Key

Empirical Formulas – Worksheet 1

Calculate the empirical formula for the compound containing the elements given in each problem.

1. 71.4% Ca, 28.6% O

Step 1: Assume that instead of percentages, the numbers represent grams.
Step 2: Convert the grams of each element to moles.
Step 3: Divide all the mole quantities by the element with the smallest number of moles.
Step 4: If you don't have whole numbers, multiply the moles by smallest whole number that works so that all the mole quantities are represented by whole numbers.
Step 5: Write the chemical formula for the compound

Ca $71.4\,g \times \frac{1\,mol}{40.08\,g} = \frac{1.78\,mol}{1.78} = 1$

O $28.6\,g \times \frac{1\,mol}{16.00\,g} = \frac{1.79\,mol}{1.78} = 1$

CaO

2. 46.5%Fe, 53.5% S

Fe $46.5\,g \times \frac{1\,mol}{55.85\,g} = \frac{0.833\,mol}{.833} = 1$

S $53.5\,g \times \frac{1\,mol}{32.07\,g} = \frac{1.67\,mol}{.833} = 2$

FeS_2

3. 46.6% Na, 21.0% P, 32.4% O

Na $46.6\,g \times \frac{1\,mol}{22.99\,g} = \frac{2.03\,mol}{0.678} = 2.99$

P $21.0\,g \times \frac{1\,mol}{30.97\,g} = 0.678\,mol$

O $32.4\,g \times \frac{1\,mol}{16.00\,g} = \frac{2.025\,mol}{0.678} = 2.99$

Na_3PO_3

4. 58.81% Ba, 13.73% S, 27.46% O

Ba $58.81\,g \times \frac{1\,mol}{137.33\,g} = 0.428\,mol$

S $13.73\,g \times \frac{1\,mol}{32.07\,g} = 0.428\,mol$

O $27.46\,g \times \frac{1\,mol}{16\,g} = \frac{1.72\,mol}{0.428} = 4.0099$

$BaSO_4$

5. 4.36 g P, 5.64 g O

$4.36\,g \times \frac{1\,mol}{30.97\,g} = 0.141\,mol = 1 \times 2 = 2$

$5.64\,g \times \frac{1\,mol}{16.00\,g} = 0.353\,mol = 2.5 \times 2 = 5$

P_2O_5

11. 1.77 g P, 2.29 g O

P $1.77\,g \times \frac{1\,mol}{30.97\,g} = 0.0572 = 1$

O $2.29\,g \times \frac{1\,mol}{16.00\,g} = 0.143 = 2.5$

P_2O_5

12. 63.6% N, 36.4% O

N $63.6\,g \times \frac{1\,mol}{14.01\,g} = 4.54\,mol = 1.99$

O $36.4\,g \times \frac{1\,mol}{16\,g} = 2.28\,mol = 1$

N_2O

13. 81.8% C, 18.2% H

C $81.8\,g \times \frac{1\,mol}{12.0\,g} = 6.81 = 1 \times 3 = 3$

H $18.2\,g \times \frac{1\,mol}{1.01\,g} = 18.02 = 2.65 \times 3 = 8$

C_3H_8

14. 40% C, 6.7% H, 53.3% O

C $40 \times \frac{}{12.01} = 3.33\,mol = 1$

H $6.7 \times \frac{}{1.01} = 6.63\,mol = 2$

O $53.3 \times \frac{}{16.00} = 3.33\,mol = 1$

CH_2O

15. 19.3% Na, 26.9% S, 53.8% O

Na $19.3\,g \times \frac{}{22.99} = 0.839\,mol = 1$

S $26.9\,g \times \frac{}{32.07} = 0.839\,mol = 1$

O $53.8\,g \times \frac{}{16.00} = 3.36\,mol = 4$

$NaSO_4$

Empirical and Molecular Formulas

Key

1. If the approximate molecular mass of an oxide of nitrogen is 108 g and 4.02 g of nitrogen combine with 11.48 g of oxygen to form the oxide, what is the molecular formula of this compound?
   Step 1: Calculate the number of moles of each element.
   Step 2: Divide by the smallest number of moles.
   Step 3: If you don't have whole numbers, multiply by the smallest whole number you can to obtain whole numbers
   Step 4: Write the empirical formula for the compound.
   Step 5: Calculate the molar mass for the empirical formula.
   Step 6: Compare the molar mass of the empirical formula to the molar mass given above. If they are the same, the empirical formula is the same as the molecular formula. If the molar mass of the empirical formula is less than the molar mass given above, multiply the empirical formula by the smallest whole number possible to obtain the molar mass given.
   Step 7: Write the molecular formula.

N $4.02\text{g} \times \frac{1\text{mol}}{14.01\text{g}} = 0.287\text{mol} = 1 \times 2 = 2$

N_2O_5 = molec. form.

