2018 Fall Semester Quiz 5
For General Chemistry I (CH101)

Date: Nov 19 (Mon),   Time: 19:00 ~ 19:45

Professor Name	Class	Student I.D. Number	Name

Use the following constants to solve problems:
Gas constant R = 8.314J/K·mol = 0.08206atm·L/K·mol
T/K = T/°C + 273.15
1 bar = 10^5 Pa = 100J/L

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1. (6 pts, 1 pt each) **Fill in the blank with the correct term. Choose from the words given below.**

Intensive; extensive; reversible; irreversible; open; closed; isolated; internal energy; enthalpy; higher; lower; positive; negative

(a) The first law of thermodynamics states that the total energy of any isolated system is conserved.

(b) Temperature is an intensive property, while volume is an extensive property.

(c) The value of heat transfer in constant pressure processes is equal to the change in enthalpy.

(d) If a nonideal solution has a stronger attraction between solute and solvent molecules than an ideal solution, this nonideal solution has negative deviation.

(e) It would take an infinite amount of time to reach from one thermodynamic state to another state during the reversible process.

(f) The boiling point of a solution is higher than that of pure solvent. The freezing point of a solution is lower than that of pure solvent.

No partial pts

2. (Total 9 pts) **Osmotic pressure is useful for measuring molar masses of large molecules like proteins. Suppose 2.37g of a protein is dissolved in water and diluted to a total volume of 100ml. The total mass of the solution is 102.2g, and the osmotic pressure of the solution is 0.0319 atm at 20°C. For water, K_b = 0.512K·kg/mol.**

(a) (2 pts) **Calculate molarity of this solution.**

$$c_{protein} = \frac{\pi}{RT} = \frac{0.0319\text{atm}}{(0.08206L \cdot atm/mol \cdot K)(293.15K)} = 0.001326M$$

+1 pt for correct equation for osmotic pressure

+1 pt for the correct answer

(b) (2 pts, no partial pts) **Calculate the molar mass of this protein.**

$$M_{protein} = \frac{2.37g/0.1L}{0.001326mol/L} = 1.79 \times 10^4 g/mol$$

+2 pts for the correct answer

(c) (2 pts) **Calculate molality of this solution.**

$$\text{mass of water } w_{water} = 102.2g - 2.37g = 99.83g$$

$$m_{protein} = 2.37g\ protein \times \frac{1\ mol\ protein}{1.79 \times 10^4 g\ protein} \times \frac{1}{0.09983kg\ water} = 0.00133mol/kg$$

+1 pt for correct equation for molality

+1 pt for the correct answer

No pts for the correct answer if the wrong equation is used

(d) (3 pts) **How much is a boiling point deviated from 100°C (boiling point of pure water)? Why is osmotic pressure better than boiling point elevation for measuring the molar mass of the protein?**

$$\Delta T_b = K_b \times m = (0.512K \cdot kg/mol) \times\ 0.00133mol/kg = 6.81 \times 10^{-4} K$$

This change is way too small and difficult to measure accurately. Therefore, osmotic pressure is a much better choice.

+1 pt for correct equation for boiling point elevation

+1 pt for the correct answer

+1 pt for the correct explanation

3. (Total 10 pts) **Consider the following redox reaction in acidic solution.**

$$Cr_2O_7^{2-}(aq) + Fe^{2+}(aq) \rightarrow Cr^{3+}(aq) + Fe^{3+}(aq)$$

(a) (5 pts) **Write a balanced equation for this reaction.**

Step 1. Write oxidation and reduction reactions separately. Balance the number of elements other than oxygen and hydrogen.

$$\text{Oxidation: } Fe^{2+}(aq) \rightarrow Fe^{3+} + e^-(aq)$$

$$\text{Reduction: } Cr_2O_7^{2-}(aq) + 6e^- \rightarrow 2Cr^{3+}(aq)$$

Step 2. Balance the number of oxygen using H_2O.

$$\text{Oxidation: } Fe^{2+}(aq) \rightarrow Fe^{3+} + e^-(aq)$$

$$\text{Reduction: } Cr_2O_7^{2-}(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Step 3. Balance the number of hydrogen using H_3O^+ (acidic).

$$\text{Oxidation: } Fe^{2+}(aq) \rightarrow Fe^{3+} + e^-(aq)$$

$$\text{Reduction: } Cr_2O_7^{2-}(aq) + 14H_3O^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 21H_2O(l)$$

Step 4. Balance the number of electrons and combine the two reactions.

