

Midterm Exam #1

Answer Sheet: (The conceptual questions are multiple choice. List the letter that corresponds to the correct answer. For the calculation problems list under a) the final equation that gives the solution. Use only symbols, not intermediate numerical results. List under b) the final numerical result. Make no mistakes when transferring the answers! Put your names on **both** answer sheets **and** the work pages, and **return all pages**! Conceptual questions are **0.5 pts** each, calculation problems **3+1 pts**. Maximum number of points you can get is **25 pts**!

General Infos:

- No programable calculators, smartphones, smartwatches, tablets, headphones, ... are allowed. Neither any notes or books.
- Any attempt of cheating or other forms of academic dishonesty will result in an automatic "F" for the course.
- **Show a picture ID** when leaving
- **Be considerate if you finish early.** Consider to stay till end, or at least be quite when leaving earlier to avoid distracting your fellow students!

Conceptual questions:

- 1) C
- 2) E
- 3) A
- 4) E
- 5) C
- 6) B
- 7) B
- 8) A
- 9) A
- 10) B

Problems & Calculations:

$$1a) \frac{M_2}{M_1} = \frac{P_1}{P_1^* - P_1} \cdot \frac{m_2}{m_1}$$

$$1b) \underline{0.27}$$

$$2a) \Delta_{\text{vap}} H = R \ln \frac{P_2}{P_1} \cdot \frac{T_1 T_2}{T_2 - T_1}$$

$$2b) \underline{22.02 \text{ kJ/mol}}$$

$$3a) \alpha = \frac{A}{RT}$$

$$3b) \underline{3.227 \times 10^{-5} \text{ mol/L}}$$

$$4a) \alpha = \frac{\Lambda}{\Lambda_0}, \Lambda = \kappa/c, \Lambda_0 = \Lambda_0^+ + \Lambda_0^-$$

$$4b) \underline{0.017}$$

$$5a) v(Li^+) = \frac{\Lambda_0(Li^+)}{F} \cdot \frac{I}{A \cdot c \cdot (\Lambda_0(Li^+) + \Lambda_0(Cl^-))}$$

$$5b) \underline{4.35 \times 10^{-4} \text{ m/s}}$$

Conceptual Questions:

1. 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)
2. When adding 1 mol of water to a large beaker filled with pure ethanol, the volume increases by 14 ml. What is the partial molar volume of water in ethanol?
 - a. 28 ml
 - b. 20 ml
 - c. 18 ml
 - d. 16 ml
 - ✓ e. 14 ml
 - f. 12 ml
3. Adding salt to water
 - ✓ a. Increases the boiling point
 - b. Decreases the boiling point
 - c. Has no effect on the boiling point
4. Which of the following is correct for a completely immiscible 2-component solution?
 - a. Raoult's law applies
 - b. It is an ideal solution mixture
 - c. It's boiling point is that of the more volatile component
 - d. It has a higher boiling point than the individual components
 - ✓ e. It has a lower boiling point than the individual components
 - f. None of a) - e)
5. When mixing ideal solutions, which quantity increases?
 - a. Mixing Gibbs free energy $\Delta_{\text{mix}} G$
 - b. Mixing enthalpy $\Delta_{\text{mix}} H$
 - ✓ c. Mixing entropy $\Delta_{\text{mix}} S$
6. After adding NaCl to a 0.01 M aqueous solution of AgNO_3 , the concentration of Ag^+ ions initially
 - a. Decreases
 - ✓ b. Increases
 - c. Does not change

7. Adding water to a beaker filled with 0.01 M aqueous solution of acetic acid
- a. Does not affect the molar conductivity of the solution
 - ✓ b. Increases the molar conductivity of the solution
 - c. Decreases the molar conductivity of the solution
8. The thickness of the ionic atmosphere
- ✓ a. Decreases with growing ionic strength of the solution
 - b. Increases with growing ionic strength of the solution
 - c. Does not depend on the ionic strength
9. The osmotic pressure for electrolytes is
- ✓ a. Much higher than that of non-electrolytes
 - b. Much lower than that of non-electrolytes.
 - c. Similar than that of non-electrolytes
10. The concentration dependence of the molar conductivity Λ is stronger for
- a. Strong electrolytes
 - ✓ b. Weak electrolytes
 - c. Similar for all electrolytes

Problems and Calculations:

1. Components 1 and 2 form an ideal solution. The pressure of pure component 1 is 15.0 kPa at 298 K; and that of component 2 approximately zero. If addition of 1.00 g of component 2 to 15.00 g of component 1 reduces the total vapor pressure to 12.0 kPa, what is the ratio of the molar mass of component 2 to that of component 1?

$$\frac{P_1}{P_1^*} = \chi_1 \Rightarrow 1 - \frac{P_1}{P_1^*} = 1 - \chi_1 = \chi_2 \Rightarrow \chi_2 = \frac{P_1^* - P_1}{P_1^*}$$

$$\chi_2 = \frac{\frac{m_2}{M_2}}{\frac{m_1}{M_1} + \frac{m_2}{M_2}} = \frac{1}{\frac{m_1}{M_1} \frac{M_2}{m_2} + 1}$$

$$\Rightarrow \frac{1}{\frac{m_2}{M_1} \frac{m_1}{m_2} + 1} = \frac{P_1^* - P_1}{P_1^*}$$

$$\Rightarrow \frac{M_2}{M_1} \frac{m_1}{m_2} + 1 = \frac{P_1^*}{P_1^* - P_1}$$

$$\Rightarrow \frac{M_2}{M_1} \frac{m_1}{m_2} = \frac{P_1^*}{P_1^* - P_1} - 1 = \frac{P_1}{P_1^* - P_1}$$

$$\Rightarrow \boxed{\frac{M_2}{M_1} = \frac{P_1}{P_1^* - P_1} \frac{m_2}{m_1}}$$

$$= \frac{12.0}{15.0 - 12.0} \cdot \frac{1}{15}$$

$$= \frac{4}{15}$$

$$= \underline{\underline{0.27}}$$

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 $\Delta_{\text{vap}}H$ of the liquid

