

CH 221 Problem Set #5

Covering: Chapter Four, Chapter Five and Chapter Guide Five

Important Tables and/or Constants: $C(\text{H}_2\text{O}) = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$, Table 5.2 pg. 181 (values of C), Table 5.3 pg. 189 (values of ΔH_f°), Appendix C pg. 1112 (values of ΔH_f°), $\log_{10} x = \ln x / \ln 10$

- Determine the oxidation number of each element in the following ions or compounds.
 - PF_6^{-1}
 - $\text{H}_2\text{AsO}_4^{-1}$
 - UO^{2+}
 - N_2O_5
 - POCl_3
 - XeO_4^{2-}
- Which of the following reactions are oxidation-reduction reactions? Explain your answer briefly. Classify the remaining reactions.
 - $\text{CdCl}_2(\text{aq}) + \text{Na}_2\text{S}(\text{aq}) \rightarrow \text{CdS}(\text{s}) + 2 \text{NaCl}(\text{aq})$
 - $2 \text{Ca}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CaO}(\text{s})$
 - $4 \text{Fe}(\text{OH})_2(\text{aq}) + 2 \text{H}_2\text{O}(\ell) + \text{O}_2(\text{g}) \rightarrow 4 \text{Fe}(\text{OH})_3(\text{aq})$
 - $\text{MgCO}_3(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\ell) + \text{CO}_2(\text{g})$
- In the following reactions, decide which reactant is oxidized and which is reduced. Designate the oxidizing agent and the reducing agent.
 - $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 3 \text{Sn}^{2+}(\text{aq}) + 14 \text{H}^+(\text{aq}) \rightarrow 2 \text{Cr}^{3+}(\text{aq}) + 3 \text{Sn}^{4+}(\text{aq}) + 7 \text{H}_2\text{O}(\ell)$
 - $\text{FeS}(\text{s}) + 3 \text{NO}_3^{-1}(\text{aq}) + 4 \text{H}^+(\text{aq}) \rightarrow 3 \text{NO}(\text{g}) + \text{SO}_4^{2-}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) + 2 \text{H}_2\text{O}(\ell)$
- What is the mass of solute, in grams, in 125 mL of a $1.023 \times 10^{-3} \text{ M}$ solution of Na_3PO_4 ? What are the molar concentrations of Na^+ and PO_4^{3-} ions?
- For each solution, identify the ions that exist in aqueous solution and specify the concentration of each ion.
 - 0.12 M BaCl_2
 - 0.0125 M CuSO_4
 - 0.500 M $\text{K}_2\text{Cr}_2\text{O}_7$
- A saturated solution of milk of magnesia, $\text{Mg}(\text{OH})_2$, has a pH of 10.5. What is the hydrogen ion concentration of the solution? Is the solution acidic or basic?
- What mass of Na_2CO_3 , in grams, is required for complete reaction with 50.0 mL of 0.125 M HNO_3 ?
 $\text{Na}_2\text{CO}_3(\text{aq}) + 2 \text{HNO}_3(\text{aq}) \rightarrow 2 \text{NaNO}_3(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\ell)$
- Potassium hydrogen phthalate, $\text{KHC}_8\text{H}_4\text{O}_4$, is used to standardize solutions of bases. The acidic anion reacts with strong bases according to the net ionic equation shown below. If a 0.902 g sample of potassium hydrogen phthalate is dissolved in water and titrated to the equivalence point with 26.45 mL of NaOH , what is the molar concentration of the NaOH ?
 $\text{HC}_8\text{H}_4\text{O}_4^{-1}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{C}_8\text{H}_4\text{O}_4^{-2}(\text{aq}) + \text{H}_2\text{O}(\ell)$
- What quantity of heat is required to raise the temperature of 50.00 mL of water from 25.52 °C to 28.75 °C? The density of water at this temperature is 0.997 g/mL.
- After absorbing 1.850 kJ of heat, the temperature of a 0.500 kg block of copper is 37 °C. What was the initial temperature of the copper? $C_{\text{Cu}} = 0.385 \text{ J/g}^\circ\text{C}$