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H_3O^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 21H_2O(l)$$

+1 pt for each correct step, +1 pt for the correct balanced equation

However, to get a point for each step, all the previous steps should be correct.

e.g. Even if step 2 through 4 are correct, you will get NO points if you got step 1 wrong.

e.g. If you get step 1 through 3 right and 4 wrong, you will get 3 points.

e.g. If you get step 1 and 3 right/ 2 and 4 wrong, you will only get 1 point. No credit for step 3, because you got step 2 wrong.

(b) (5 pts) **A solution is prepared by dissolving 5.134g of $K_2Cr_2O_7$ in water and diluting to a total volume of 1.000L. A total of 34.26ml of this solution is required to reach the end point in a titration of a 500.0ml sample containing Fe^{2+} (*aq*). Determine molarity of Fe^{2+} in the original 500.0ml solution. (Note: MW of $K_2Cr_2O_7$ = 294.18g/mol)**

The potassium dichromate solution contains 5.134 g of solute per 1000 mL of solution. 34.26 mL of it brings the titration to the endpoint. The chemical amount of $K_2Cr_2O_7$ that reacts is

$$n_{K_2Cr_2O_7} = 34.26 \text{ mL solution} \times \left(\frac{5.134 \text{ g } K_2Cr_2O_7}{1000 \text{ mL solution}}\right)\left(\frac{1 \text{ mol } K_2Cr_2O_7}{294.18 \text{ g } K_2Cr_2O_7}\right) = 5.979 \times 10^{-4} \text{ mol}$$

In aqueous solution, 1 mol of $Cr_2O_7^{2-}(aq)$ forms for every 1 mol of $K_2Cr_2O_7$ that dissolves. Also, according to the balanced equation (which is a net ionic equation), 1 mol of $Cr_2O_7^{2-}(aq)$ reacts with 6 mol of $Fe^{2+}(aq)$. Cast these facts as unit-factors to compute the chemical amount of Fe^{2+}

$$n_{Fe^{2+}} = 5.979 \times 10^{-4} \text{ mol } K_2Cr_2O_7 \times \left(\frac{1 \text{ mol } Cr_2O_7^{2-}}{1 \text{ mol } K_2Cr_2O_7}\right)\left(\frac{6 \text{ mol } Fe^{2+}}{1 \text{ mol } Cr_2O_7^{2-}}\right) = 0.003587 \text{ mol}$$

This is the amount of Fe^{2+} in 500.0 mL of solution. The amount per liter (1000.0 mL) is twice as much. The concentration of Fe^{2+} in the sample is $\boxed{0.007175 \text{ mol L}^{-1}}$.

+1 pt for the correct mole number of potassium dichromate

+2 pts for the correct mole number of Fe(II) ion

+2 pts for the correct answer

4. (Total 10 pts) **At 40°C, the vapor pressure of pure carbon tetrachloride (MW=153.82g/mol) is 0.293 atm and the vapor pressure of pure dichloroethane (MW = 98.96g/mol) is 0.209 atm. A nearly ideal solution is prepared by mixing 30.0g of carbon tetrachloride with 20.0g of dichloroethane.**

(a) (2 pts) **Calcualte the mole fraction of each component in the solution.**

a) Convert the masses of CCl_4 and $C_2H_4Cl_2$ to chemical amounts by dividing by their respective molar masses

$$n_{CCl_4} = \frac{30.0 \text{ g}}{153.82 \text{ g mol}^{-1}} = 0.1950 \text{ mol} \qquad n_{C_2H_4Cl_2} = \frac{20.0 \text{ g}}{98.96 \text{ g mol}^{-1}} = 0.2021 \text{ mol}$$

