CHEM 3423 001 Spring 2024

Name: KEY
ID:

Midterm Exam # 2

Answer Sheet: (All problems are multiple choice. List the letter that corresponds to the correct answer. Maximum number of points you can get is 18 pts!)

Conceptual questions (each **0.75 pts**):
1) C
2) F
3) c
4) C
5) A
6) A
7) C
8) d
9) A
10) B
11) B
12) A

Problems and Calculations (each **1.5 pts**):
1) d
2) F
3) F
4) H
5) A
6) E

Conceptual Questions:

1. Under constant temperature and constant volume conditions, a system is said to be in equilibrium when
    a. $\Delta G < 0$
    b. $\Delta G = 0$
    [✓ c.] $\Delta A = 0$
    d. $\Delta A < 0$
    e. $\Delta S > 0$
    f. $\Delta S = 0$
    g. None of a) – f)

2. For the chemical reaction, $2H \rightarrow H_2$, at constant pressure, the change in Gibb's energy is
    a. $\Delta G = 0$
    b. $\Delta G = \Delta H$
    c. $\Delta G \neq \Delta G$
    d. $\Delta G = \Delta S$
    e. $\Delta G > 0$
    [✓ f.] $\Delta G < 0$
    g. None of a) – f)

3. How many different phases can at most co-exist in a one-component system?
    a. 1
    b. 2
    [✓ c.] 3
    d. 4
    e. 5
    f. none of a) - e)

4. Consider water above the critical temperature Tc,. Which of the following statements is correct for this system?
    a. The number of possible phase depends on the pressure in the system
    b. There will be a liquid vapor transition
    [✓ c.] Only one phase exists.
    d. None of a) – c)

5. In equilibrium, the total Gibbs energy of the reactants and products
    [✓ a.] Is the same
    b. Differs, but has the same sign
    c. Differs in both value and sign
    d. is both zero
    e. adds up to zero
    f. None of a) – e)

6. The following reaction describes dissociation of chlorine into atoms: $Cl_2 \Leftrightarrow 2Cl$.
   If the volume is doubled, the degree of dissociation
   [✓ a.] increases
   b. decreases
   c. depending on temperature may or may not change
   d. None of a) – c)

7. Which statement is true for an ideal solution mixture of two components A and B?
   a. The liquid curve in the temperature-composition phase diagram is a straight line
   b. The vapor curve in the temperature-composition phase diagram is a straight line
   [✓ c.] Raoult's law applies
   d. None of a) – c)

8. A way to shift the equilibrium is to couple the reaction of interest with a second one. To make an unfavorable reaction possible, what is the requirement for the second reaction?
   a. $\Delta G^0_2 < \Delta G^0_1$
   b. $\Delta G^0_2 > \Delta G^0_1$
   c. $\Delta G^0_2 + \Delta G^0_1 > 0$
   [✓ d.] $\Delta G^0_2 + \Delta G^0_1 < 0$
   e. None of a) – d)

9. Consider an ideal solution mixture of components A and B in equilibrium with vapor. A is more volatile than B. Compared to the liquid, the vapor contains
   [✓ a.] More of component A
   b. More of component B
   c. Equal amounts of A and B
   d. None of a) – c)

10. Which of the following is true for an equilibrium constant K_c^0?
    a. Its value does not depend on the units of concentration
    [✓ b.] Its value depends on the stoichiometric equation used in its definition
    c. Its value does not depend on temperature
    d. None of a) – c)

11. For a chemical reaction $A + B \Leftrightarrow C$ we measure an equilibrium constant $K^0 < 1$.
    Under standard conditions, the reaction will proceed spontaneously from
    a. Left to right ($A + B \Rightarrow C$)
    [✓ b.] Right to left ($C \Rightarrow A + B$)

12. Assume a chemical reaction $A + B \Leftrightarrow C$ in equilibrium. When we remove a certain amount of B, the equilibrium
    [✓ a.] Shifts to the left
    b. Shifts to the right
    c. Stays unchanged

Problems and Calculations:

1. In a 25-liter container, at 25°C, and assuming ideal gas behavior, A atoms and B atoms combine to give AB: $A(g) + B(g) \Leftrightarrow AB\ (g)$. Suppose, we put into the container 0.3 mol of A, 0.38 mol of B and 0.02 mol of AB. After reaching equilibrium, only 0.03 mol of A is left. Assuming a standard concentration of 0.5 mol/l, what is K_c^0?
   a. 5113.2
   b. 313.86
   c. 2197.0
   [✓ d.] 1098.5
   e. 511.32
   f. 313.86
   g. 219.70
   h. 109.85
   i. 51.132
   j. none of a) – i)

$\Delta n_A = -0.27\,mol \Rightarrow \Delta n_{AB} = 0.27\,mol,\ \Delta n_B = -0.27\,mol$

