CHEM 103
R&R 6
6 June 2024
Adapted from a 10 June 2020 document

1. Vanillin, the dominant flavoring in vanilla, contains C, H, and O. When 1.05 g of this substance is completely combusted, 2.43 g CO_2 and 0.50 g H_2O are produced. What is the empirical formula of vanillin?

2. A mixture of N_2 (g) and H_2 (g) reacts in a closed container to form ammonia, NH_3 (g). The reaction ceases before either reactant has been totally consumed. At this stage, 3.0 mol N_2, 3.0 mol H_2, and 3.0 mol NH_3 are present. How many moles of N_2 and H_2 were present originally?

3. A mixture containing $KClO_3$, $KHCO_3$, K_2CO_3, and KCl was heated, producing CO_2, O_2, and H_2O gases according to the following equations:

$$2\ KClO_3\ (s) \rightarrow 2\ KCl\ (s) + 3\ O_2\ (g)$$

$$2\ KHCO_3\ (s) \rightarrow K_2O\ (s) + H_2O\ (g) + 2\ CO_2\ (g)$$

$$K_2CO_3\ (s) \rightarrow K_2O\ (s) + CO_2\ (g)$$

The KCl and K_2O do not react under the conditions of the reaction. If 100.0 g of the mixture produces 1.80 g H_2O, 13.20 g CO_2, and 4.00 g O_2, what was the composition of the original mixture? (Assume complete decomposition of the mixture.)

4. Your friend has heard that she can make ethanol by reacting C_2H_4 with H_2O under acidic conditions, but she's not sure how much of each starting material she needs. She randomly mixes 101.7 g C_2H_4 with 55.19 g H_2O.

$$C_2H_4 + H_2O \rightarrow C_2H_6O$$

a. What is the theoretical yield of ethanol in mL? (ethanol density = 0.789 g mL^{-1})

b. Which reactant is in excess? How much of it remains, by mass?

5. Complete and balance the following molecular equations, and then write the net ionic equation for each. (Note: in past answer keys, we have written H^+ in net ionic equations, but it is more correct to write H_3O^+ instead. H^+ doesn't actually exist by itself in solution.)

a. $HBr\ (aq) + NH_3\ (aq) \rightarrow$

b. Aqueous hydrochloric acid and sodium acetate

c. Aqueous perchloric acid and aqueous strontium hydroxide

6. Give the oxidation number of each element in the following compounds:

a. BrO_3^-

b. H_2SO_4

c. CrO_4^{2-}

d. HCO_3^-

e. $LiAlH_4$

7. Starting with solid sucrose, $C_{12}H_{22}O_{11}$, describe how you would:

a. Prepare 250 mL of a 0.250 M sucrose solution

b. Prepare 350.0 mL of 0.100 M $C_{12}H_{22}O_{11}$ starting with 3.00 L of 1.50 M $C_{12}H_{22}O_{11}$

c. (Optional) if you have some beverage that contains sucrose—lemonade, soft drink, etc.—calculate the molarity of sucrose for that drink.

8. A 0.180 g sample of caffeine is combusted to yield 0.326 g CO_2, 0.0835 g H_2O, and 0.171 g NO_2. The molar mass of caffeine is 194.20 g mol^{-1}.

a. Provide the empirical and molecular formulae for caffeine.

b. According to a cursory Google search, 237 mL of coffee contains 95 mg of caffeine. What is the concentration of caffeine in coffee?