

2019 Spring Semester Quiz 3
For General Chemistry I (CH101)

Date: May 13 (Mon), Time: 19:00 ~ 19:45

Professor Name	Class	Student I.D. Number	Name

Use the following constants to solve problems.

(Avogadro's number $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$)

(Gas constant $R = 0.082 \text{ L atm K}^{-1} \text{ mol}^{-1} = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$)

NOTICE : Make sure that the significant digits are displayed up to the second decimal points. Rounding has to be done at the end of the calculation.

1. (Total 15 pts, each 5 pts) Read the following questions and answer them. Solubility of BaSO_4 is 0.0025 g/L in water at 25 °C. Molecular weight of BaSO_4 is 233.38 g/mol.

(a) Write down chemical equation of dissolution of BaSO_4 and calculate the K value.

Answer

Equation: $\text{BaSO}_4 (\text{s}) \rightarrow \text{Ba}^{2+} (\text{aq}) + \text{SO}_4^{2-} (\text{aq})$

In this case, $K = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$ at equilibrium state.

Based on their solubility, $[\text{Ba}^{2+}] = [\text{SO}_4^{2-}] = (\text{Dissolved BaSO}_4 / \text{MW of BaSO}_4) = (0.0025 \text{ g/L}) / (233.38 \text{ g/mol}) = 1.0712143 \dots \times 10^{-5}$

$K = [\text{Ba}^{2+}][\text{SO}_4^{2-}] = (1.0712143 \dots \times 10^{-5})^2 = 1.1475 \dots \times 10^{-10} \approx 1.15 \times 10^{-10}$

(Chemical equation: +2 pts, correct coefficient, chemicals and state have to be contained

Correct K value: +3 pts)

(b) Right after the mixing of the 1 M BaCl_2 solution 50 mL and 1 M K_2SO_4 solution 100 mL, calculate the reaction quotient (Q) value. If the dissolution process of BaSO_4 is regarded as a forward reaction, which reaction is going to be dominant: a forward reaction or a reverse reaction?

Answer

After the mixing, $[\text{Ba}^{2+}] = 1 \text{ M} / 3 = 0.3333 \dots \text{ M}$ and $[\text{SO}_4^{2-}] = 2 \text{ M} / 3 = 0.6666 \dots \text{ M}$ due to dilution.

$Q = [\text{Ba}^{2+}][\text{SO}_4^{2-}] = 0.2222 \dots \approx 0.22$

Q is larger than K, reverse reaction will occur

(Correct Q value: +2 pts, correct prediction: +3 pts)

(Inverse value of Q can be correct answer)

(c) After reaching equilibrium in (b), if you pour more 100 mL of water into it, will this drive the forward reaction or the reverse reaction? Justify your answer.

Answer

After the addition of water, $[Ba^+]$ and $[SO_4^-]$ will be decreased. It lower the Q value and forward reaction should occur.

(Correct explanation: +5 pts)

(Explanation with Le Chatelier's principle can be correct answer)

2. (Total 15 pts, each 5 pts)

(a) Balance the following chemical equation in acidic condition.



Answer

Step 1. Separate half reactions

- $MnO_4^- (aq) \rightarrow Mn^{2+} (aq)$ (Mn(VII) to Mn(II), reduction half reaction)
- $H_2C_2O_4 (aq) \rightarrow CO_2 (g)$ (oxidation number of carbon: +3 to +4, oxidation half reaction)

Step 2. Balance each half reactions

- $MnO_4^- (aq) \rightarrow Mn^{2+} (aq)$
- $H_2C_2O_4 (aq) \rightarrow 2CO_2 (g)$

Step 3. Balance oxygen by adding H₂O

- $MnO_4^- (aq) \rightarrow Mn^{2+} (aq) + 4H_2O (l)$
- $H_2C_2O_4 (aq) \rightarrow 2CO_2 (g)$

Step 4. Balance hydrogen adding H₃O⁺/H₂O

- $MnO_4^- (aq) + 8H_3O^+ (aq) \rightarrow Mn^{2+} (aq) + 4H_2O (l) + 8H_2O (l)$
- $H_2C_2O_4 (aq) + 2H_2O (l) \rightarrow 2CO_2 (g) + 2H_3O^+ (aq)$

Step 5. Balance charge using e⁻

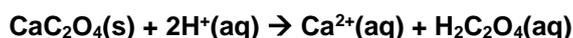
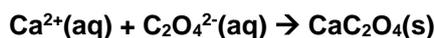
- $\text{MnO}_4^- (\text{aq}) + 8\text{H}_3\text{O}^+ (\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+} (\text{aq}) + 12\text{H}_2\text{O} (\text{l})$
- $\text{H}_2\text{C}_2\text{O}_4 (\text{aq}) + 2\text{H}_2\text{O} (\text{l}) \rightarrow 2\text{CO}_2 (\text{g}) + 2\text{H}_3\text{O}^+ (\text{aq}) + 2\text{e}^-$

