CHEM 3523 001 Spring 2023

Name: KEY
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:

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

Problems & Calculations:

1a) $M_{solute} = K_F \cdot \frac{W_{solute}}{W_{H_2O}} \cdot \frac{1}{\Delta_F T}$
1b) 0.0142 kg/mol

2a) $M_B = M_A \cdot \frac{m_B}{m_A} \left(\frac{1}{x_B} - 1 \right) = M_A \frac{m_B}{m_A} \frac{x_A}{x_B}$
2b) 0.055 kg/mol

3a) $c = \frac{\pi}{RT}$
3b) 5.16×10^{-5} mol/L

4a) $\alpha = \frac{\Lambda}{\Lambda_0} = \frac{\kappa}{c(\Lambda_0(CH_3COO^-) + \Lambda_0(H^+))}$
4b) 2.5 %

5a) $[Sn^{2+}]^4 = exp\left\{ -\left(E - E_0 + ln[Cu^{2+}]^4\right) \cdot 2\frac{F}{RT} \right\}$
5b) 4.1×10^{-5}

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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 $\Delta_{mix} G$
    b. Mixing enthalpy $\Delta_{mix} H$
    c. Mixing entropy $\Delta_{mix} S$

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 $K_f = 1.78$ 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.

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

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

$$\Rightarrow \boxed{M_{solute} = K_f \cdot \frac{W_{solute}}{W_{H_2O}} \cdot \frac{1}{\Delta_f T}}$$

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

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

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 $n_A >> n_B$**

$$\frac{P_A}{P_A^*} = x_A = 1 - x_B \Rightarrow x_B = 1 - \frac{P_A}{P_A^*} = \frac{P_A^* - P_A}{P_A^*} = 0.026$$

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

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

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

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

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

$$= 54.75 \; g/mol$$

$$= 0.055 \; kg/mol$$

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?

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

$$= \frac{50 \text{ Pa}}{8.3145 \frac{J}{K\,mol} \cdot 298.15}$$

$$= 2.0169 \times 10^{-2} \frac{mol}{m^3}$$

$$= 2.017 \times 10^{-5} \frac{mol}{\ell}$$

4. The electrolytic conductivity of a 0.0312 M solution of acetic acid is 1.83 x 10^{-4} S/cm. If the limiting ionic conductance (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?

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

$$\Lambda = \frac{\kappa}{c} = \frac{1.83 \times 10^{-4}\ S/cm}{0.0312\ mol/l} = \frac{1.83 \times 10^{-4}}{3.12 \times 10^{-5}} \frac{S\,cm^2}{mol}$$

$$= 5.865 \frac{S\,cm^2}{mol}$$

$$\alpha = \frac{\Lambda}{\Lambda_0} = \frac{\kappa}{c\,(\Lambda_0(CH_3COO^-) + \Lambda_0(H^+))}$$

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

5. Given that $Cu^{2+} + 2\,e^- \rightarrow Cu$ $\quad E_1^0 = +0.3419$ V

$Sn^{2+} + 2\,e^- \rightarrow Sn$ $\quad E_2^0 = -0.1375$ V,

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

Sn(s) | Sn^{2+}(aq) || Cu^{2+}(1.0 m) | Cu(s)

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

$$E^0 = E_1^0 - E_2^0 = 0.4794\,V$$

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

$$\Rightarrow \ln [Sn^{2+}]^u = -(E - E^0 + \ln [Cu^{2+}]^u) \cdot z \frac{F}{RT}$$

$$= -(0.55 - 0.4794 + 0) \cdot 2 \cdot 38.92$$

$$= -5.496$$

$$\Rightarrow [Sn^{2+}]^u = \exp\{-(E - E_0 + \ln [Cu^{2+}]^u) \cdot z \frac{F}{RT}\}$$

$$= \exp(-5.496)$$

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