CHEM 103
R&R 9
12 June 2024
Adapted from a 15 June 2021 document

1. You mix aqueous silver nitrate with aqueous aluminum chloride and a precipitate forms. You use 200.0 g of aluminum chloride and 325 g of silver nitrate.

a. Write the balanced and net ionic equations.

$3AgNO_3(aq) + AlCl_3(aq) \longrightarrow 3AgCl(s) + Al(NO_3)_3(aq)$

net ionic: $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

b. How much solid can theoretically be produced?

limiting reactant

$200.0\,g\ AlCl_3 \cdot \frac{3\ mol\ Cl^-}{133.341\,g\ AlCl_3} = 4.500\ mol\ Cl^-$; $325\,g\ AgNO_3 \cdot \frac{mol\ Ag^+}{169.878\,g\ AgNO_3} = 1.91\ mol\ Ag^+$

$1.91\ mol\ Ag^+ \cdot \frac{mol\ AgCl}{mol\ Ag^+} \cdot \frac{143.321\,g\ AgCl}{mol\ AgCl} = 274\,g\ AgCl$ theoretical yield

c. After doing the experiment, you got a 92.0% yield. How many chlorine atoms are there in the solid that you made?

$0.920 \cdot 273\,g\ AgCl \cdot \frac{mol\ AgCl}{143.321\,g\ AgCl} \cdot \frac{mol\ Cl}{mol\ AgCl} \cdot \frac{6.022\times10^{23}\ atoms\ Cl}{mol\ Cl} = 1.06\times10^{24}\ atoms\ Cl$

2. The commercial production of nitric acid involves the following reactions. Balance them and identify which ones are redox reactions. For the redox reactions, identify each element's oxidation number, the oxidizing agent (OA), and the reducing agent (RA).

$4\,NH_3(g) + 5\,O_2(g) \rightarrow 4\,NO(g) + 6\,H_2O(g)$ REDOX

(−3 +1 in NH_3; 0 in O_2; +2 −2 in NO; +1 −2 in H_2O)

OA: O_2 RA: NH_3

$2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$ REDOX

(+2 −2 in NO; 0 in O_2; +4 −2 in NO_2)

OA: O_2 RA: NO

$3\,NO_2(g) + H_2O(l) \rightarrow 2\,HNO_3(aq) + NO(g)$ REDOX

(+4 −2 in NO_2; +1 −2 in H_2O; +1 +5 −2 in HNO_3; +2 −2 in NO)

OA: NO_2 RA: NO_2

★ disproportionation, AKA dismutation

3. An oxoacid with the formula $H_xE_yO_z$ has a formula mass of 178 g mol^{-1} and has 13 atoms in its formula unit. The oxoacid is 34.80% element E by mass and 15.38% element E by number of atoms. What is element E, and what is the formula of the oxoacid?

15.38% · 13 atoms = 2 atoms ; 34.80% · 178 $g \cdot mol^{-1}$ = 61.944 $g \cdot mol^{-1}$ from the 2 atoms E.

$\Rightarrow$ E has atomic mass 30.972 $\Rightarrow$ E is phosphorus

$x+z=11$, $x+16z=116 \Rightarrow 15z=105 \Rightarrow z=7$, $x=4$

acid is $H_4P_2O_7$, pyrophosphoric acid

4. Find ΔH_{rxn} for: 3 C (s) + 4 H_2 (g) → C_3H_8 (g). Use these reactions with known ΔH_{rxn}:

C_3H_8 (g) + 5 O_2 (g) → 3 CO_2 (g) + 4 H_2O (g) ΔH_{rxn} = -2043 kJ x (-1)

C (s) + O_2 (g) → CO_2 (g) ΔH_{rxn} = -393.5 kJ x 3

2 H_2 (g) + O_2 (g) → 2 H_2O (g) ΔH_{rxn} = -483.6 kJ x 2

$3CO_2(g) + 4H_2O(g) \longrightarrow C_3H_8(g) + 5O_2(g)$ $\Delta H = +2043$ kJ

$3C(s) + 3O_2(g) \longrightarrow 3CO_2(g)$ $\Delta H = -1180.5$ kJ

$4H_2(g) + 2O_2(g) \longrightarrow 4H_2O(g)$ $\Delta H = -967.2$ kJ

$3C(s) + 4H_2(g) \longrightarrow C_3H_8(g)$ $\Delta H_{rxn} = -105$ kJ

5. When 5.03 g solid potassium hydroxide are dissolved in 100.0 mL distilled water in a coffee-cup calorimeter, the temperature of the liquid increases from 23.0 °C to 34.7 °C. What is the solvation ΔH (the enthalpy for dissolving) in kJ per mole of KOH? Assume the calorimeter absorbs a negligible amount of heat, and because of the large volume of water, that the specific heat of the solution is the same as that of pure water (4.184 J/(g·°C)). The density of water is 1.00 g cm^{-3}.