$\Rightarrow [A] = \frac{0.03}{25}\frac{mol}{\ell} = 0.0012\frac{mol}{\ell} \Rightarrow [A]^0 = 0.0024$

$[B] = \frac{0.38-0.27}{25}\frac{mol}{\ell} = 0.0044\frac{mol}{\ell} \Rightarrow [B]^0 = 0.0088$

$[AB] = \frac{0.02+0.27}{25}\frac{mol}{\ell} = 0.0116\frac{mol}{\ell} \Rightarrow [AB]^0 = 0.0232$

$$K_c^0 = \frac{[AB]^0}{[A]^0[B]^0} = \frac{0.0232}{0.0024 \cdot 0.0088} = 1098.5$$

2. In an experiment, the vapor pressure of a liquid is measured as 10 kPa at 300K, and as 150 kPa at 400 K. Calculate from these data the enthalpy of vaporization $\Delta_{vap}H$ of the liquid.
   - a. – 27.02 kJ/mol
   - b. -3.25 kJ/mol
   - c. -0,0188 J/mol
   - d. 0.188J/mol
   - e. 3.23 kJ/mol
   - [✓ f.] 27.02 kJ/mol
   - g. None of a) - f)

$$\ln \frac{P_2}{P_1} = \frac{\Delta_{vap} H}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right) = \frac{\Delta_{vap} H}{R} \frac{T_2 - T_1}{T_1 T_2}$$

$$\Rightarrow \Delta_{vap} H = R \cdot \ln \frac{P_2}{P_1} \frac{T_1 T_2}{T_2 - T_1}$$

$$= 8.3145 \cdot \ln \frac{150}{10} \cdot \frac{300 \cdot 400}{100} \ J/mol$$

$$= 8.3145 \cdot 2.7081 \cdot 1200 \ J/mol$$

$$= 27.02 \ kJ/mol$$

3. The ratio of a component A to water collected in a steam distillation is 6, when the mixture was boiled at 344 K and 75 kPa. If the vapor pressure of water at this temperature is 43.2 kPa, calculate the molar mass of A (molar mass of water: 18.02 g/mol)

   a. 21.31 g/mol
   b. 46.08 g/mol
   c. 72.21 g/mol
   d. 90.42 g/mol
   e. 124.82 g/mol
   [✓ f.] 146.88 g/mol
   g. none of a) – f)

$m = n \cdot M$

$$\frac{m_A}{m_{H_2O}} = \frac{n_A \; M_A}{n_{H_2O} \cdot M_{H_2O}} = \frac{p_A^*}{p_{H_2O}^*} \; \frac{M_A}{M_{H_2O}}$$

$$\Rightarrow M_A = \frac{p_{H_2O}^*}{p_A^*} \; \frac{m_A}{m_{H_2O}} \cdot M_{H_2O}$$

$$P = p_A^* + p_{H_2O}^*$$

$$\Rightarrow p_A^* = P - p_{H_2O}^*$$

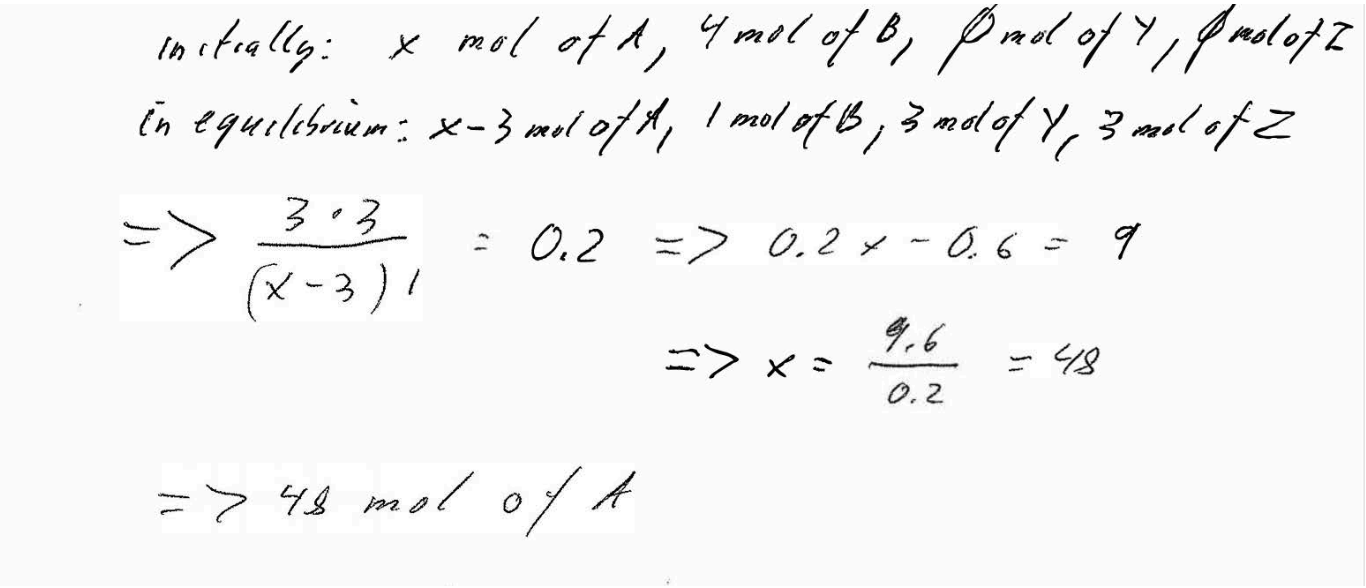
$$= \frac{p_{H_2O}^*}{1 - p_{H_2O}^*} \; \frac{m_A}{m_{H_2O}} \; M_{H_2O}$$

