Chemistry 11

The Mole V

Name: Key.
Date:
Block:

1. Empirical Formula
2. Percent Composition

Empirical Formula

Molecular Formula: identifies the # of each type of atom

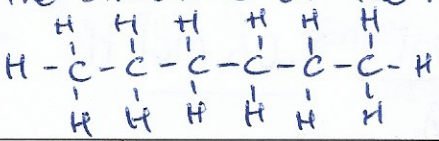
Ex: hexane = C_6H_{14}

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

Ex: hexane = $C_6H_{14} \longrightarrow C_3H_7$

Structural Formula: shows the structure of the molecule

Ex: hexane =



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

$CH_2O \rightarrow$ molar mass: $(1 \times 12.01) + (2 \times 1.01) + (1 \times 16.00) = 30.03\ g/mol$

$$\frac{60.06\ g/mol}{30.03\ g/mol} = 2 \qquad 2 \times CH_2O \Rightarrow \boxed{C_2H_4O_2}$$

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.

$C_3H_4 \rightarrow$ molar mass: $(3 \times 12.01) + (4 \times 1.01) = 40.07\ g/mol$

$(40.07) \times 2 = 80.14\ g/mol = 80\ g/mol$ ✓

$(40.07) \times 3 = 120.21\ g/mol = 120\ g/mol$ ✓

* 80 g/mol and 120 g/mol are possible.

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

$CH_2 = (1 \times 12.01) + (2 \times 1.01) = 14.03 g/mol$

$\frac{42.09}{14.03} = 3 \qquad 3(CH_2) \Rightarrow \boxed{C_3H_6}$

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...

$C: 48.65 g \times \frac{1 mol}{12.01 g} = 4.051 mol\ C$

$O: 43.24 g \times \frac{1 mol}{16.00} = 2.703 mol$

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

* ⇒ Divide each molar quantity by the smallest one

$C: \frac{4.051 mol\ C}{2.703 mol\ O} = 1.499 \qquad H: \frac{8.03 mol\ H}{2.703 mol\ O} = 2.97$

* for every 1 mol of O, there must be 1.5 mol C and 3.0 mol H

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

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

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

$C: 9.93 g \times \frac{1 mol}{12.01 g} = 0.827 mol\ C \qquad \frac{1.65 mol\ Cl}{0.827 mol\ C} = 2.00$

$Cl: 58.6 g \times \frac{1 mol}{35.45 g} = 1.65 mol\ Cl \qquad \frac{1.65 mol\ F}{0.827 mol\ C} = 2.00$

$F: 31.4 g \times \frac{1 mol}{19.00 g} = 1.65 mol\ F \Rightarrow \boxed{CCl_2F_2}$

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

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

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

$\frac{1.12 mol\ H}{0.376 mol\ (C \text{ and } O)} = 2.98 \sim 3$

Emperical: CH_3O

molar mass: $(1 \times 12.01) + (3 \times 1.01) + (1 \times 16.00)$
$= 31.04 g/mol$

$\frac{62.0 g/mol}{31.04 g/mol} = 2$ $\quad 2 \times (CH_3O)$

$= \boxed{C_2H_6O_2}$

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?

100 − 92.29

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

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

$\frac{7.684 mol\ C}{7.63 mol\ H} = 1.007 \sim 1$

Emperical: CH

Molar mass $(12.01 + 1.01) = 13.02 g/mol$

$\frac{78.0 g/mol}{13.02 g/mol} = 5.99 = 6$

$6(CH) \Rightarrow \boxed{C_6H_6}$ ← molecular formula.

molecular formula ↑

Percent Composition

Percent Composition:

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

8a. Find the percent of carbon by <u>mass</u> in ethane, C_2H_6.

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

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

$\frac{C}{total} = \frac{24.02}{30.08} \times 100\% = 79.85\%\ C$

8b. Find the percent of hydrogen by <u>mass</u> in ethane, C_2H_6.

molar mass $C_2H_6 = 30.08 g/mol$

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

$\frac{H}{total} = \frac{6.06}{30.08} \times 100\% = 20.15\%\ H$

$= 20.2\%\ H$

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

$C_{12}H_{22}O_{11} = (12 \times 12.01) + (22 \times 1.01) + (11 \times 16.00) = 342.34\ g/mol$

C only = $12 \times 12.01 = 144.1\ g/mol\ C$

H only = $22 \times 1.01 = 22.2\ g/mol\ H$

O only = $11 \times 16.00 = 176.0\ g/mol\ O$

C: $\frac{144.1}{342.34} = 42.09\%\ C$ H: $\frac{22.2}{342.34} = 6.48\%\ H$ O: $\frac{176.0}{342.34} = 51.41\%\ O$

