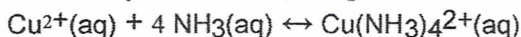


Read questions carefully before answering. No outside paper is allowed. Write **set up equation** for a mathematical problem, then put the raw data with **units**, before showing the calculation. Use the reverse side of your answer paper as scratch. Use the periodic table and important constants charts provided. (Total points = 56 + 40 + 16 = 112).

Show your calculation with set up and units (when appropriate)

1) For the equilibrium reaction given below:



1) _____

a) Write the equilibrium constant expression for this reaction (4 pts.).

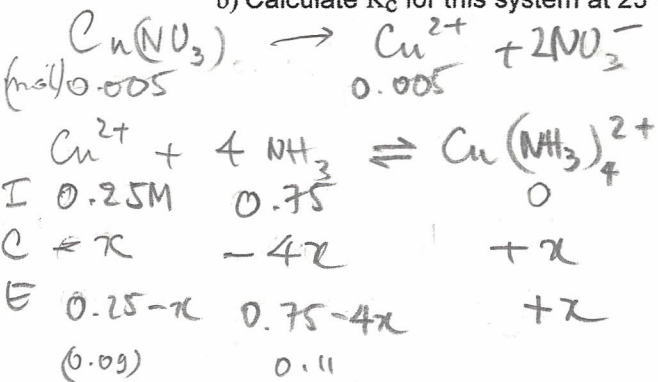
$$K_{eq} = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{[\text{Cu}^{2+}][\text{NH}_3]^4}$$

To measure the equilibrium constant, 5.0 mL of 1.00 M $\text{Cu}(\text{NO}_3)_2(\text{aq})$ solution was mixed with 15.0 mL of 1.0 M $\text{NH}_3(\text{aq})$ at 25°C. When the equilibrium reached, the absorbance of $\text{Cu}(\text{NH}_3)_4^{2+}(\text{aq})$ at equilibrium was determined using spectroscopy to be 0.31. A standard curve of $\text{Cu}(\text{NH}_3)_4^{2+}(\text{aq})$, plotting the absorbance (y-axis) vs. the concentration (x-axis) gave a straight line with a slope of 1.948 and intercept of 0.0018.

$$\begin{aligned} \text{mole Cu}(\text{NO}_3)_2 &= 0.005 \text{ L} \times 1 \text{ M} \\ &= 0.005 \text{ mol} \\ \text{mole NH}_3 &= 0.015 \text{ L} \times 1 \text{ M} \\ &= 0.015 \text{ mol} \end{aligned}$$

$$0.31 = 1.948x + 0.0018$$

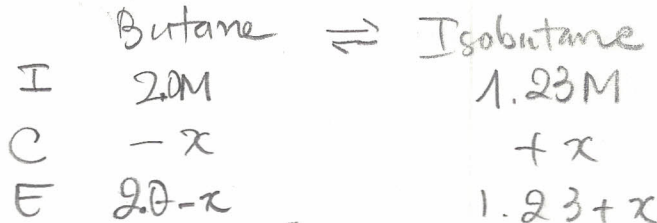
b) Calculate K_c for this system at 25°C (10 pts.). $\Rightarrow x = 0.16$



$$\begin{aligned} [\text{Cu}^{2+}] &= \frac{0.005 \text{ mol}}{(5+15) \times 10^{-3} \text{ L}} = 0.25 \text{ M} \\ [\text{NH}_3] &= \frac{0.015 \text{ mol}}{(5+15) \times 10^{-3} \text{ L}} = 0.75 \text{ M} \\ K_c &= \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{[\text{Cu}^{2+}][\text{NH}_3]^4} = \frac{0.16}{(0.25-0.16)(0.75-4 \times 0.16)^4} = 1.2 \times 10^4 \end{aligned}$$

2) In the equilibrium rxn. Butane (g) \leftrightarrow Isobutane (g), assume equilibrium has reached in a 1.0 L flask with [Butane] = 0.5 M and [Isobutane] = 1.23 M at 298 K. The equilibrium constant for the reaction = 2.5 and afterwards 1.5 mol of Butane was added to the mixture. Calculate the new values of [Butane] and [Isobutane] when equilibrium was reestablished (8 pts.)?

