2023 Fall Chemistry 2

Assignment 1 (Atkins, Focus 5)

(Total 200 pt; Due 2023/10/4 Class)

1. When sodium chloride dissolves in water, can a chloride ion be removed from the crystal by one water molecule, or are several required to remove it? Explain your answer. [10 pt]

2. Explain how the vapor pressure of a liquid is affected by each of the following changes in conditions: (a) an increase in temperature; (b) an increase in surface area of the liquid; (c) an increase in volume above the liquid; (d) the addition of air to the volume above the liquid. [10 pt]

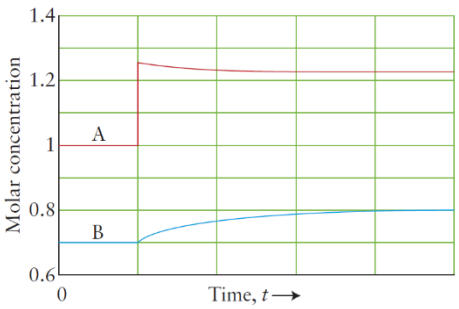
3. The freezing point of benzene is 5.53 °C. Suppose that 10.0 g of an organic compound used as a component of mothballs is dissolved in 80.0 g of benzene. The freezing point of the solution is 1.20 °C. (a) What is an approximate molar mass of the organic compound? (b) An elemental analysis of that substance indicated that the empirical formula is C_3H_2Cl. What is its molecular formula? (c) Using the atomic molar masses from the periodic table, calculate a more accurate molar mass of the compound. [20 pt]

4. (a) From data in Appendix 2A and Table 4C.1, derive a numerical form of the Clausius–Clapeyron equation for benzene. (b) Use the equation to plot the appropriate quantities that should give a straight-line relation between vapor pressure and temperature. (c) Estimate the boiling point of benzene when the external pressure is 0.655 atm. (d) Calculate $S_m°$ for gaseous benzene. [25 pt]

5. The combustion analysis of l-carnitine, an organic compound thought to build muscle strength, reported its composition as 52.16% C, 9.38% H, 8.69% N, and 29.78% O. The osmotic pressure of 100.00 mL of solution containing 0.322 g of l-carnitine in methanol was found to be 0.501 atm at 32 °C. Assuming that l-carnitine does not ionize in methanol, determine (a) the molar mass; (b) the molecular formula of l-carnitine. [15 pt]

6. At 25 °C, $K = 47.9$ for N_2O_4 (g) ↔ 2 NO_2 (g). (a) If 0.180 mol N_2O_4 and 0.0020 mol NO_2 are placed in a reaction vessel of volume 20.0 L and the reaction is allowed to reach equilibrium, what are the equilibrium concentrations of N_2O_4 and NO_2? (b) An additional 0.0020 mol NO_2 is added to the flask. How will this change affect the concentration of N_2O_4? (c) Justify your conclusion by calculating the new equilibrium concentrations of NO_2 and N_2O_4. [25 pt]

7. The following plot shows a system composed of the gaseous compounds A and B in a rigid, constant-volume flask. The system was initially at equilibrium, then a change occurred. (a) Describe the change that occurred and how it affected the system. (b) Write the chemical equation for the reaction that occurred. (c) Calculate the value of K_c for that reaction. [15 pt]



8. The gas phosphine, PH_3, decomposes by the reaction 2 PH_3 (g) → 2 P(s) + 3 H_2 (g). In an experiment, pure phosphine was placed in a rigid, sealed flask of volume 1.00 L at 0.64 bar and 298 K. After equilibrium was attained, the total pressure in the flask was found to be 0.93 bar. (a) Calculate the equilibrium partial pressures of H_2 and PH_3. (b) Calculate the mass (in grams) of P produced once equilibrium was reached. (c) Calculate K for this reaction. [20 pt]

9. A reaction vessel is filled with Cl_2 (g) at 1.00 bar and Br_2 (g) at 1.00 bar, which are allowed to react at 1000. K to form BrCl(g) according to the equation Br_2 (g) + Cl_2 (g) ↔ 2 BrCl (g), K = 0.2. Construct a plot of the reaction Gibbs free energy as a function of partial pressure of BrCl as the reaction approaches equilibrium. [15 pt]

10. Cyclohexane (C) and methylcyclopentane (M) are isomers with the chemical formula C_6H_{12}. The equilibrium constant for the rearrangement C ↔ M in solution is 0.140 at 25 °C. (a) A solution of 0.0200 mol•L^{-1} cyclohexane and 0.100 mol•L^{-1} methylcyclopentane is prepared. Is the system at equilibrium? If not, will it form more reactants or more products? (b) What are the concentrations of cyclohexane and methylcyclopentane at equilibrium? (c) If the temperature is raised to 50 °C, the concentration of cyclohexane becomes 0.100 mol•L^{-1} when equilibrium is re-established. Calculate the new equilibrium constant. (d) Is the reaction exothermic or endothermic at 25 °C? Explain your conclusion. [20 pt]

11. To generate the starting material for a polymer that is used to make water bottles, hydrogen is removed from the ethane in natural gas to produce ethene in the catalyzed reaction C_2H_6 (g) → H_2 (g) + C_2H_4 (g). Use the information in Appendix 2A to calculate the equilibrium constant for the reaction at 298 K. (a) If the reaction is begun by adding the catalyst to a flask containing C_2H_6 at 40.0 bar, what will be the partial pressure of the C_2H_4 at equilibrium? (b) Identify three steps the manufacturer can take to increase the yield of product. [15 pt]

12. Adenosine triphosphate (ATP) is a compound that provides energy for biochemical reactions in the body when it undergoes hydrolysis. For the hydrolysis of ATP at 37 °C (normal body temperature), $\Delta H_r^\circ = -20$ kJ•mol^{-1} and $\Delta S_r^\circ = +34$ J•K^{-1}•mol^{-1}. Assuming that these quantities are independent of temperature, calculate the temperature at which the equilibrium constant for the hydrolysis of ATP becomes greater than 1. [10 pt]