Compute the mole fraction of CCl_4 in the solution from these values

$$X_{CCl_4} = \frac{0.1950 \text{ mol}}{(0.1950 + 0.2021) \text{ mol}} = \boxed{0.491}$$

+0.5 pt for the correct mole number of each compound

+1 pt for the correct answer

(b) (2 pts) **Calculate the total vapor pressure of the solution at 40°C.**

b) The total vapor pressure above the solution equals the sum of the partial pressures of the two components in the vapors above the solution. Raoult's law gives these partial pressures. Therefore

$$P_{tot} = P_{CCl_4} + P_{C_2H_4Cl_2} = X_{CCl_4}P^{\circ}_{CCl_4} + X_{C_2H_4Cl_2}P^{\circ}_{C_2H_4Cl_2}$$
$$= (0.491)(0.293 \text{ atm}) + (1 - 0.491)(0.209 \text{ atm}) = \boxed{0.250 \text{ atm}}$$

where the mole fraction of CCl_4 comes from the preceding part, and the vapor pressures of the pure components are given in the problem. The two mole fractions add up to 1 because there are only two components in the solution.

+1 pt for any expression that shows Raoult's law

+1 pt for the correct answer

(c) (3 pts) **Calculate the mole fraction of CCl_4 in the vapor in equilibrium with the solution.**

c) According to Dalton's law of partial pressures, the mole fraction of a component in a gaseous mixture equals its partial pressure divided by the total pressure

$$X_{CCl_4,vap} = \frac{P_{CCl_4}}{P_{tot}}$$

According to Raoult's law, the partial pressure of $CCl_4(g)$ in the vapor above the solution equals its mole fraction in the solution times its vapor pressure when pure

$$X_{CCl_4,vap} = \frac{P_{CCl_4}}{P_{tot}} = \frac{X_{CCl_4}P^{\circ}_{CCl_4}}{P_{tot}}$$

But $P^{\circ}_{CCl_4}$ is given in the problem and X_{CCl_4} was found in part **a)**. Substitution gives

$$X_{CCl_4,vap} = \frac{0.491(0.293 \text{ atm})}{0.250 \text{ atm}} = \boxed{0.575}$$

+1 pt for the equation:

$$X_{CCl_4,vap} = \frac{P_{CCl_4}}{P_{tot}}$$

+2 pts for the correct answer

(d) (3 pts) **If the vapor of this solution is collected and recondensed to form a separate solution, what will be the mole fraction of CCl_4 in the vapor in equilibrium with this new solution at 40°C?**

$$P_{tot} = P_{CCl_4} + P_{C_2H_4Cl_2} = X_{CCl_4}P^{\circ}_{C_2H_4Cl_2} + X_{C_2H_4Cl_2}P^{\circ}_{C_2H_4Cl_2}$$
$$= (0.575)(0.293 \text{ atm}) + (1 - 0.575)(0.209 \text{ atm}) = 0.257 \text{ atm}$$

$$X_{CCl_4,vap} = \frac{0.575(0.293 \text{ atm})}{0.257 \text{ atm}} = 0.655$$

+1 pt for the correct vapor pressure value

+2 pts for the correct mole fraction

5. (5 pts) **Iron pellets with total mas 17.0g at a temperature of 92.0°C are mixed in an insulated container with 17.0g water at temperature of 20°C. The specific heat capacity of water is 10 times greater than that of iron. What is the final temperature of the container?**

This problem can be solved by setting up an equation like the one used to solve problem **12.12**. One can also use the rule derived in problem **12.13**. In the special case of mixing equal masses of substances 1 and 2 at different temperatures

$$\frac{c_{s\,1}}{c_{s\,2}} = -\frac{\Delta t_2}{\Delta t_1}$$

In this problem, this expression becomes

$$0.10 = -\frac{\left(t_f - 20.0°\mathrm{C}\right)}{\left(t_f - 92.0°\mathrm{C}\right)}$$

The minus signs appear in these two equations because of the convention that a change in a quantity is the final value minus the initial. Solving gives $t_f = 26.5°\mathrm{C}$.

+2 pts for any expression that shows:

$$\mathbf{mc_{iron}\Delta T = -mc_{water}\Delta T}$$

+3 pts for the correct answer