Answer Key

PLI Sheet #3

Monday, 7 June 2021

1. When the following elements or compounds are present in ionic compounds, what will their charge be? Write the symbol and charge, e.g. Chlorine: Cl^-

   a. Nitrogen: N^{3-}
   b. Oxygen: O^{2-}
   c. Bromine: Br^-
   d. Magnesium: Mg^{2+}
   e. Rubidium: Rb^+
   f. Silver: Ag^+
   g. Nitrite: NO_2^-
   h. Phosphate: PO_4^{3-}
   i. Ammonium: NH_4^+

2. Balance the following ionic compounds:

   Na_1NO_2 $\quad$ $Be(ClO)_2$

   $Mg_3(PO_4)_2$ $\quad$ $Li(OH)_1$ $\quad$ $Na_2(HPO_4)$

   Mg^{2+} $\quad$ PO_4^{3-}
   $(+2)(3)=6$ $\quad$ $(-3)(2)=-6$

3. Mercury forms a compound with chlorine that is 73.9% mercury and 26.1% chlorine by mass. What is the empirical formula?

assume 100g of sample $\quad Hg_xCl_y$

$$73.9\text{ g Hg} \times \frac{1\text{ mol Hg}}{200.59\text{ g Hg}} = 0.368\text{ mol Hg}$$

$$26.1\text{ g Cl} \times \frac{1\text{ mol Cl}}{35.45\text{ g Cl}} = 0.736\text{ mol Cl}$$

Now, divide by smallest mol value:

Hg: $\frac{0.368\text{ mol}}{0.368\text{ mol}} = 1$ $\quad$ Cl $\frac{0.736\text{ mol}}{0.368\text{ mol}} = 2.0006 = 2$

$\therefore$ $\boxed{HgCl_2}$

4. Complete combustion of a 20.10g sample of naphthalene in oxygen yields 69.00g of CO_2 and 11.30g of H_2O. Determine the empirical formula of naphthalene. *4 SF

Naphthalene: $C_xH_yO_z$

combustion chemical equation: $C_xH_yO_z + O_2 \longrightarrow CO_2 + H_2O$

20.10g 69.00g 11.30g

Because we are told this is a complete combustion, all of the carbon and hydrogen must come from naphthalene!

$69.00\,g\,CO_2 \times \frac{1\,mol\,CO_2}{44.01\,g\,CO_2} \times \frac{1\,mol\,C}{1\,mol\,CO_2} = 1.5678\,mol\,C$ $\quad$ $11.30\,g\,H_2O \times \frac{1\,mol\,H_2O}{18.02\,g\,H_2O} \times \frac{2\,mol\,H}{1\,mol\,H_2O} = 1.2511\,mol\,H$

Now let's determine the C:H ratio.

$H: \frac{1.251\,mol}{1.251\,mol} = 1\,mol\,H$ $\quad$ $C: \frac{1.568\,mol}{1.251\,mol} = 1.25 = \frac{5}{4}$ → roughly a 1.25C : 1H ratio $\xrightarrow{(\times 4)}$ 5C : 4H

What about oxygen?

$1.568\,mol\,C \times \frac{12.01\,g\,C}{1\,mol\,C} = 18.83\,g\,C$ $\quad$ $1.251\,mol\,H \times \frac{1.01\,g\,H}{1\,mol\,H} = 1.263\,g\,H$ $\Rightarrow 18.83\,g + 1.263\,g = 20.093\,g \rightarrow 20.10\,g$ ✓

Since we started with a 20.10g sample of naphthalene, we can determine that there is no oxygen in naphthalene!

$\boxed{C_5H_4}$

5. Isoprene is a compound that can be polymerized to form synthetic rubber. It is composed (by mass) of 88.17% carbon and 11.83% hydrogen. Its molar mass is 136.10g/mol. What are the empirical and molecular formulae for isoprene?

trick: determine what the number greater than 1 is equal to in fraction form. Multiple by denominator to get whole numbers for ratio!

assume 100g of sample

Isoprene = C_xH_y

$88.17\,g\,C \times \frac{1\,mol\,C}{12.01\,g\,C} = 7.341\,mol\,C$

$11.83\,g\,H \times \frac{1\,mol\,H}{1.01\,g\,H} = 11.71\,mol\,H$

$\Rightarrow$ Establish ratio!

