CH 221 Practice Problem Set #5

*This is a **practice problem set** and not the actual graded problem set that you will turn in for credit.*
Answers to each problem can be found at the end of this assignment.

Covering: **Chapter Three (3.3-3.4), Chapter Five** *and* **Chapter Guide Five**
Important Tables/Constants: **$C(H_2O)$ = 4.184 J g^{-1} K^{-1}**, **$\log_{10}$ x = ln x / ln 10** *and the* ***Thermodynamic Values*** *found in problem set #5 and here:* **http://mhchem.org/thermo**

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1. Determine the oxidation number of each element in the following ions or compounds.
   a. BrO_3^- b. $C_2O_4^{2-}$ c. F^- d. CaH_2 e. H_4SiO_4 f. HSO_4^-
2. Which two of the following reactions are oxidation–reduction reactions? Explain your answer in each case. Classify the remaining reaction.
   a. $Zn(s) + 2\ NO_3^{-1}(aq) + 4\ H^+(aq) \rightarrow Zn^{2+}(aq) + 2\ NO_2(g) + 2\ H_2O(l)$
   b. $Zn(OH)_2(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + 2\ H_2O(l)$
   c. $Ca(s) + 2\ H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$
3. In the following reactions, decide which reactant is oxidized and which is reduced. Designate the oxidizing agent and the reducing agent.
   a. $C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$
   b. $Si(s) + 2\ Cl_2(g) \rightarrow SiCl_4(l)$
4. Some potassium dichromate ($K_2Cr_2O_7$), 2.335 g, is dissolved in enough water to make exactly 500. mL of solution. What is the molar concentration of the potassium dichromate? What are the molar concentrations of the K^+ and $Cr_2O_7^{2-}$ ions?
5. For each solution, identify the ions that exist in aqueous solution, and specify the concentration of each ion.
   a. 0.25 M $(NH_4)_2SO_4$
   b. 0.123 M Na_2CO_3
   c. 0.056 M HNO_3
6. A table wine has a pH of 3.40. What is the hydrogen ion concentration of the wine? Is it acidic or basic?
7. What volume of 0.109 M HNO_3, in milliliters, is required to react completely with 2.50 g of $Ba(OH)_2$? $2\ HNO_3(aq) + Ba(OH)_2(s) \rightarrow 2\ H_2O(l) + Ba(NO_3)_2(aq)$
8. You have 0.954 g of an unknown acid, H_2A, which reacts with NaOH according to the balanced equation: **$H_2A(aq) + 2\ NaOH(aq) \rightarrow Na_2A(aq) + 2\ H_2O(l)$** If 36.04 mL of 0.509 M NaOH is required to titrate the acid to the equivalence point, what is the molar mass of the acid?
9. `The specific heat capacity of copper is 0.385 J/g·K. What quantity of heat is required to heat 168 g of copper from -12.2 °C to +25.6 °C?
10. The initial temperature of a 344 g sample of iron is 18.2 °C. If the sample absorbs 2.25 kJ of heat, what is its final temperature? C_{Fe} = 0.449 J/g·K
11. One beaker contains 156 g of water at 22 °C and a second beaker contains 85.2 g of water at 95 °C. The water in the two beakers is mixed. What is the final water temperature?
12. A 237 g piece of molybdenum, initially at 100.0 °C, is dropped into 244 g of water at 10.0 °C. When the system comes to thermal equilibrium, the temperature is 15.3 °C. What is the specific heat capacity of molybdenum?

13. What quantity of heat is required to vaporize 125 g of benzene, C_6H_6, at its boiling point, 80.1 °C? The heat of vaporization of benzene is 30.8 kJ/mol.
14. Isooctane (2,2,4-trimethylpentane), one of the many hydrocarbons that make up gasoline, burns in air to give water and carbon dioxide.

$$2\ C_8H_{18}(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(l) \quad \Delta H^\circ_{rxn} = -10{,}922\ \text{kJ}$$

If you burn 1.00 L of isooctane (density = 0.69 g/mL), what quantity of heat is evolved?

