KEY

CHEM 3523 001 Fall 2023 **Name:**
ID:

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:	Problems & Calculations:
1) c	1a) $m_A = \frac{P^*_{H_2O}}{P_A} \cdot \frac{M_A}{M_{H_2O}} \cdot m_{H_2O} = \frac{P^*_{H_2O}}{P - P^*_{H_2O}} \cdot \frac{M_A}{M_{H_2O}} \cdot m_{H_2O}$
2) c	1b) 54.82 g/mol
3) e	
4) a	2a) $m_{solute} = K_F \cdot \frac{w_{solute}}{w_{H_2O}} \cdot \frac{1}{\Delta T_F}$
5) c	2b) 0.0118 K kg/mol
6) c	
7) a	3a) $c = \frac{\pi}{RT}$
8) b	3b) $1.939 \times 10^{-5} \frac{mol}{dm^3}$
9) c	4aj $\Lambda_o = \Lambda_o(CH_3COO^-) + \Lambda_o(H^+)$; $\Lambda = \frac{\kappa}{c}$; $\alpha = \frac{\Lambda}{\Lambda_o}$
10) b	4bj 0.0187 or ≈1.9%
	5a) $u_+ = t^+ \cdot \frac{\Lambda_o}{F}$ $u_- = t^- \cdot \frac{\Lambda_o}{F}$
	5b) $u_+ = 3.45 \times 10^{-3} \frac{cm^2}{V \cdot s}$
	$u_- = 9.67 \times 10^{-4} \frac{cm^2}{V \cdot s}$

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Conceptual Questions:

1. When water boils, a phase transition occurs. Which thermodynamic quantity remains always the same in both phases?
   a. Volume V
   b. Internal energy U
   c. Gibbs free energy G
   d. Entropy S
   e. None of these
   f. All of these

2. Adding salt to water
   a. Decreases the boiling point
   b. Has no effect on the boiling point
   c. Increases the boiling point

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

4. The osmotic pressure of a solution
   a. Increases with increasing solute concentration
   b. Decreases with increasing solute concentration
   c. Is independent of solute concentration

5. Suppose we mix two similar liquids A and B. At what mol fraction χ_A of component A would we expect maximal mixing entropy $\Delta_{mix} S$?
   a. $\chi_A < 0.1$
   b. $\chi_A = 1/\pi$
   c. $\chi_A = 0.5$
   d. $\chi_A = 0.666$
   e. $\chi_A \approx 1$

6. After adding NaCl to a 0.01 M aqueous solution of $AGNO_3$, the concentration of Ag^+ ions initially
   a. Will not change
   b. Decreases
   c. Increases

7. 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.

8. The concentration dependence of the molar conductivity Λ is stronger for
   a. Strong electrolytes
   b. Weak electrolytes
   c. Similar for all electrolytes

9. Which gradient gives rise to the Nernst potential?
   a. Gravity
   b. temperature
   c. concentration
   d. none of a) - c)

10. 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

Problems and Calculations:

1. The ratio of a component A to that of water collected in a steam distillation (i.e. we have a solution of immiscible liquids) is 4. when the mixture was boiled at 344 K and 100 kPa. If the vapor pressure of water at this temperature is 43.2 kPa, calculate the molar mass of A (in g/mol). (Molar mass of water: 18.02 g/mol)

$m = n \cdot M$

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

$p_A^* = p - p_{H_2O}^*$

$$= \frac{p_{H_2O}^*}{p - p_{H_2O}^*} \cdot \frac{m_A}{m_{H_2O}} \cdot M_{H_2O}$$

$$= \frac{43.2}{100 - 43.2} \cdot 4 \cdot 18.02 \frac{g}{mol}$$

$$= \frac{43.2}{56.8} \cdot 4 \cdot 18.02 \frac{g}{mol}$$

$$= 54.82 \frac{g}{mol}$$

2. **When 10 g of a nonvolatile solute is dissolved in 500.0 g of water, the freezing point depression is 3 K. Calculate the molar mass (in kg/mol) of the compound assuming a freezing point depression coefficient $K_f = 1.78$ K*kg/mol. Use that the molality $m=n/W_{solvent}=W_{solute}/(M_{Solute} * W_{solvent})$ with W the total mass of solute/solvent and M the molar mass.**

$$\Delta_f T = K_F \cdot m_{solute}$$

$$= K_F \cdot \frac{W_{solute}}{M_{solute} \cdot W_{H_2O}}$$

$$\Rightarrow M_{solute} = K_F \cdot \frac{W_{solute}}{W_{H_2O}} \cdot \frac{1}{\Delta_F T}$$

$$= 1.78\ K\ \frac{kg}{mol} \cdot \frac{10g}{500g} \cdot \frac{1}{3.0\ K}$$

$$= 0.0118\ \frac{kg}{mol}$$

3. **When 60 mg of a polymer are dissolved in a certain amount of water at 37°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?**

$$\Pi = c\,RT \quad \Rightarrow \quad c = \frac{\Pi}{RT}$$

$$= \frac{50\ Pa}{8.314\ \frac{J}{K \cdot mol} \cdot 310.15\ K}$$

$$= \frac{50\ Pa}{2578.7\ J/mol}$$

$$= 1.939 \times 10^{-2}\ \frac{mol}{m^3}$$

$$= 1.939 \times 10^{-5}\ \frac{mol}{dm^3}$$

4. The electrolytic conductivity K of a 0.0412 M solution of acetic acid is 1.83×10^{-4} S/cm. If the limiting ionic conductance Λ_0 (infinite dilution) for CH_3COO^- is 100 $S*cm^2/mol$, and 137 $S*cm^2/mol$ for H^+, what is the degree of dissociation α?

$$\Lambda_0 = \Lambda_0(CH_3COO^-) + \Lambda_0(H^+) = 237 \frac{S\,cm^2}{mol}$$

$$\Lambda = \frac{K}{c} = \frac{1.83 \times 10^{-4}\ S/cm}{0.0412\ mol/L} = \frac{1.83 \times 10^{-4}}{4.12 \times 10^{-5}} \frac{S\,cm^2}{mol}$$

$$= 4.442 \frac{S\,cm^2}{mol}$$

$$\alpha = \frac{\Lambda}{\Lambda_0} = 0.0187 \approx 1.9\%$$

5. **The transport numbers of HCl at infinite dilution are estimated to be $t^+ = 0.781$ and $t^- = 0.219$. The molar conductivity is 426.16 S cm²/mol. Calculate the mobilities u (in cm²/(V s)) of the hydrogen and chloride ions.**

$$\Lambda_+ = t^+ \Lambda_0 \qquad \Lambda_+ = u_+ F \Rightarrow u_+ = t^+ \frac{\Lambda_0}{F}$$

$$u_- = t^- \frac{\Lambda_0}{F}$$

$$\Rightarrow u_+ = \frac{0.781 \cdot 426.16}{96485} \frac{S\,cm^2}{C} = 3.45 \times 10^{-3} \frac{cm^2}{V \cdot s}$$

$$u_- = \frac{0.219 \cdot 426.16}{96485} \frac{S\,cm^2}{C} = 9.67 \times 10^{-4} \frac{cm^2}{V \cdot s}$$