

CHEM 103

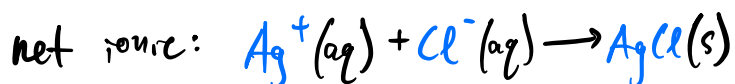
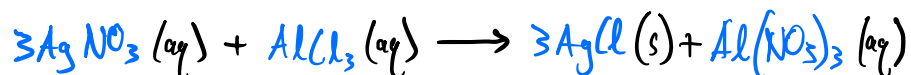
R&R 9

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.



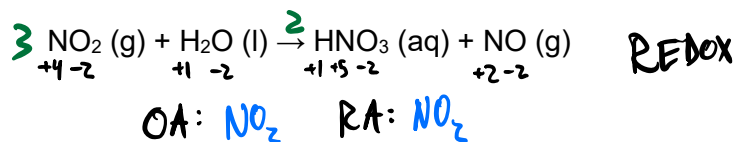
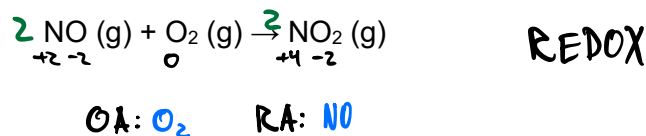
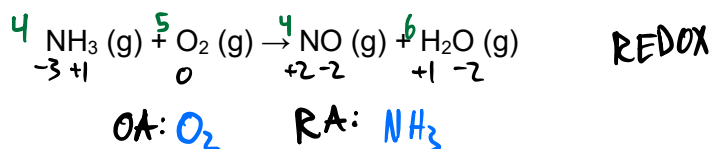
b. How much solid can theoretically be produced?

$$200.0 \text{ g AlCl}_3 \cdot \frac{3 \text{ mol Cl}^-}{133.34 \text{ g AlCl}_3} = 4.500 \text{ mol Cl}^- ; 325 \text{ g AgNO}_3 \cdot \frac{\text{mol Ag}^+}{169.87 \text{ g AgNO}_3} = 1.91 \text{ mol Ag}^+ \quad \text{limiting reactant}$$
$$1.91 \text{ mol Ag}^+ \cdot \frac{\text{mol AgCl}}{\text{mol Ag}^+} \cdot \frac{143.32 \text{ g AgCl}}{\text{mol AgCl}} = 274 \text{ g AgCl} \quad \text{theoretical yield}$$

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

$$0.920 \cdot 273 \text{ g AgCl} \cdot \frac{\text{mol AgCl}}{143.32 \text{ g AgCl}} \cdot \frac{\text{mol Cl}}{\text{mol AgCl}} \cdot \frac{6.022 \times 10^{23} \text{ atoms Cl}}{\text{mol Cl}} = 1.06 \times 10^{24} \text{ atoms Cl}$$

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).



★ disproportionation, AKA dismutation

3. An oxoacid with the formula  $H_xE_yO_z$  has a formula mass of  $178 \text{ g mol}^{-1}$  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?

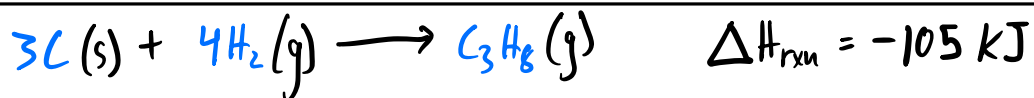
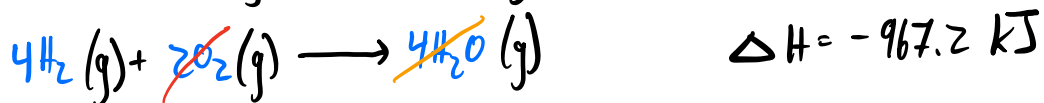
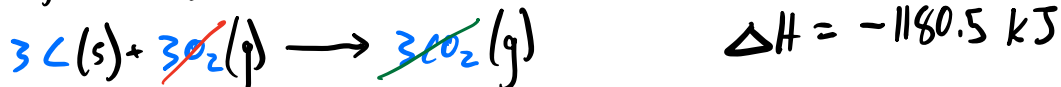
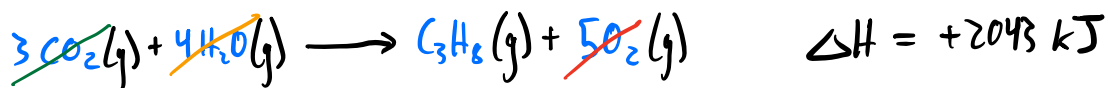
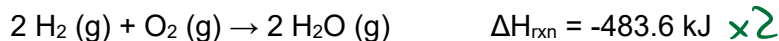
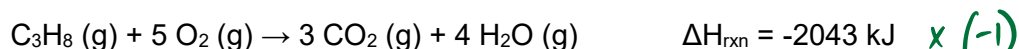
$$15.38\% \cdot 13 \text{ atoms} = 2 \text{ atoms} ; 34.80\% \cdot 178 \text{ g} \cdot \text{mol}^{-1} = 61.944 \text{ g} \cdot \text{mol}^{-1} \text{ from the 2 atoms E.}$$

