}$ ÷2	C_5H_{11}
$C_6H_{18}O_3$ ÷3	C_2H_6O
$C_5H_{12}O$	$C_5H_{12}O$
N_2O_4 ÷2	NO_2

1. Vinegar is a dilute solution of acetic acid. The molar mass of acetic acid is 60.06 g/mol and it has an empirical formula of CH_2O. What is the molecular formula of acetic acid?

C : 12.01 g/mol
H : 1.01 g/mol
O : 16.00 g/mol

$CH_2O = (1\times12.01) + (2\times1.01) + (1\times16.00)$
$= 30.03\ g/mol$

$\frac{60.06\ g/mol}{30.03\ g/mol} = 2$

$2 \times CH_2O = C_2H_4O_2$

2. A compound has an empirical formula of C_3H_4. Which of the following are possible molar masses of the compound? 20 g/mol, 55 g/mol, 80 g/mol, 120 g/mol.

$C_3H_4 = (3\times12.01) + (4\times1.01)$
$= 40.07\ g/mol$

$\frac{80\ g/mol}{40.07\ g/mol} = 2$ ✓ C_6H_8

$\frac{120\ g/mol}{40.07\ g/mol} = 3$ ✓ C_9H_{12}

3. A compound has an empirical formula of CH_2 and a molar mass of 42.09 g/mol. Determine its molecular formula.

$CH_2 = (1 \times 12.01) + (2 \times 1.01)$

$= 14.03\ g/mol$

$\frac{42.09\ g/mol}{14.03\ g/mol} = 3$

$3 \times CH_2 = \boxed{C_3H_6}$

4. A compound is 48.65% carbon, 8.11% hydrogen and 43.24% oxygen. Determine the empirical formula.

⇒ Think about having 100.0 g of the substance rather than as a %...

$48.65\ g_C \quad 8.11\ g_H \quad 43.24\ g_O$

⇒ Convert % into moles...

$C: 48.65\ g \times \frac{1\ mol}{12.01\ g} = 4.05\ mol_C$

$H: 8.11\ g \times \frac{1\ mol}{1.01\ g} = 8.03\ mol_H$

$O: 43.24\ g \times \frac{1\ mol}{16.00\ g} = 2.70\ mol_O$ ↳ smallest

⇒ Divide each molar quantity by the smallest one

$C: \frac{4.05\ mol_C}{2.70\ mol_O} = \sim 1.5$

$H: \frac{8.03\ mol_H}{2.70\ mol_O} = \sim 3$

* For every 1 mol of oxygen, there must be 1.5 mol of carbon and 3 mol of hydrogen

⇒ Multiply by whatever factor is necessary to get a whole number ratio.

$(C_{1.5}H_3O) \times 2 \qquad \boxed{C_3H_6O_2}$

5. A compound contains 9.93 g C, 58.6 g Cl, and 31.4 g F. Determine its empirical formula.

$C: 9.93\ g \times \frac{1\ mol}{12.01\ g} = 0.827\ mol_C \leftarrow$ smallest = 1 C

$Cl: 58.6\ g \times \frac{1\ mol}{35.45\ g} = 1.65\ mol_{Cl} \rightarrow \frac{1.65\ mol_{Cl}}{0.827\ mol_C} = \sim 2$ Cl

$F: 31.4\ g \times \frac{1\ mol}{19.00\ g} = 1.65\ mol_F \rightarrow \frac{1.65\ mol_F}{0.827\ mol_C} = \sim 2$ F

$\boxed{CCl_2F_2}$

6. A small sample of antifreeze was analyzed. It contained 4.51 g C, 1.13 g H and 6.01 g O. It was determined that the molar mass is 62.0 g/mol. What is the molecular formula of antifreeze?

$C: 4.51\,g \times \frac{1\,mol}{12.01\,g} = 0.376\,mol\,C$ ← Smallest

$H: 1.13\,g \times \frac{1\,mol}{1.01\,g} = 1.12\,mol\,H$

$O: 6.01\,g \times \frac{1\,mol}{16.00\,g} = 0.376\,mol\,O$ ← Smallest

$\frac{1.12\,mol\,H}{0.376\,mol\,(C\text{ or }O)} = \sim 3$

Empirical CH_3O

Molar Mass CH_3O: $(12.01) + (3 \times 1.01) + (16.00) = 31.04\,g/mol$

$2 \times (CH_3O) = \boxed{C_2H_6O_2} \leftarrow 2 = \frac{62.0\,g/mol}{31.04\,g/mol}$

7. A hydrocarbon is a compound containing only carbon and hydrogen. One particular hydrocarbon is 92.29% carbon by mass. If the compound's molar mass is 78.0 g/mol then what is its molecular formula?