15. The enthalpy changes for the following reactions can be measured:

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g) \qquad \Delta H^\circ = -802.4\ \text{kJ}$$
$$CH_3OH(g) + {}^3/_2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g) \qquad \Delta H^\circ = -676\ \text{kJ}$$

Use these values and Hess's law to determine the enthalpy change for the reaction:

$$CH_4(g) + {}^1/_2\ O_2(g) \rightarrow CH_3OH(g) \qquad \Delta H^\circ = ?$$

16. Enthalpy changes for the following reactions can be determined experimentally:

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g) \qquad \Delta H^\circ = -91.8\ \text{kJ}$$
$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g) \qquad \Delta H^\circ = -906.2\ \text{kJ}$$
$$H_2(g) + {}^1/_2\ O_2\ (g) \rightarrow H_2O(g) \qquad \Delta H^\circ = -241.8\ \text{kJ}$$

Use these values to determine the enthalpy change for the formation of NO(g) from the elements (an enthalpy change that cannot be measured directly because the reaction is reactant-favored) of

$${}^1/_2\ N_2(g) + {}^1/_2\ O_2(g) \rightarrow NO(g) \qquad \Delta H^\circ = ?$$

17. Write a balanced chemical equation for the formation of Li_2CO_3(s) from the elements in their standard states. Find the value of ΔH_f° for Li_2CO_3(s) in the appendix of your textbook.
18. Use standard heats of formation in the appendix of your textbook to calculate standard enthalpy changes for the following:
    a. 1.0 g of white phosphorus burns, forming P_4O_{10}(s)
    b. 0.20 mol of NO(g) decomposes to N_2(g) and O_2(g)
    c. 2.40 g of NaCl is formed from Na(s) and excess Cl_2(g)
    d. 250 g of iron is oxidized with oxygen to Fe_2O_3(s)
19. The Romans used calcium oxide, CaO, to produce a strong mortar to build stone structures. The CaO was mixed with water to give $Ca(OH)_2$, which reacted slowly with CO_2 in the air to give $CaCO_3$. **$Ca(OH)_2(s) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(g)$**
    a. Calculate the standard enthalpy change for this reaction.
    b. What quantity of heat is evolved or absorbed if 1.00 kg of $Ca(OH)_2$ reacts with a stoichiometric amount of CO_2?

Answers to the Practice Problem Set:

1. *Answers:*
   a. Br is +5 and O is –2
   b. C is +3 and O is –2
   c. F is –1
   d. Ca is +2 and H is –1
   e. H is +1, Si is +4, and O is –2
   f. H is +1, S is +6, and O is –2
2. *Answers:*
   a. oxidation-reduction reaction
      Oxidation # of Zn changes from 0 to +2, N changes from +5 to +4
   b. acid-base reaction
   c. oxidation-reduction reaction
      Oxidation number of Ca changes from 0 to +2, H from +1 to 0
3. a. C_2H_4 is oxidized / reducing agent; O_2 is reduced / oxidizing agent b. Si is oxidized / reducing agent; Cl_2 is reduced / oxidizing agent
4. $[Cr_2O_7^{2-}] = [K_2Cr_2O_7] = 0.0159$ M, $[K^+] = 0.0318$ M
5. a. 0.50 M NH_4^+; 0.25 M SO_4^{2-} b. 0.246 M Na^+; 0.123 M CO_3^{2-} c. 0.056 M H^+; 0.056 M NO_3^-
6. $[H^+] = 4.0 \times 10^{-4}$ M, acidic
7. 268 mL
8. 104 g/mol
9. 2440 J
10. 32.8 °C
11. 48 °C
12. 0.27 J/g·K
13. 49.3 kJ
14. 3.3 x 10^4 kJ heat evolved
15. -126 kJ
16. 90.3 kJ
17. 2 Li(s) + C(s) + $^3/_2$ O_2(g) → Li_2CO_3(s) $\Delta H_f^\circ = -1216.04$ kJ *(OpenStax)*
18. a. -24 kJ b. -18 kJ c. -16.9 kJ d. -1800 kJ
19. a. -83.1 kJ b. -1120 kJ evolved