CHEM 103
R&R 4
4 June 2024
Adapted from an 8 June 2021 document

1. The combustion of 1.38 g of a compound which contains C, H, O, and N yields 1.72 g CO_2 and 1.18 g H_2O. Another sample of the compound with a mass of 22.34 g is found to contain 6.75 g O. What is the empirical formula of the compound?

Equation: $C_wH_xN_yO_z + O_2 \rightarrow CO_2 + H_2O + NO_2$

$1.72\ g\ CO_2 \cdot \frac{mol\ CO_2}{44.01\ g\ CO_2} \cdot \frac{mol\ C}{mol\ CO_2} = 0.0391\ mol\ C \Leftrightarrow 0.470\ g\ C$

$1.18\ g\ H_2O \cdot \frac{mol\ H_2O}{18.02\ g\ H_2O} \cdot \frac{2\ mol\ H}{mol\ H_2O} = 0.131\ mol\ H \Leftrightarrow 0.132\ g\ H$

$1.38\ g\ compound \cdot \frac{6.75\ g\ O}{22.34\ g\ compound} \cdot \frac{mol\ O}{16.00\ g\ O} = 0.0261\ mol\ O \Leftrightarrow 0.416\ g\ O$

$0.0260\ mol\ N \Leftrightarrow 0.362\ g\ N$

1.5 : 6 : 1 : 1 ratio

emp. form. is $C_3H_{10}N_2O_2$

2. Write balanced equations corresponding to the following descriptions.

a. When hydrogen sulfide gas is passed over hot solid iron(III) hydroxide, the resultant reaction produces solid iron(III) sulfide and gaseous water.

$3\ H_2S(g) + 2\ Fe(OH)_3(s) \rightarrow Fe_2S_3(s) + 6\ H_2O(g)$

b. When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphorous acid, H_3PO_3 (aq), and aqueous hydrochloric acid.

$PCl_3(l) + 3\ H_2O(l) \rightarrow H_3PO_3(aq) + 3\ HCl(aq)$

c. The complete combustion of acetic acid (CH_3COOH), the main active ingredient in vinegar.

$CH_3COOH(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

3. Washing soda is a compound used to prepare hard water for washing laundry. Its formula is represented as $Na_2CO_3 \cdot x\ H_2O$, where x is the number of moles of H_2O per mole of Na_2CO_3. When a 2.558 g sample of washing soda is heated, all of the water of hydration is lost, leaving 0.948 g of anhydrous Na_2CO_3 left. What is x?

$0.948\ g\ Na_2CO_3 \cdot \frac{mol\ Na_2CO_3}{105.99\ g\ Na_2CO_3} = 0.00894\ mol\ Na_2CO_3$

$1.610\ g\ H_2O \cdot \frac{mol\ H_2O}{18.02\ g\ H_2O} = 0.0893\ mol\ H_2O$

1:10 ratio

$x = 10$

4. Determine the oxidation number of each element in each of the following substances:

a. SO_2 S +4 O −2

b. $COCl_2$ C +4 O −2 Cl −1

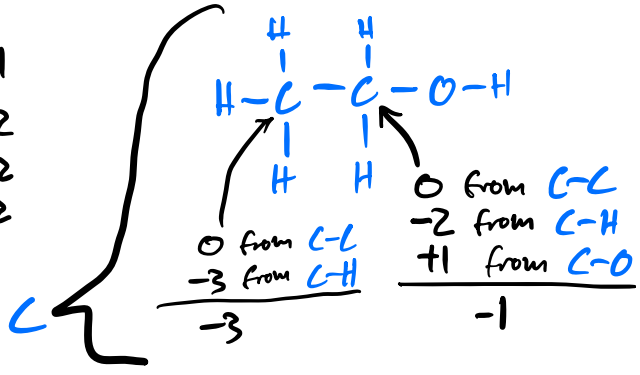
c. $HBrO$ H +1 Br +1 O −2

d. $BaCrO_4$ Ba +2 Cr +6 O −2

e. $HClO_4$ H +1 Cl +7 O −2

f. PO_4^{3-} P +5 O −2

g. CH_3CH_2OH H +1 O −2



5. Which of the following are redox reactions? For reaction that are, indicate which elements are being oxidized and reduced. For reactions that are not, indicate whether they are neutralization or precipitation reactions.

a. $\overset{0}{P_4}\ (s) + 10\ \overset{+1\ +1\ -2}{HClO}\ (aq) + 6\ \overset{+1\ -2}{H_2O}\ (l) \rightarrow 4\ \overset{+1\ +5\ -2}{H_3PO_4}\ (aq) + 10\ \overset{+1\ -1}{HCl}\ (aq)$ REDOX

P: OX, Cl: RED

b. $\overset{0}{Br_2}\ (l) + 2\ \overset{0}{K}\ (s) \rightarrow 2\ \overset{+1\ -1}{KBr}\ (s)$ REDOX

Br: RED, K: OX

c. $CH_3CH_2OH\ (l) + 3\ \overset{0}{O_2}\ (g) \rightarrow 3\ H_2O\ (l) + 2\ \overset{+4\ -2}{CO_2}\ (g)$ REDOX

C: OX, O: RED

d. $ZnCl_2\ (aq) + 2\ NaOH\ (aq) \rightarrow Zn(OH)_2\ (s) + 2\ NaCl\ (aq)$ precip.