Step 6. Combine the two half reactions canceling e⁻

- $2\text{MnO}_4^- (\text{aq}) + 16\text{H}_3\text{O}^+ (\text{aq}) + 10\text{e}^- \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 24\text{H}_2\text{O} (\text{l})$
- $5\text{H}_2\text{C}_2\text{O}_4 (\text{aq}) + 10\text{H}_2\text{O} (\text{l}) \rightarrow 10\text{CO}_2 (\text{g}) + 10\text{H}_3\text{O}^+ (\text{aq}) + 10\text{e}^-$
- $2\text{MnO}_4^- (\text{aq}) + 5\text{H}_2\text{C}_2\text{O}_4 (\text{aq}) + 6\text{H}_3\text{O}^+ (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 10\text{CO}_2 (\text{g}) + 14\text{H}_2\text{O} (\text{l})$
- $2\text{MnO}_4^- (\text{aq}) + 5\text{H}_2\text{C}_2\text{O}_4 (\text{aq}) + 6\text{H}^+ (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 10\text{CO}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l})$ is can be alternative answer

(Correct balanced equation: +5 pts, correct coefficient, chemicals and state have to be contained)

(b) Based on following two more chemical equations, briefly explain a method for indirect quantification of Ca²⁺ ion in a solution.



Answer

- 1) Separate the precipitated CaC₂O₄ by adding excess C₂O₄²⁻ to the Ca²⁺ solution.
- 2) Excess acid solution is added to make all of CaC₂O₄ into Ca²⁺ ion and H₂C₂O₄.
- 3) The redox titration of H₂C₂O₄ with a KMnO₄ solution of known concentration can be used to indirectly determine the concentration of Ca²⁺ ion.

(Correct explanation: +5 pts, if only partial step is correct, +1 pts for each step)

(c) The end point is reached after the addition of 28.5 mL of 0.5 M KMnO₄ solution to H₂C₂O₄ with unknown concentration. Calculate the initial number of Ca²⁺ ions. Write down the number with mol units.

Answer

$$\text{Number of used MnO}_4^- = (28.5 \text{ mL}) \times (0.5 \text{ M}) = 14.25 \text{ mmol}$$

$$\text{Number of H}_2\text{C}_2\text{O}_4 = (\text{Number of used MnO}_4^-) / 2 \times 5 = 35.625 \text{ mmol} = \text{Number of initial Ca}^{2+}$$

$$\text{Then, answer is } 3.5625 \times 10^{-2} \text{ mol} \approx 3.56 \times 10^{-2} \text{ mol}$$

(Correct answer: +5 pts, wrong unit: -2 pts)

3. (Total 10 pts, each 5 pts)

(a) Explain Raoult's law.

Answer

For ideal solution, vapor pressure of solvent in solution is proportional to its mole fraction. In equation, $P_1 = X_1 P_1^\circ$

(Correct explanation: +5 pts, Only equation: +3 pts)

(b) After the mixing solvent A and nonvolatile solute B, higher vapor pressure is observed than expected by Raoult's law. Explain this.

Answer

One of the assumptions of an ideal solution is that the interaction between solvent and solute is the same in size as solvent and solvent interaction. If higher vapor pressures are observed than Raoult's law predicts, it can be explained that the interaction between the solute and the solvent is actually weaker than the interaction between the solvent and the solvent, which makes it easier to vaporize the solvent.

(Containing explanation of difference of interactions: +5 pts, no partial points)

4. (10 pts) The vapor pressure of water is 23.756 mmHg at 25 °C, and the boiling point of water is 100 °C at 1 atm (= 760 mmHg). Calculate the ΔH_{vap} of water.

Answer

$$\text{Van't Hoff equation : } \ln \frac{K_2}{K_1} = - \frac{\Delta H^\circ}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\text{In this case, Van't Hoff equation can be written like } \ln \frac{P_2}{P_1} = - \frac{\Delta H_{vap}}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\text{Assuming that } T_1 = T_b \text{ and } P_1 = 1 \text{ atm, } \ln P_2 = - \frac{\Delta H_{vap}}{R} \left[\frac{1}{T_2} - \frac{1}{T_b} \right]$$

$$\text{After rearrangement, } - \ln P_2 \times R \times \left[\frac{1}{T_2} - \frac{1}{T_b} \right]^{-1} = \Delta H_{vap}$$

$$\text{Then, } \Delta H_{vap} = 42.7009... \text{ kJ} \approx 42.70 \text{ kJ/mol}$$

(Correct answer: +10 pts)

(If answer is wrong → Van't Hoff equation: +3 pts)

(Without unit, correct value can be correct answer. Ex: 42.70 or 42700.90)