$$q_{soln} = mc_p\Delta T = \left[\left(100.0\ mL \cdot \frac{1.00\ g}{mL}\right) + 5.03\ g\right] \cdot \frac{4.184\ J}{g \cdot °C}\left(34.7°C - 23.0°C\right) = 5141\ J$$

total mass heated

$$q_{dissolution} + q_{soln} = 0 \Longrightarrow q_{dissolution} = -5141\ J$$

$$5.03\ g\ KOH \cdot \frac{mol}{56.105\ g} = 0.08965\ mol\ KOH$$

$$\Delta H = \frac{-5141\ J}{0.08965\ mol\ KOH} = -57.3\ \frac{kJ}{mol\ KOH}$$

6. Consider the following reaction:

$$2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s) \qquad \Delta H_{rxn} = -1204\ kJ$$

a. Is this reaction exothermic or endothermic?

exothermic b/c $\Delta H_{rxn} < 0$

b. Calculate the amount of heat transferred when 3.55 g solid Mg reacts at constant pressure.

$$q = |n\ \Delta H_{rxn}| = 3.55\ g\ Mg \cdot \frac{mol}{24.305\ g\ Mg} \cdot \frac{1204\ kJ}{2\ mol\ Mg} = 87.9\ kJ$$

c. How many grams of MgO are produced during an enthalpy change of -234 kJ?

$$-234\ kJ \cdot \frac{2\ mol\ MgO}{-1204\ kJ} \cdot \frac{40.304\ g}{mol} = 15.7\ g\ MgO$$

d. How many kilojoules of heat are absorbed when 40.3 g of MgO (s) decomposes into Mg (s) and O_2 (g) at constant pressure?

$$40.3\ g\ MgO \cdot \frac{mol}{40.304\ g} \cdot \frac{1204\ kJ}{2\ mol\ MgO} = 602\ kJ$$

7. Ethanol (C_2H_5OH) is currently blended with gasoline as an automobile fuel.

a. Write a balanced equation for the combustion of liquid ethanol in air.

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

b. Calculate the standard enthalpy change for the reaction, assuming H_2O (g) as a product. Some useful $\Delta H_f°$ values: H_2O (g): -241.82 kJ mol^{-1}; CO_2 (g): -393.5 kJ mol^{-1}; C_2H_5OH (l): -277.7 kJ mol^{-1}.

$$\Delta H_{rxn} = \left[2(\Delta H_f° CO_2) + 3(\Delta H_f° H_2O)\right] - \left[\Delta H_f° C_2H_5OH\right]$$
$$= -1234.8 \text{ kJ} \cdot \text{mol}^{-1}$$

c. Calculate the heat produced per liter of ethanol by combustion of ethanol under constant pressure. Ethanol has a density of 0.789 g mL^{-1}.

$$\frac{1234.8 \text{ kJ}}{\text{mol EtOH}} \cdot \frac{\text{mol EtOH}}{46.07 \text{ g EtOH}} \cdot \frac{0.789 \text{ g}}{\text{mL}} \cdot \frac{1000 \text{ mL}}{\text{L}} = \frac{21100 \text{ kJ}}{\text{L EtOH}}$$

d. Calculate the mass of CO_2 produced per kJ of heat emitted.

$$\frac{\text{mol EtOH}}{1234.8 \text{ kJ}} \cdot \frac{2 \text{ mol } CO_2}{\text{mol EtOH}} \cdot \frac{44.01 \text{ g } CO_2}{\text{mol } CO_2} = 0.07128 \frac{\text{g } CO_2}{\text{kJ}}$$

8.

a. A strontium hydroxide solution is prepared by dissolving 12.50 g $Sr(OH)_2$ in water to make 50.00 mL of solution. What is the molarity of this solution?

$$\frac{12.50 \text{ g } Sr(OH)_2}{50.00 \text{ mL}} \cdot \frac{1000 \text{ mL}}{\text{L}} \cdot \frac{\text{mol } Sr(OH)_2}{121.63 \text{ g } Sr(OH)_2} = 2.055 \text{ M } Sr(OH)_2$$

b. Next, the strontium hydroxide solution prepared in part (a) is used to titrate a nitric acid solution of unknown concentration. Write a balanced chemical equation to represent this reaction.

$$Sr(OH)_2(aq) + 2HNO_3(aq) \longrightarrow Sr(NO_3)_2(aq) + 2H_2O(l)$$

c. If 23.9 mL of the strontium hydroxide solution was needed to neutralize a 37.5 mL sample of the nitric acid solution, what is the concentration of the acid?

$$(2.055 \text{ M } Sr(OH)_2)(23.9 \text{ mL}) \cdot \frac{2 \text{ mol } HNO_3}{\text{mol } Sr(OH)_2} \cdot \frac{1}{37.5 \text{ mL}} = 2.62 \text{ M } HNO_3$$

moles $Sr(OH)_2$ — convert to moles HNO_3 — divide by volume to get concentration