$$= \frac{43.2}{75 - 43.2} \cdot 6 \cdot 18.02 \, g/mol$$

$$= 1.358 \cdot 6 \cdot 18.02 \, g/mol$$

$$= 146.88 \, g/mol$$

4. The equilibrium constant for a reaction A + B ⇔ Y + Z is 0.2. What amount of A must be mixed with 4 mol of B to yield, at equilibrium, 3 mol of Y?
   h. 48 mol
   i. 24 mol
   j. 16 mol
   k. 4.8 mol
   l. 2.4 mol
   m. 1.6 mol
   n. none of a) –f)



Initially: x mol of A, 4 mol of B, 0 mol of Y, 0 mol of Z

in equilibrium: $x-3$ mol of A, 1 mol of B, 3 mol of Y, 3 mol of Z

$$\Rightarrow \frac{3\cdot 3}{(x-3)\,1} = 0.2 \Rightarrow 0.2x - 0.6 = 9$$

$$\Rightarrow x = \frac{9.6}{0.2} = 48$$

$\Rightarrow$ 48 mol of A

5. The Gibbs energies of formation of A(g) and B(g) are 150 kJ/mol and 76 kJ/mol, respectively. The standard state is 1 bar and 300 K. Assume ideal behavior and a reaction A ⇔ 2B. Calculate the pressure where 50% of A is dissociated.

[✓ a.] 0.338 bar
b. 0.450 bar
c. 0.503 bar
d. 0.600 bar
e. 0.802 bar
f. none of a) – e)

$$\Delta G^0 = 152\ KJ/mol - 150\ KJ/mol = 2\ KJ/mol$$

$$= -RT \ln K_p^0$$

$$\Rightarrow \ln K_p^0 = \frac{-\Delta G^0}{RT} = \frac{-2000\ J/mol}{8.3145 \cdot 300\ J/mol} = \frac{-20}{8.3145 \cdot 3}$$

$$= -0.8018$$

$$\Rightarrow K_p^0 = 0.45$$

$$A \Leftrightarrow 2B$$

$1-\alpha$ 2α total amount $1+\alpha$

$$p_A = \frac{1-\alpha}{1+\alpha} p, \quad p_B = \frac{2\alpha}{1+\alpha} p$$

$$K_p^0 = \frac{[2\alpha/1+\alpha]^2 p}{1-\alpha/_{1+\alpha}\ bar} = \frac{4\alpha^2}{1-\alpha^2} \frac{p}{bar}$$

Text

$$\Rightarrow p = \frac{1-\alpha^2}{4\alpha^2} K_p^0\ bar$$

$$\alpha = 0.5$$

$$\Rightarrow p = \frac{0.75}{4 \cdot 0.25} \cdot 0.45\ bar$$

$$= 0.3375\ bar$$

6. Assume an ideal solution of two components A and B. At T=300 K, $P^*(A) = 4$ kPa, and $P^*(B) = 16$ kPa. What is the mole fraction of A in the vapor over the liquid containing 0.8 mol fractions of A?

- a. 0.01
- b. 0.05
- c. 0.09
- d. 0.1
- [✓ e.] 0.5
- f. 0.9
- g. none of a) – f)

$$P = x_A P_A^* + (1-x_A) P_B^*$$

$$P_A = y_A P \Rightarrow y_A = \frac{P_A}{P}$$

$$= \frac{x_A P_A^*}{x_A P_A^* + (1-x_A) P_B^*}$$

$$= \frac{0.8 \cdot 4 \cdot 10^3 \, Pa}{0.8 \cdot 4 \cdot 10^3 \, Pa + 0.2 \cdot 16 \cdot 10^3 \, Pa}$$

$$= \frac{0.8}{0.8 + 0.8}$$

$$= 0.5$$