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

$$\Rightarrow \boxed{\Delta_{\text{vap}}H = R \cdot \ln \frac{P_2}{P_1} \cdot \frac{T_1 \cdot T_2}{T_2 - T_1}}$$
$$= 8.3145 \cdot \ln \frac{150}{10} \cdot \frac{300 \cdot 400}{100} \frac{\text{J}}{\text{mol}}$$
$$= 8.3145 \cdot \ln 15 \cdot 1200 \frac{\text{J}}{\text{mol}}$$
$$= 8.3145 \cdot 2.7081 \cdot 1200 \frac{\text{J}}{\text{mol}}$$
$$= 27019 \frac{\text{J}}{\text{mol}}$$
$$= 27.02 \frac{\text{kJ}}{\text{mol}}$$

3. When 80 mg of a polymer are dissolved in 16.0ml of water at 25°C, the osmotic pressure of the solution is found to be 80 Pa. What is the concentration of polymer (in mol/dm³) in the solution? (1 l = 1 dm³)

$$\pi = cRT \Rightarrow \boxed{c = \frac{\pi}{RT}}$$

$$= \frac{80 \text{ Pa}}{8.3145 \frac{\text{J}}{\text{K mol}} \cdot 298.15 \text{ K}}$$

$$= 3.227 \times 10^{-2} \frac{\text{mol}}{\text{m}^3}$$

$$= 3.227 \times 10^{-5} \frac{\text{mol}}{\text{l}}$$

- 4 The electrolytic conductivity k of a 0.0412 M solution of acetic acid is $1.63 \times 10^{-4} \text{ S/cm}$. If the limiting ionic conductance (infinite dilution) for CH_3COO^- is $100 \text{ S}\cdot\text{cm}^2/\text{mol}$, and $137 \text{ S}\cdot\text{cm}^2/\text{mol}$ for H^+ , what is the degree of dissociation α ?

$$\Lambda_0 = \Lambda_0 [\text{CH}_3\text{COO}^-] + \Lambda_0 [\text{H}^+] = 237 \frac{\text{S}\cdot\text{cm}^2}{\text{mol}}$$

$$\Lambda = \frac{k}{c} = \frac{1.63 \times 10^{-4} \text{ S/cm}}{0.0412 \times 10^{-3} \text{ mol/cm}^3} = 3.952 \frac{\text{S}\cdot\text{cm}^2}{\text{mol}}$$

$$\Rightarrow \alpha = \frac{\Lambda}{\Lambda_0} = 0.017$$

5. A solution of LiCl at a concentration of 0.05 M is contained in a tube with cross-sectional area of 8 cm². Calculate the speeds v of the Li⁺ ions if a current of 5.0 A is passed. Use ionic conductivities $\Lambda_0(\text{Li}^+) = 38.6 \text{ S cm}^2/\text{mol}$ and $\Lambda_0(\text{Cl}^-) = 76.4 \text{ S cm}^2/\text{mol}$.

$$\Lambda_0 = (38.6 + 76.4) \frac{\text{S cm}^2}{\text{mol}} = 115 \frac{\text{S cm}^2}{\text{mol}}$$

$$\text{or } \Lambda_0 = \frac{\kappa}{c} \Rightarrow \kappa = \Lambda_0 \cdot c = 575 \times 10^{-5} \frac{\text{S}}{\text{cm}}$$

$$G = \kappa \cdot \frac{A}{l} = \frac{I}{\Delta V} \Rightarrow \frac{\Delta V}{l} = \frac{I}{A \kappa} = \frac{I}{A \cdot c \Lambda_0} = \frac{I}{A c (\Lambda_0(\text{Li}^+) + \Lambda_0(\text{Cl}^-))}$$

$$u(\text{Li}^+) = \frac{\Lambda_0(\text{Li}^+)}{F}$$

$$\begin{aligned} V(\text{Li}^+) &= u(\text{Li}^+) \cdot \frac{\Delta V}{l} \\ &= \frac{\Lambda_0(\text{Li}^+)}{F} \cdot \frac{I}{A \cdot c (\Lambda_0(\text{Li}^+) + \Lambda_0(\text{Cl}^-))} \end{aligned}$$

$$= 4.06 \times 10^{-4} \frac{\text{cm}^2}{\text{V} \cdot \text{s}} \cdot \frac{5.0 \text{ A}}{0.05 \text{ M} \cdot 115 \frac{\text{S cm}^2}{\text{mol}} \cdot 8 \text{ cm}^2}$$

$$= 4.06 \times 10^{-4} \cdot \frac{5.0}{575 \times 10^{-5} \cdot 8} \frac{\text{cm}}{\text{s}}$$

$$= \frac{2.5}{575} \cdot 10^1 \frac{\text{cm}}{\text{s}}$$

$$= 0.0135 \frac{\text{cm}}{\text{s}}$$

$$= 4.35 \times 10^{-4} \frac{\text{m}}{\text{s}}$$