$C: 92.29\,g \times \frac{1\,mol}{12.01\,g} = 7.684\,mol\,C$

$H: 7.71\,g \times \frac{1\,mol}{1.01\,g} = 7.63\,mol\,H$

100 − 92.29

$\frac{7.684\,mol\,C}{7.63\,mol\,H} = \sim 1$

Empirical CH

Molar mass $(12.01 \times 1) + (1.01 \times 1) = 13.02\,g/mol$

$6 \times (CH) = \boxed{C_6H_6} \leftarrow \frac{78.0\,g/mol}{13.02\,g/mol} = \sim 6$

Percent Composition

Percent Composition:

- The percent of a compound's **mass** contributed by each type of atom in the compound.
- Determined from the formula.

8a. Find the percent of carbon by mass in ethane, C_2H_6.

Molar mass $C_2H_6 = (2 \times 12.01) + (6 \times 1.01) = 30.08\,g/mol$

$C: (2 \times 12.01) = 24.02\,g/mol$

$\frac{\text{molar mass of C}}{\text{total}} = \frac{24.02\,g/mol}{30.08\,g/mol} \times 100\% = \boxed{79.85\%}$

8b. Find the percent of hydrogen by mass in ethane, C_2H_6.

$100\% - 79.85\% = 20.15\%$

$H: (6 \times 1.01) = 6.06\,g/mol$

$\frac{\text{molar mass of H}}{\text{total}} = \frac{6.06\,g/mol}{30.08\,g/mol} \times 100\% = \boxed{20.15\%}$

9. What is the percent composition of each type of a sugar with the formula $C_{12}H_{22}O_{11}$?

Molar mass $C_{12}H_{22}O_{11}$ = $(12\times12.01)+(22\times1.01)+(11\times16.00)=342.34\ g/mol$

C : $\frac{12\times12.01\ g/mol}{342.34\ g/mol}\times100\% = 42.10\%\ C$

H : $\frac{22\times1.01\ g/mol}{342.34\ g/mol}\times100\% = 6.49\%\ H$

O : $\frac{11\times16.00\ g/mol}{342.34\ g/mol}\times100\% = 51.41\%\ O$

*2 decimal places

Practice:

10. Calculate the % composition of the following compounds:

a. $FeCl_2$

~~b.~~ $C_2H_4O_2$

c. $CaCl_2.2H_2O$

~~d.~~ $(NH_4)_3PO_4$

e. NaOH

~~f.~~ $Ag(NH_3)_2Cl$

g. $K_3Fe(CN)_6$

~~h.~~ $CaCO_3$

11. Calculate the % of the bold species in the following compounds:

a. $CaCl_2.2\mathbf{H_2O}$

~~b.~~ $Al_2(SO_4)_3.18\mathbf{H_2O}$

c. $Cr(\mathbf{NH_3})_6Cl_3.H_2O$

~~d.~~ $Fe_2(\mathbf{SO_4})_3.9H_2O$

e. $Cu(\mathbf{C_2H_3O_2})_2.2NH_3$

~~f.~~ $NiSO_4.7\mathbf{H_2}$

1. $C_2H_4O_2$ 2. 80g/mol and 120g/mol 3. C_3H_6 4. $C_3H_6O_2$ 5. CCl_2F_2 6. $C_2H_6O_2$ 7. C_6H_6 8a. 79.85% b. 20.15%
9. 42.098% C, 6.491% H, 51.411% O 10a. Fe: 44.06% Cl: 55.94% b. C: 39.99% H: 6.73% O: 53.28%
c. Ca:27.26% Cl: 48.22% H: 2.75% O: 21.77% d. N: 28.19% H: 8.13% P: 20.77% O: 42.92%
e. Na: 57.48% O: 40.00% H: 2.53% f. Ag: 60.81% N: 15.79% H: 3.42% Cl: 19.98%
g. K: 35.62% Fe: 16.96% C: 21.88% N: 25.53% h. Ca: 40.04% C: 12.00% O: 47.96%
11a. 24.51% b. 48.66% c. 36.70% d. 51.27% e. 54.74% f. 8.37%

