

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) d
- 2) a
- 3) b
- 4) b
- 5) c
- 6) a
- 7) a
- 8) b
- 9) b
- 10) c

Problems & Calculations:

- 1a)
$$M_{\text{solute}} = K_F \cdot \frac{W_{\text{solute}}}{W_{\text{H}_2\text{O}}} \cdot \frac{1}{\Delta T}$$
- 1b) 0.0142 kg/mol
- 2a)
$$M_B = M_A \cdot \frac{m_B}{m_A} \left(\frac{1}{x_B} - 1 \right) = M_A \cdot \frac{m_B}{m_A} \cdot \frac{x_A}{x_B}$$
- 2b) 0.055 kg/mol
- 3a)
$$C = \frac{\pi}{RT}$$
- 3b) 5.16×10^{-5} mol/L
- 4a)
$$\alpha = \frac{\Lambda}{\Lambda_0} = \frac{K}{C(\Lambda_0(\text{CH}_3\text{COO}^-) + \Lambda_0(\text{H}^+))}$$
- 4b) 2.5%
- 5a)
$$[S_n^{2+}]^u = \exp \left\{ - \left(E - E_0 + \theta_n [Cu^{II}]^u \right) \cdot z \frac{F}{RT} \right\}$$
- 5b) 4.1×10^{-5}

Conceptual Questions:

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

2. At triple point what is the thermodynamic quantity that is the same for each component in all three phases?
 - a. Chemical potential μ
 - b. Entropy S
 - c. Enthalpy H
 - d. Internal energy U
 - e. Concentration c
 - f. None of a) - e)

3. 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. 12 ml
 - b. 14 ml
 - c. 16 ml
 - d. 18 ml
 - e. 20 ml
 - f. 28 ml

4. The osmotic pressure of a solution
 - a. Decreases with increasing solute concentration
 - b. Increases with increasing solute concentration

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. Which kind of electrolyte can be described already quite good with the Arrhenius theory?
- a. Only weak electrolytes
 - b. Only strong electrolytes
 - c. Both are equally well described by the theory
 - d. Deviations are for both kinds of electrolytes too large to make the theory useful.
7. After adding NaCl to a 0.01 M aqueous solution of AgNO_3 , the concentration of Ag^+ ions initially
- a. Increases
 - b. Decreases
 - c. Does not change
8. The concentration dependence of the molar conductivity Λ is stronger for
- a. Strong electrolytes
 - b. Weak electrolytes
 - c. Similar for all electrolytes
9. The direction of the Nernst potential of a positive ion is
- a. The same as that of the concentration gradient
 - b. Opposite to the concentration gradient
 - c. Independent of the concentration gradient
10. In order to maximize the emf of an electrochemical cell, the concentration of the products should be
- a. High compared to that of the reactants
 - b. Equal to that of the reactants
 - c. Low compared to that of the reactants

Problems and Calculations:

1. When 10 g of a nonvolatile solute is dissolved in 500.0 g of water, the freezing point depression is 2.5 K. Calculate the molar mass (in kg/mol) of the compound assuming a freezing point depression coefficient $K_f = 1.78 \text{ K} \cdot \text{kg/mol}$. Use that the molality $m = n/W_{\text{solvent}} = W_{\text{solute}} / (M_{\text{solute}} \cdot W_{\text{solvent}})$ with W the total mass of solute/solvent and M the molar mass.

$$\begin{aligned}\Delta_f T &= K_f \cdot m_{\text{solute}} \\ &= K_f \cdot \frac{W_{\text{solute}}}{M_{\text{solute}} \cdot W_{\text{H}_2\text{O}}}\end{aligned}$$

$$\Rightarrow M_{\text{solute}} = K_f \cdot \frac{W_{\text{solute}}}{W_{\text{H}_2\text{O}}} \cdot \frac{1}{\Delta_f T}$$

$$= 1.78 \text{ K} \cdot \frac{\text{kg}}{\text{mol}} \cdot \frac{10 \text{ g}}{500 \text{ g}} \cdot \frac{1}{2.5 \text{ K}}$$

$$= 0.0142 \frac{\text{kg}}{\text{mol}}$$

2. When 15 g of the nonvolatile component B is dissolved in 500 g of A, the vapor pressure of the pure solvent, 7.50 kPa, is reduced to 7.30 kPa. Calculate the molar mass of compound B if that of compound A is 50 g/mol. Hint: assume that $n_A \gg n_B$