★ check oxidation numbers to be sure.

6. Write the overall balanced equation, total ionic equation, and net ionic equations for each of the following cases. Identify the spectator ions.

a. $Cr_2(SO_4)_3$ (aq) + 3 $(NH_4)_2CO_3$ (aq) → $3(NH_4)_2SO_4(aq) + Cr_2(CO_3)_3(s)$

total: $2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 6NH_4^+(aq) + 3CO_3^{2-}(aq) \rightarrow 6NH_4^+(aq) + 3SO_4^{2-}(aq) + Cr_2(CO_3)_3(s)$

net: $2Cr^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow Cr_2(CO_3)_3(s)$ } spectators: NH_4^+, SO_4^{2-}

b. $Ba(NO_3)_2$ (aq) + K_2SO_4 (aq) → $2KNO_3(aq) + BaSO_4(s)$

total: $Ba^{2+}(aq) + 2NO_3^-(aq) + 2K^+(aq) + SO_4^{2-}(aq) \rightarrow 2K^+(aq) + 2NO_3^-(aq) + BaSO_4(s)$

net: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ } spectators: K^+, NO_3^-

c. $Fe(NO_3)_2$ (aq) + 2 KOH (aq) → $2KNO_3(aq) + Fe(OH)_2(s)$

total: $Fe^{2+}(aq) + 2NO_3^-(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow 2K^+(aq) + 2NO_3^-(aq) + Fe(OH)_2(s)$

net: $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ } spectators: K^+, NO_3^-

7. Write the balanced chemical and net ionic equations for the following situations.

a. Reaction of acetic acid (CH_3COOH) with water

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

net ionic is same.

★ acetic acid is a weak acid.

b. HCl (aq) + NaOH (aq) → $NaCl(aq) + H_2O(l)$

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

c. HCN (aq) + KOH (aq) → $KCN(aq) + H_2O(l)$ (hint: HCN is a weak acid)

$HCN(aq) + OH^-(aq) \rightarrow CN^-(aq) + H_2O(l)$

8.

a. How many grams of PF_5 can be formed from 9.46 g PF_3 and 9.42 g of XeF_4 in the following unbalanced reaction?

$$2PF_3 + XeF_4 \rightarrow 2PF_5 + Xe$$

$9.46\ g\ PF_3 \cdot \frac{mol\ PF_3}{87.97\ g\ PF_3} = 0.1075\ mol\ PF_3$

$9.42\ g\ XeF_4 \cdot \frac{mol\ XeF_4}{207.29\ g\ XeF_4} = 0.04544\ mol\ XeF_4$ ← limiting reactant

$0.04544\ mol\ XeF_4 \cdot \frac{2\ mol\ PF_5}{mol\ XeF_4} \cdot \frac{125.96\ g\ PF_5}{mol\ PF_5} = 11.4\ g\ PF_5$

b. Identify the species being oxidized and the one being reduced. What is the oxidizing agent; what is the reducing agent?

P is oxidized and Xe is reduced.

XeF_4 is the oxidizing agent.

PF_3 is the reducing agent.

9. You combine 0.871 moles of sodium phosphate with 1.23 L of water. What is the molarity of the solutions, of sodium ions, and of phosphate ions?

solution: $(0.871\ mol\ Na_3PO_4)/(1.23\ L) = 0.708\ M\ Na_3PO_4$

$[Na^+]$ $(0.708\ M\ Na_3PO_4) \cdot \frac{3\ mol\ Na^+}{mol\ Na_3PO_4} = 2.12\ M$

$[PO_4^{3-}]$ $(0.708\ M\ Na_3PO_4) \cdot \frac{mol\ PO_4^{3-}}{mol\ Na_3PO_4} = 0.708\ M$

notation meaning "concentration of"

10. I purchased a stock solution of 15 M HNO_3 with the goal of dissolving a penny.

a. If I pour 15 mL of the stock solution into a beaker, how many O atoms are inside the beaker **without** considering the O atoms that are part of the water?

$$0.015\ L \cdot \frac{15\ mol\ HNO_3}{L} \cdot \frac{3\ mol\ O}{mol\ HNO_3} \cdot \frac{6.022\times10^{23}\ atoms\ O}{mol\ O} = 4.1\times10^{23}\ atoms\ O$$

b. How many milliliters of water do I need to add to my beaker to dilute the 15 mL stock solution to a concentration of 3.0 M HNO_3?

moles HNO_3 does not change when adding water.

$$(15\ mL)(15\ M\ HNO_3) = (3.0\ M\ HNO_3)\,V_2 \Rightarrow V_2 = 75\ mL$$

Need to add 60. mL water

c. I successfully diluted my stock solution and was ready to dissolve my penny (yay!). However, I was very clumsy and spilled 34 mL of my stock solution into the beaker of 3.0 M HNO_3. What is the new concentration of nitric acid in the beaker?

From part (b), I had $(75\ mL)(3.0\ M\ HNO_3) = 225\ mmol\ HNO_3$.

I spilled an additional $(34\ mL)(15\ M\ HNO_3) = 510\ mmol\ HNO_3$.

I have 735 mmol HNO_3 in 109 mL

$$\Rightarrow [HNO_3] = \frac{735\ mmol\ HNO_3}{109\ mL} = 6.7\ M$$