Problem Set #5 continues on next page

Problem Set #5, Continued from previous page

11. A 45.5 g sample of copper at 99.8 °C is dropped into a beaker containing 152 g of water at 18.5 °C. What is the final temperature when thermal equilibrium is reached? $C_{\text{Cu}} = 0.385 \text{ J/g}^\circ\text{C}$
12. Chloromethane, CH_3Cl , arises from the oceans and from microbial fermentation and is found throughout the environment. It is used in the manufacture of various chemicals and has been used as a topical anesthetic. What quantity of heat must be absorbed to convert 92.5 g of liquid to a vapor at its boiling point, -24.09°C ? The heat of vaporization of CH_3Cl is 21.40 kJ/mol.
13. Calcium carbide, CaC_2 , is manufactured by the reaction of CaO with carbon at high temperatures. Calcium carbide can then be used to make acetylene. Using the reaction below, is this reaction endothermic or exothermic? If 10.0 g of CaO is allowed to react with an excess of carbon, what quantity of heat is absorbed or evolved by the reaction?
- $$\text{CaO(s)} + 3 \text{C(s)} \rightarrow \text{CaC}_2\text{(s)} + \text{CO(g)} \quad \Delta H_{\text{rxn}}^\circ = +464.8 \text{ kJ}$$
14. A piece of chromium metal with a mass of 24.26 g is heated in boiling water to 98.3°C and then dropped into a coffee cup calorimeter containing 82.3 g of water at 23.3°C . When thermal equilibrium is reached, the final temperature is 25.6°C . Calculate the specific heat of the chromium.
15. The enthalpy changes of the following reactions can be measured:
- $$\text{C}_2\text{H}_4\text{(g)} + 3 \text{O}_2\text{(g)} \rightarrow 2 \text{CO}_2\text{(g)} + 2 \text{H}_2\text{O(l)} \quad \Delta H^\circ = -1411.1 \text{ kJ}$$
- $$\text{C}_2\text{H}_5\text{OH(l)} + 3 \text{O}_2\text{(g)} \rightarrow 2 \text{CO}_2\text{(g)} + 3 \text{H}_2\text{O(l)} \quad \Delta H^\circ = -1367.5 \text{ kJ}$$
- Use these values and Hess's law to determine the enthalpy change for the reaction:
- $$\text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{O(l)} \rightarrow \text{C}_2\text{H}_5\text{OH(l)}$$
16. You wish to know the enthalpy change for the formation of liquid PCl_3 from the elements:
- $$\frac{1}{4} \text{P}_4\text{(s)} + \frac{3}{2} \text{Cl}_2\text{(g)} \rightarrow \text{PCl}_3\text{(l)}$$
- The enthalpy change for the formation of solid PCl_5 from the elements can be determined experimentally, as can the enthalpy change for the reaction of $\text{PCl}_3\text{(l)}$ with more chlorine to give $\text{PCl}_5\text{(s)}$. Use the equations below to calculate the enthalpy change for the formation of 1.00 mol $\text{PCl}_3\text{(l)}$ from phosphorus and chlorine.
- $$\text{P}_4\text{(s)} + 10 \text{Cl}_2\text{(g)} \rightarrow 4 \text{PCl}_5\text{(s)} \quad \Delta H^\circ = -1774.0 \text{ kJ}$$
- $$\text{PCl}_3\text{(l)} + \text{Cl}_2\text{(g)} \rightarrow \text{PCl}_5\text{(s)} \quad \Delta H^\circ = -123.8 \text{ kJ}$$
17. Write a balanced chemical equation for the formation of $\text{CaCO}_3\text{(s)}$ from the elements in their standard states. Find the value of ΔH_f° for $\text{CaCO}_3\text{(s)}$ 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:
- 0.054 g of sulfur burns, forming $\text{SO}_2\text{(g)}$
 - 0.20 mol of HgO(s) decomposes to Hg(l) and $\text{O}_2\text{(g)}$. ($\Delta H_f^\circ = -90.83 \text{ kJ/mol}$ for HgO)
 - 2.40 g of $\text{NH}_3\text{(g)}$ is formed from $\text{N}_2\text{(g)}$ and excess $\text{H}_2\text{(g)}$
 - 1.05×10^{-2} mol of carbon is oxidized to $\text{CO}_2\text{(g)}$
19. The first step in the production of nitric acid from ammonia involves the oxidation of NH_3 :
- $$4 \text{NH}_3\text{(g)} + 5 \text{O}_2\text{(g)} \rightarrow 4 \text{NO(g)} + 6 \text{H}_2\text{O(g)}$$
- Use standard enthalpies of formation to calculate the standard enthalpy change for this reaction.
 - What quantity of heat is evolved or absorbed in the formation of 10.0 g of NH_3 ?