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

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

acid is  $H_4P_2O_7$ , pyrophosphoric acid

4. Find  $\Delta H_{\text{rxn}}$  for:  $3 \text{ C (s)} + 4 \text{ H}_2 \text{ (g)} \rightarrow \text{C}_3\text{H}_8 \text{ (g)}$ . Use these reactions with known  $\Delta H_{\text{rxn}}$ :



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  $\Delta H$  (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<sup>-3</sup>.

$$q_{\text{soln}} = m c_p \Delta T = \left[ \underbrace{\left( 100.0 \text{ mL} \cdot \frac{1.00 \text{ g}}{\text{mL}} \right) + 5.03 \text{ g}}_{\text{total mass heated}} \right] \cdot \frac{4.184 \text{ J}}{\text{g} \cdot ^\circ\text{C}} (34.7^\circ\text{C} - 23.0^\circ\text{C}) = 5141 \text{ J}$$

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

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

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

6. Consider the following reaction:



a. Is this reaction exothermic or endothermic?

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

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

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

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

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

d. How many kilojoules of heat are absorbed when 40.3 g of MgO (s) decomposes into Mg (s) and O<sub>2</sub> (g) at constant pressure?

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

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.



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

$$\begin{aligned}\Delta H_{rxn} &= [2(\Delta H_f^\circ CO_2) + 3(\Delta H_f^\circ H_2O)] - [\Delta H_f^\circ C_2H_5OH] \\ &= -1234.8 \text{ kJ} \cdot \text{mol}^{-1}\end{aligned}$$

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

$$\frac{1234.8 \text{ kJ}}{\text{mol } C_2H_5OH} \cdot \frac{\text{mol } C_2H_5OH}{46.07 \text{ g } C_2H_5OH} \cdot \frac{0.789 \text{ g}}{\text{mL}} \cdot \frac{1000 \text{ mL}}{\text{L}} = \frac{21100 \text{ kJ}}{\text{L } C_2H_5OH}$$

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

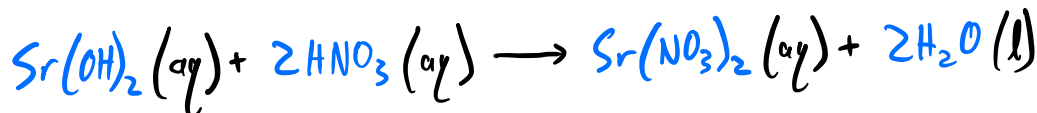
$$\frac{\text{mol } C_2H_5OH}{1234.8 \text{ kJ}} \cdot \frac{2 \text{ mol } CO_2}{\text{mol } C_2H_5OH} \cdot \frac{44.01 \text{ g } CO_2}{\text{mol } CO_2} = 0.07128 \frac{\text{g } CO_2}{\text{kJ}}$$

8.

a. A strontium hydroxide solution is prepared by dissolving  $12.50 \text{ g Sr(OH)}_2$  in water to make  $50.00 \text{ mL}$  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.



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

$$\underbrace{(2.055 \text{ M } Sr(OH)_2)(23.9 \text{ mL})}_{\text{moles } Sr(OH)_2} \cdot \underbrace{\frac{2 \text{ mol } HNO_3}{\text{mol } Sr(OH)_2}}_{\text{convert to moles } HNO_3} \cdot \underbrace{\frac{1}{37.5 \text{ mL}}}_{\text{divide by volume to get concentration}} = 2.62 \text{ M } HNO_3$$