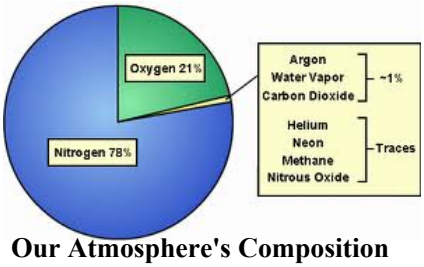
9.4 Percent Composition; Empirical and Molecular Formulas



Our Atmosphere's Composition

Percent Composition

Unknown compounds are identified by percent composition: each element (by mass) adds a particular amount to the overall compound mass.

To find the % composition of any element in a compound:

$$\%\,Element_{(mass)} = \frac{Mass\ of\ Element\ in\ Compound}{Molar\ Mass\ of\ Compound} \cdot 100\%$$

Use this for EACH element in your compound.

1. HCN Example

Find the percent mass of the elements in hydrocyanic acid, HCN.

1: Determine molar mass of HCN:

$$1\,mol\,H \cdot \frac{1.01\,g\,H}{1\,mol\,H} = 1.01\,g\,H$$

$$1\,mol\,C \cdot \frac{12.01\,g}{1\,mol\,C} = 12.01\,g\,C$$

$$1\,mol\,N \cdot \frac{14.01\,g}{1\,mol\,N} = 14.01\,g\,N$$

$$= 27.03\,g\,/\,mol\,HCN$$

1. Example

Apply the formula for each element:

$$\%\,Hydrogen = \frac{1.01\,g\,H}{27.03\,g\,HCN} \cdot 100\% = 3.74\%$$

$$\%\,Carbon = \frac{12.01\,g\,C}{27.03\,g\,HCN} \cdot 100\% = 44.43\%$$

$$\%\,Nitrogen = \frac{14.01\,g\,N}{27.03\,g\,HCN} \cdot 100\% = 51.83\%$$

The total should be 100.00 %.

Empirical Formula (E. F.)

A chemical formula with the smallest whole number ratio of elements.

2. Ex: The sugar glucose ($C_6H_{12}O_6$) has an E. F. of CH_2O.

3. What the E. F. of Teflon, C_2F_4?

Answer: CF_2

If a compound's percent composition is known, its E. F. can be calculated.

4. Guided Example Process

What's the empirical formula for a compound with 40.05% sulfur and 59.95% oxygen?

Step 1: Assume you have 100 grams, so:

40.05 grams S

59.95 grams O

4. Guided Example Process

Step 2: Convert mass to moles for all elements.

Sulfur: $40.05\,g\,S \bullet \frac{1\,mol\,S}{32.07\,g\,S} = 1.249\,mol\,S$

Oxygen: $59.95\,g\,O \bullet \frac{1\,mol\,O}{16.00\,g\,O} = 3.747\,mol\,O$

Mole ratio sulfur : oxygen is 1.249 : 3.747

Possible formula: $S_{1.249}O_{3.747}$

4. Guided Example Process

Step 3: Divide both molar values by the SMALLEST to get whole numbers.

S → $\frac{1.249\,mol\,S}{1.249} = 1\,mol\,S$

O → $\frac{3.747\,mol\,O}{1.249} = 3\,mol\,O$

Thus, E. F. is SO_3

4. Guided Example Process

Possible Step 4: If values are not whole numbers (within 0.05), find a small multiplier that makes them so.

Ex: Compound's ratio: C: 1.32 H: 3.0 O: 1.0

Multiply each by three (to fix carbon), and you'll get $C_4H_9O_3$

Ex: Fix: C: 2.24 H: 6.49 O: 1.0

Multiply by 4: $C_9H_{26}O_4$.

Molecular Formula Process

Finding the E. F. of a compound doesn't always yield the compound's molecular (actual) formula.

Step 1: You **must** have the molar mass; calculate E. F, and E. F. mass of the compound.

Step 2: Divide molar mass by the E. F. mass. This tells the number of times the E. F. is repeated in the molecule.

Step 3: Multiply the E. F. by this value: this gives the molecular formula.

5. Molecular Formula Guided Practice

Find the molecular formulas of benzene and acetylene, two compounds with E.F of CH, but very different properties.

Benzene's molar mass = 78.12 g/mol.

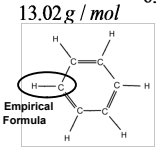
Acetylene's molar mass = 26.04 g/mol.

E. F. mass = 13.02 g/mol

5. Molecular Formula Guided Practice

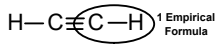
Benzene: $\frac{benzene's\,molar\,mass}{E.F.mass} = \frac{78.12\,g/mol}{13.02\,g/mol} = 6.0$

Multiplying CH (E. F.) by 6.0 yields the formula $\mathbf{C_6H_6}$.



Acetylene: $\frac{acetylene's\,molar\,mass}{E.F.mass} = \frac{26.04\,g/mol}{13.02\,g/mol} = 2.0$

Multiplying CH by 2.0 yields a formula of $\mathbf{C_2H_2}$.



Homework

9.4 Booklet Problems.
Due Next Class.