$$\frac{P_A}{P_A^*} = \chi_A = 1 - \chi_B \Rightarrow \chi_B = 1 - \frac{P_A}{P_A^*} = \frac{P_A^* - P_A}{P_A^*} = 0.026$$

$$\chi_B = \frac{\frac{m_B}{M_B}}{\frac{m_A}{M_A} + \frac{m_B}{M_B}} = \frac{1}{\frac{m_A}{M_A} \frac{M_B}{m_B} + 1}$$

$$\Rightarrow \frac{1}{\chi_B} = \frac{m_A}{M_A} \frac{M_B}{m_B} + 1$$

$$\Rightarrow \frac{1}{\chi_B} - 1 = \frac{m_A}{M_A} \frac{M_B}{m_B}$$

$$\Rightarrow M_B = \frac{m_B}{m_A} M_A \left(\frac{1}{\chi_B} - 1 \right)$$

$$= \frac{15.0}{500} \cdot 50.0 \cdot (375 - 1) \frac{\text{g}}{\text{mol}}$$

$$= 561.75 \frac{\text{g}}{\text{mol}}$$

$$= 0.056 \frac{\text{mol}}{\text{g}}$$

3. When 50 mg of a polymer are dissolved in a certain amount of water at 25°C, the osmotic pressure of the solution is found to be 50 Pa. What is the concentration of polymer (in mol/dm³) in the solution?

$$\pi = cRT \Rightarrow$$

$$c = \frac{\pi}{RT}$$

$$= \frac{50 \text{ Pa}}{8,3145 \frac{\text{J}}{\text{mol} \cdot \text{K}} \cdot 298,15 \text{ K}}$$

$$= 2,0169 \times 10^{-2} \frac{\text{mol}}{\text{m}^3}$$

$$= 2,017 \times 10^{-5} \frac{\text{mol}}{\text{l}}$$

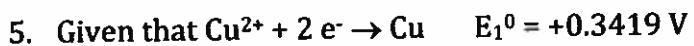
4. The electrolytic conductivity of a 0.0312 M solution of acetic acid is 1.83×10^{-4} S/cm. If the limiting ionic conductance (infinite dilution) for CH_3COO^- is $100 \text{ S}^*\text{cm}^2/\text{mol}$, and $137 \text{ S}^*\text{cm}^2/\text{mol}$ for H^+ , what is the degree of dissociation α ?

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

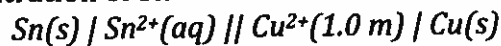
$$\Lambda = \frac{\kappa}{c} = \frac{1.83 \times 10^{-4} \text{ S/cm}}{0.0312 \text{ mol/l}} = \frac{1.83 \times 10^{-4} \text{ S cm}^2}{3.12 \times 10^{-4} \text{ mol}} = 5.865 \frac{\text{S cm}^2}{\text{mol}}$$

$$\alpha = \frac{\Lambda}{\Lambda_0} = \frac{\kappa}{c (\Lambda_0(\text{CH}_3\text{COO}^-) + \Lambda_0(\text{H}^+))}$$

$$= \frac{5.865}{237} = 0.02475 = 2.5\%$$



Determine the concentration of Sn^{2+} used in the electrochemical cell



that leads to an emf of $E=0.55 \text{ V}$ at 298.15 K . Note that the concentrations of metallic Sn and Cu do not change and that you know the concentration $[\text{Cu}^{2+}] = 1.0 \text{ m}$. Standard concentration is 1.0 m .

$$E^0 = E_1^0 - E_2^0 = 0.4794 \text{ V}$$

$$E = E^0 - \frac{RT}{2F} \ln \frac{[\text{Sn}^{2+}]}{[\text{Cu}^{2+}]}$$

$$\begin{aligned} \Rightarrow \ln [\text{Sn}^{2+}]^4 &= - (E - E^0 + \ln [\text{Cu}^{2+}]^4) \cdot 2 \frac{F}{RT} \\ &= - (0.55 - 0.4794 + 0) \cdot 2 \cdot 38.92 \\ &= -5.496 \end{aligned}$$

$$\Rightarrow [\text{Sn}^{2+}]^4 = \exp \left\{ - (E - E^0 + \ln [\text{Cu}^{2+}]^4) \cdot 2 \frac{F}{RT} \right\}$$

$$= \exp (-5.496)$$

$$= 4.1 \times 10^{-3}$$