10. a) $FeCl_2 = 126.75\ g/mol$

Fe: $\frac{55.85}{126.75} = 44.06\%\ Fe$

Cl: $\frac{(2\times35.45)}{126.75} = 55.94\%\ Cl$

b) $C_2H_4O_2 = 60.06\ g/mol$

C: $\frac{(2\times12.01)}{60.06} = 39.99\%\ C$

H: $\frac{(4\times1.01)}{60.06} = 6.73\%\ H$

O: $\frac{(2\times16.00)}{60.06} = 53.28\%\ O$

c) $CaCl_2 \cdot 2H_2O = 147.02\ g/mol$

Ca: $\frac{(40.08)}{147.02} = 27.26\%\ Ca$

Cl: $\frac{(2\times35.45)}{147.02} = 48.22\%\ Cl$

H: $\frac{(4\times1.01)}{147.02} = 2.75\%\ H$

O: $\frac{(2\times16.00)}{147.02} = 21.77\%\ O$

d) $(NH_4)_3PO_4 = 149.12\ g/mol$

N: $\frac{(3\times14.01)}{149.12} = 28.19\%\ N$

H: $\frac{(12\times1.01)}{149.12} = 8.13\%\ H$

P: $\frac{30.97}{149.12} = 20.77\%\ P$

O: $\frac{(4\times16.00)}{149.12} = 42.92\%\ O$

e) $NaOH = 40.00\ g/mol$

Na: $\frac{22.99}{40.00} = 57.48\%\ Na$

O: $\frac{16.00}{40.00} = 40.00\%\ O$

H: $\frac{1.01}{40.00} = 2.53\%\ H$

f) $Ag(NH_3)_2Cl = 177.40\ g/mol$

Ag: $\frac{107.87}{177.40} = 60.81\%\ Ag$

N: $\frac{2\times14.01}{177.40} = 15.79\%\ Cl$

H: $\frac{6\times1.01}{177.40} = 3.42\%\ H$

Cl: $\frac{35.45}{177.40} = 19.98\%\ Cl$

g) $K_3Fe(CN)_6 = 329.27\ g/mol$

K: $\frac{(3\times39.10)}{329.27} = 35.62\%\ K$

Fe: $\frac{55.85}{329.27} = 16.96\%\ Fe$

C: $\frac{6\times12.01}{329.27} = 21.88\%\ C$

N: $\frac{6\times14.01}{329.27} = 25.53\%\ N$

h) $CaCO_3 = 100.09\ g/mol$

Ca: $\frac{40.08}{100.09} = 40.04\%\ Ca$

C: $\frac{12.01}{100.09} = 12.00\%\ C$

O: $\frac{3\times16.00}{100.09} = 47.96\%\ O$

11. a) $CaCl_2 \cdot 2H_2O = 147.02\ g/mol$

$H_2O: \frac{(4\times1.01)+(2\times16.00)}{147.02} = 24.51\%\ H_2O$

b) $Al_2(SO_4)_3 \cdot 18H_2O = 666.53\ g/mol$

$H_2O: \frac{(36\times1.01)+(18\times16.00)}{147.02} = 48.66\%\ H_2O$

c) $Cr(NH_3)_6Cl_3H_2O = 278.61\ g/mol$

$NH_3: \frac{(6\times14.01)+(18\times1.01)}{278.61} = 36.70\%\ NH_3$

d) $Fe_2(SO_4)_3 \cdot 9H_2O = 562.09\ g/mol$

$SO_4: \frac{(3\times32.07)+(12\times16.00)}{562.09} = 51.27\%\ SO_4$

e) $Cu(C_2H_3O_2)_2 \cdot 2NH_3 = 215.73\ g/mol$

$C_2H_3O_2: \frac{(4\times12.01)+(6\times1.01)+(4\times16.00)}{215.73} = 54.74\%\ C_2H_5O_2$

f) $NiSO_4 \cdot 7H_2 = 168.90\ g/mol$

$H: \frac{14\times1.01}{168.90} = 8.37\%\ H$