O $11.48\text{g} \times \frac{1\text{mol}}{16.00\text{g}} = 0.718\text{mol} = 2.5 \times 2 = 5$

$N_2O_5 = \begin{array}{r} 28.02 \\ +80.00 \\ \hline 108.029\text{g/mol} \end{array}$

2. The approximate formula mass of a compound is 92 g. Analysis of the compound shows that there are 0.608 g of nitrogen and 1.388 g of oxygen. What is the molecular formula of this compound?

$0.608\text{g N} \times \frac{1\text{mol}}{14.01\text{g}} = 0.0434 = 1$ $\quad NO_2 = \begin{array}{r} 14 \\ 32 \\ \hline 46\text{g/mol} \end{array}$

$1.388\text{g O} \times \frac{1\text{mol}}{16.00\text{g}} = 0.0868 = 2$ $\quad \frac{92\text{g/mol}}{46\text{g/mol}} = 2$ $\quad N_2O_4$

3. There are two oxides of phosphorus. Both oxides can exist in different forms depending on the temperature and the pressure. Calculate the empirical and molecular formulas for each oxide from the data given:
   a. phosphorus 56.4 %, oxygen 43.7 %; molar mass is 220 g

P $56.4\text{g} \times \frac{1\text{mol}}{31\text{g}} = 1.82 = 1 = 2$ $\quad \frac{220}{110} = 2$

O $43.7\text{g} \times \frac{1\text{mol}}{16\text{g}} = 2.73 = 1.5 = 3$ $\quad P_4O_6$

$P_2O_3 \quad \begin{array}{r} 62 \\ +48 \\ \hline 110\text{g/mol} \end{array}$

b. phosphorus 43.6 %, oxygen 56.4 %; molar mass is 284 g

P $43.6\,g \times \frac{}{31\,g} = 1.41 = 1 = 2$ $\quad \frac{284}{142} = 2$

O $56.4\,g \times \frac{}{16\,g} = 3.53 = 2.5 = 5$

P_2O_5 $\quad \frac{62}{+\,80}{142}$ $\quad P_4O_{10}$

4. A hydrated compound has an analysis of 18.29 % Ca, 32.37 % Cl, and 49.34 % H_2O. What is its formula?

Ca $18.29\,g \times \frac{}{40\,g} = 0.457 = 1$

Cl $32.37\,g \times \frac{1\,mol}{35\,g} = 0.925 = 2$ $\quad CaCl_2 \cdot 6H_2O$

H_2O $49.34\,g \times \frac{}{18\,g} = 2.74 = 6$

5. A certain hydrate analyzes as follows: 29.7 % copper, 15.0 % sulfur, 2.8 % hydrogen, and 52.5 % oxygen. Determine the empirical formula of this hydrate from these percentages. Assume all of the hydrogen is in the water associated with the compound.

Cu $29.7\,g \times \frac{}{64\,g} = 0.464 = 1$ $\quad CuSH_6O_7$

$\hookrightarrow H_2O = \cdot 3H_2O$

S $15\,g \times \frac{}{32\,g} = 0.468 = 1$

H $2.8 \times \frac{}{1.01\,g} = 2.77 = 5.92 = 6$ $\quad CuSO_4 \cdot 3H_2O$

O $52.5\,g \times \frac{}{16\,g} = 3.28 = 7.07 = 7$

6. A compound subjected to analysis was found to have the following composition by weight: 69.96 % carbon, 7.83 % hydrogen, and 22.21 % oxygen. If the molecular weight of this compound is 360 g/mole, what is its molecular formula?

C $69.96\,g \times \frac{1\,mol}{12\,g} = 5.83 = 4.19 =$

$4.2 \times 5 = 21$ $\quad C_{21}H_{28}O_5$

H $7.83\,g \times \frac{}{1\,g} = 7.83 = 5.63 =$

$5.6 \times 5 = 28$

O $22.21\,g \times \frac{}{16\,g} = 1.39 = 1 =$

$\times 5 = 5$

C = 252
H = 28
O = +80
360

7. The most common constituent of gasoline is iso-octane. It is a hydrocarbon, composed by weight of 84.12 % carbon, and 15.88 % hydrogen. Given that it contains 5.27×10^{21} molecules per gram, what is its molecular formula?

C $84.12\text{g} \times \frac{1\text{mol}}{12\text{g}} = 7.01 = 1 = 4$

H $15.88\text{g} \times \frac{1\text{mol}}{1\text{g}} = 15.88 = 2.25 = 9$

C_4H_9 = C 48, H 9 → 57 g/mol

$\frac{1\text{mol}}{57\text{g}} \times \frac{6.02\times10^{23}\text{ molec}}{1\text{mol}} = \frac{5.30\times10^{21}\text{ molec}}{\text{g}}$

$\frac{5.27\times10^{21}\text{ molec}}{1\text{g}} \times \frac{1\text{ mol}}{6.02\times10^{23}\text{ molec}} = 0.00875\ \frac{\text{mol}}{\text{g}} = 114.23\text{g/mol}$

$\frac{114.23}{57} = 2$

C_8H_{18}