$C: \frac{7.341\,mol}{7.341\,mol} = 1$

$H: \frac{11.71\,mol}{7.341\,mol} = 1.59 \approx 1.6 = \frac{8}{5}$

$1.6\,H : 1\,C \xrightarrow{(\times 5)} 8\,H : 5\,C$ $\quad \therefore$ empirical formula C_5H_8 $\Rightarrow 1\,mol\,C_5H_8 = 68.13\,g$

$\frac{136.10\,g}{68.13\,g} \approx 2$ $\quad \therefore$ molecular formula $\boxed{C_{10}H_{16}}$

6. A large family of boron-hydrogen compounds has the general formula B_xH_y. One member of this family contains 88.5% boron (by mass); the remainder is hydrogen. What is its empirical formula?

*assume 100g sample

100g B_xH_y − 88.5g B = 11.5g H

$88.5\text{ g B} \times \frac{1\text{ mol B}}{10.81\text{ g B}} = 8.187\text{ mol B}$

$11.5\text{ g H} \times \frac{1\text{ mol H}}{1.01\text{ g H}} = 11.39\text{ mol H}$

Establish ratio!

B: $\frac{8.187\text{ mol}}{8.187\text{ mol}} = 1$

H: $\frac{11.39\text{ mol}}{8.187\text{ mol}} \approx 1.4 = 7/5$

1 B : 1.4 H $\xrightarrow{\times 5}$ 5 B : 7 H ∴ empirical formula $\boxed{B_5H_7}$

CHALLENGE

7. Valproic acid, which is used to treat seizures and bipolar disorder, is composed of C, H, and O. A 0.165-gram sample is combusted, yielding 0.166g of H_2O and 0.403g of CO_2. The molar mass of valproic acid is 144g/mol. What are the empirical and molecular formulas?

0.165g 0.403g 0.166g

General combustion reaction: $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$

* very similar setup to #4, but now we know there is oxygen in valproic acid...

The carbon and hydrogen in the CO_2 and H_2O must be derived from valproic acid.

The oxygen in the CO_2 and H_2O (products) is derived from BOTH O_2 and valproic acid

$0.166\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.02\text{ g } H_2O} \times \frac{2\text{ mol H}}{1\text{ mol } H_2O} = 0.0184\text{ mol}$

$0.403\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44.01\text{ g } CO_2} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} = 0.00916\text{ mol C}$

0.165g of valproic acid is combusted

$0.00916\text{ mol C} \times \frac{12.01\text{ g C}}{1\text{ mol C}} = 0.11\text{g C}$

$0.0184\text{ mol H} \times \frac{1.01\text{ g H}}{1\text{ mol H}} = 0.0186\text{g H}$

Now, to determine the amount (in grams) of oxygen that came from valproic acid we subtract the masses of C and H from the sample mass!

$0.165\text{g } C_xH_yO_z - (0.11\text{g C} + 0.0186\text{g H}) = 0.0364\text{ g O}$

now we can calculate mols O in valproic acid → $0.0364\text{ g O} \times \frac{1\text{ mol O}}{16.00\text{ g O}} = 0.00228\text{ mol O}$

Establish integer ratio by dividing mol amounts by smallest mol value

C: $\frac{0.00916\text{ mol}}{0.00228\text{ mol}} \approx 4$ H: $\frac{0.0184\text{ mol}}{0.00228\text{ mol}} \approx 8$ O: $\frac{0.00228\text{ mol}}{0.00228\text{ mol}} = 1$

⟹ 4C : 8H : 1O ∴ Empirical formula = $\boxed{C_4H_8O}$

To determine molecular formula, divide given molar mass by molar mass of empirical formula: $\frac{144\text{ g/mol}}{72\text{ g/mol}} = 2$

∴ molecular formula = $\boxed{C_8H_{16}O_2}$