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%

80 a) $FeCl_2$

molar mass = (1 x 55.85) + (2 x 35.45)
= 126.75 g/mol

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

Cl: $\frac{(2 \times 35.45)}{126.75} = 55.94\%$

b) $C_2H_4O_2$

molar mass: (2 x 12.01) + (4 x 1.01) + (2 x 16.00)
= 60.06 g/mol

C: $\frac{(2 \times 12.01)}{60.06} = 39.99\%$

H: $\frac{(4 \times 1.01)}{60.06} = 6.73\%$

O: $\frac{(2 \times 16.00)}{60.06} = 53.28\%$

c) $CaCl_2 \cdot 2H_2O$

molar mass: (1 x 40.08) + (2 x 35.45) + (4 x 1.01) + (2 x 16.00)
= 147.02 g/mol

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

H: $\frac{(4 \times 1.01)}{147.02} = 2.75\%$

Cl: $\frac{(2 \times 35.45)}{147.02} = 48.22\%$

O: $\frac{(2 \times 16.00)}{147.02} = 21.77\%$

d) $(NH_4)_3PO_4$

molar mass: (3 x 14.01) + (12 x 1.01) + (1 x 30.97) + (4 x 16.00)
= 149.12 g/mol

N: $\frac{(3 \times 14.01)}{149.12} = 28.19\%$

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

H: $\frac{(12 \times 1.01)}{149.12} = 8.13\%$

O: $\frac{4 \times 16.00}{149.12} = 42.92\%$

e) NaOH

molar mass: (22.99 + 16.00 + 1.01) = 40.00 g/mol

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

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

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

f) $Ag(NH_3)_2Cl$

molar mass: (1 x 107.87) + (2 x 14.01) + (6 x 1.01) + (35.45) = 177.40 g/mol

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

H: $\frac{6 \times 1.01}{177.40} = 3.42\%$

N: $\frac{2 \times 14.01}{177.40} = 15.79\%$

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

g) $K_3Fe(CN)_6$

molar mass: (3 x 39.10) + (55.85) + (6 x 12.01) + (6 x 14.01)
= 329.27 g/mol

K: $\frac{(3 \times 39.10)}{329.27} = 35.62\%$

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

C: $\frac{6 \times 12.01}{329.27} = 21.88\%$

N: $\frac{6 \times 14.01}{329.27} = 25.53\%$

h) $CaCO_3$

molar mass = (40.08) + (12.01) + (3 x 16.00)
= 100.09 g/mol

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

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

O: $\frac{3 \times 16.00}{100.09} = 47.96\%$

11. a) $CaCl_2 2 \cdot H_2O$

molar mass: $(40.08) + (2 \times 35.45) + (4 \times 1.01) + (2 \times 16.00)$
$= 147.02\ g/mol$

$H_2O : \frac{(4 \times 1.01) + (2 \times 16.00)}{147.02} = 24.51\%$

b) $Al_2(SO_4)_3 \cdot 18 H_2O$

molar mass: $(2 \times 26.98) + (3 \times 32.07) + (12 \times 16.00) + (36 \times 1.01) + (18 \times 16.00)$
$= 666.53\ g/mol$

$H_2O : \frac{(36 \times 1.01) + (18 \times 16.00)}{666.53} = 48.66\%$

c) $Cr(NH_3)_6 Cl_3 H_2O$

molar mass: $(52.00) + (6 \times 14.01) + (18 \times 1.01) + (3 \times 35.45) + (2 \times 1.01) + (16.00)$
$= 278.61\ g/mol$

$NH_3 : \frac{(6 \times 14.01) + (18 \times 1.01)}{278.61} = 36.70\%$

d) $Fe_2(SO_4)_3 \cdot 9H_2O$ molar mass: $(2 \times 55.85) + (3 \times 32.07) + (12 \times 16.00) + (18 \times 1.01) + (9 \times 16.00)$
$= 562.09\ g/mol$

$SO_4 : \frac{(3 \times 32.07) + (12 \times 16.00)}{562.09} = 51.27\%$

e) $Cu(C_2H_3O_2)_2 2 \cdot NH_3$: molar mass: $63.55 + (4 \times 12.01) + (6 \times 1.01) + (4 \times 16.00) + (2 \times 14.01) + (6 \times 1.01) = 215.73\ g/mol$

$C_2H_3O_2 = \frac{(4 \times 12.01) + (6 \times 1.01) + (4 \times 16.00)}{215.73} = 54.74\%$

f) $NiSO_4 7 \cdot H_2$ molar mass: $58.69 + 32.07 + (4 \times 16.00) + (14 \times 1.01) = 168.90\ g/mol$

$H_2 = \frac{14 \times 1.01}{168.90} = 8.37\%$