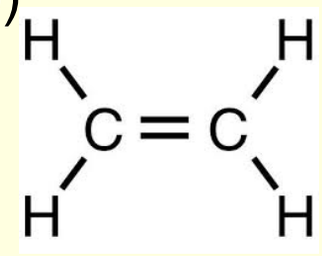
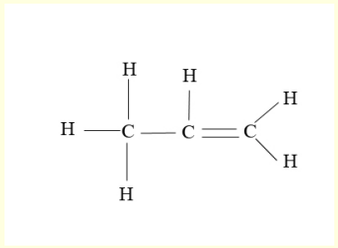
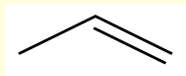
# Molecular Vs. Empirical Formulas

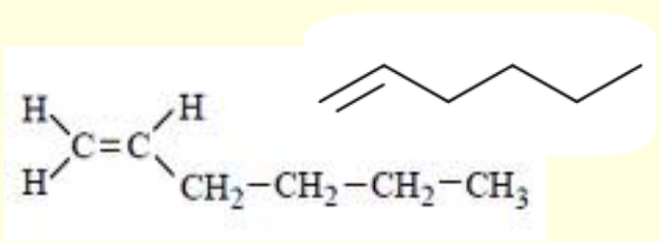
## Molecular Formulas

(may not be simplest ratio)

boiling point

$C_2H_4$ ethene  -103.7°C

$C_3H_6$ propene   - 47.6°C

$C_6H_{12}$ 1-hexene  63 °C

All 3 have same ratio but have different properties!

Their **empirical formulas** are the same: $CH_2$
(simplest ratio)

# Determining Empirical Formulas

A compound has 80% Carbon and 20 % H.
Determine the Empirical Formula.

1. Convert % mass to mass: 80% C and 20 % H ↓ ↓ 80 g C and 20 g H.

2. Convert mass to moles:

$$\frac{80\text{ g C}}{} \left| \frac{1\text{ mole C}}{12\text{ g C}} \right. = 6.66\text{ mol C}$$

$$\frac{20\text{ g H}}{} \left| \frac{1\text{ mole H}}{1\text{ g H}} \right. = 20\text{ mol H}$$

3. Divide out all moles by the smallest value -give smallest ratio.

$$\frac{6.66}{6.66} = 1\text{ C}$$

$$\frac{20.0}{6.66} = 3\text{ H}$$

$CH_3$ is the empirical formula

Determine the empirical formula of a substance with:

25.9 % N and 74.1 % O

Convert to from % → grams → moles

$$\frac{25.9\text{g N}}{} \left| \frac{1\text{ mol N}}{14\text{ g N}} \right. = 1.85\text{ mol N}$$

$$\frac{74.1\text{ g O}}{} \left| \frac{1\text{ mol O}}{16\text{ g O}} \right. = 4.63\text{ mol O}$$

find simplest ratio

$$\frac{1.85}{1.85} = \mathbf{1\ N} \qquad \frac{4.63}{1.85} = \mathbf{2.5\ O}$$

cannot have 1/2 of an atom

Multiply both by 2 to get whole number

1 N x 2 = **2 N** 2.5 O x 2 = **5 O**

empirical formula: $N_2O_5$

# Determining molecular formula from the empirical formula:

**empirical formula:**

$CH_2$

empirical weight;
14 g/mol

**potential molecular formulas:**

| | mol. wt. |
|---|---|
| $CH_2$ | 14g/mol |
| $C_2H_4$ | 28 g/mol |
| $C_3H_6$ | 42 g/mol |
| $C_4H_8$ | 56 g/mol |
| $C_5H_{10}$ | 70 g/mol |
| (Etc.) | |

Calculation: $\frac{\text{molecular wt.}}{\text{empirical wt.}}$ = multiple of subscript

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85.7% C and 14.3% H
with a molecular wt= 56 g/mol

$$\frac{85.7\text{g C}}{} \left| \frac{1\text{mol C}}{12\text{ g C}} \right. = 7.14 \text{ mol C} \qquad \frac{7.14}{7.14} = 1 \text{ C}$$

$$\frac{14.3\text{g H}}{} \left| \frac{1\text{ mol H}}{1\text{ g H}} \right. = 14.3 \text{ mol H} \qquad \frac{14.3}{7.14} = 2 \text{ H}$$

empirical formula: $CH_2$
empirical weight: 14 g/mol

$$\frac{\text{molecular wt.}}{\text{empirical wt.}} = \frac{56\text{g/mol}}{14\text{g/mol}} = 4$$

(multiple of subscripts)

molecular formula = 4 x $(CH_2)$ = $C_4H_8$

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It contains 60%C, 4.4%H and 35.6% O.
What is its molecular formula?

$$\frac{60\text{g C}}{}\left|\frac{1\text{ mol C}}{12\text{ g C}}\right. = 5\text{ mol C} \qquad \frac{5}{2.23} = 2.24 \qquad \text{x4} = 9\text{ C}$$

$$\frac{4.4\text{g H}}{}\left|\frac{1\text{ mol H}}{1\text{ g H}}\right. = 4.4\text{ mol H} \qquad \frac{4.4}{2.23} = 2 \qquad \text{x4} = 8\text{ H}$$

$$\frac{35.6\text{g O}}{}\left|\frac{1\text{ mol O}}{16\text{ g O}}\right. = 2.23\text{ mol O} \qquad \frac{2.23}{2.23} = 1 \qquad \text{x4} = 4\ 0$$

empirical formula: $C_9H_8O_4$

Empirical weight: (12x9) + (1x8) + (16x4) = 180g/mol

$$\frac{540\text{g/mol}}{180\text{ g/mol}} = 3$$

molecular formula: $C_{27}H_{24}O_{12}$

Lactobionic Acid has a molecular wt of 358g/mol

It contains 40.2%C, 6.2%H and 53.6% O.
What is its molecular formula?

Lactobionic Acid has a molecular wt of 358.3g/mol

It contains 40.2%C, 6.2%H and 53.6% O.

What is its molecular formula?

$$\frac{40.23\text{g C}}{12.01\text{ g C}}\left|\frac{1\text{ mol C}}{}\right. = 3.349\text{ mol C} \qquad \frac{3.349}{3.349} = 1.000 \qquad \times 6 = 6\text{ C}$$

$$\frac{6.189\text{g H}}{1.008\text{ g H}}\left|\frac{1\text{ mol H}}{}\right. = 6.140\text{ mol H} \qquad \frac{6.140}{3.349} = 1.833 \qquad \times 6 = 11\text{ H}$$

$$\frac{53.59\text{g O}}{16.00\text{ g O}}\left|\frac{1\text{ mol O}}{}\right. = 3.349\text{ mol O} \qquad \frac{3.349}{3.349} = 1.000 \qquad \times 6 = 6\ 0$$

empirical formula: $C_6H_{11}O_6$

Empirical weight: (12.01x6) + (1.008 x11) + (16.00x6) = 179.15g/mol

$$\frac{358.3\text{g/mol}}{179.15\text{ g/mol}} = 2$$

molecular formula: $C_{12}H_{22}O_{12}$