2) _____ = 1.2×10^4



$$\begin{aligned} [\text{butane}]_{\text{after adding}} &= \frac{0.5 \text{ M} \times 1.0 \text{ L} + 1.5 \text{ mol}}{1.0 \text{ L}} \\ &= 2.0 \text{ M} \end{aligned}$$

$$K_{eq} = \frac{[\text{isobutane}]}{[\text{butane}]} = \frac{1.23+x}{2.0-x} = 2.5$$

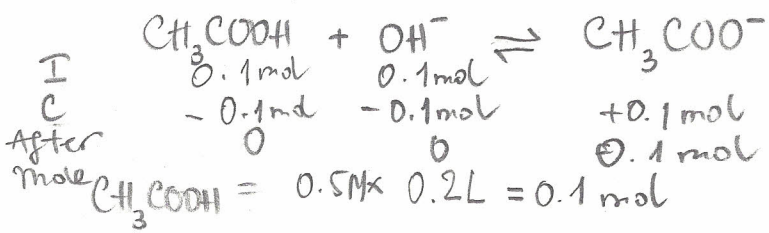
$$\begin{aligned} \Rightarrow x &= 1.1 \text{ M} \\ \Rightarrow [\text{butane}]_{eq} &= 2.0 - 1.1 = 0.9 \text{ (M)} \\ \Rightarrow [\text{isobutane}]_{eq} &= 1.23 + 1.1 = 2.33 \text{ (M)} \end{aligned}$$

$$M = \frac{n}{V}$$

0.5M CH₃COOH

3) 200.0 ml of a solution containing 0.5000 moles of acetic acid per liter is added to 200.0 ml of 0.5000 M NaOH. What is the final pH? The K_a of acetic acid is 1.770 × 10⁻⁵ (10 pts) (Note: Check what components you have in the final solution.)

3) _____



mole NaOH = 0.5M × 0.2L = 0.1 mol



$$[\text{CH}_3\text{COO}^-] = \frac{0.1 \text{ mol}}{(0.2+0.2)\text{L}} = 0.25 \text{ M}$$

$$K_b = \frac{10^{-14}}{1.770 \times 10^{-5}} = 5.65 \times 10^{-10}$$

$$\Rightarrow \frac{[\text{OH}^-][\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]} = 5.65 \times 10^{-10}$$

$$\Rightarrow \frac{x^2}{0.25-x} = 5.65 \times 10^{-10}$$

$$\Rightarrow x = 2.82 \times 10^{-5} = [\text{OH}^-]$$

$$\Rightarrow \text{pOH} = -\log[\text{OH}^-] = 4.55$$

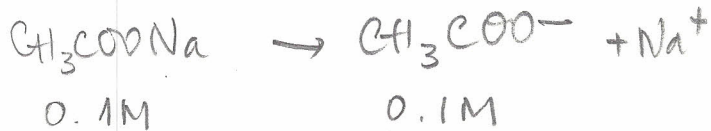
$$\Rightarrow \text{pH} = 14 - 4.55 = 9.45$$

pH = 9.075

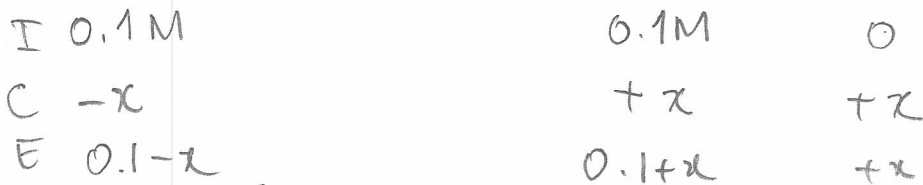
4) Calculate the pH of a buffer solution that contains 0.820 grams of sodium acetate and 0.01 moles of acetic acid in 100 ml of water. The K_a of acetic acid is 1.77 × 10⁻⁵ (8 pts).

4) _____

$$\text{CH}_3\text{COONa} : 0.82 \text{ g} \Rightarrow \text{mole} = \frac{0.82 \text{ g}}{82 \text{ g/mol}} = 0.01 \text{ mol} \Rightarrow [\text{CH}_3\text{COONa}] = \frac{0.01 \text{ mol}}{0.1 \text{ L}} = 0.1 \text{ M}$$



$$[\text{CH}_3\text{COOH}] = \frac{0.01 \text{ mol}}{0.1 \text{ L}} = 0.1 \text{ M}$$



$$K_a = \frac{(0.1+x)x}{(0.1-x)} = 1.77 \times 10^{-5}$$

$$\Rightarrow x = 1.77 \times 10^{-5} = [\text{H}_3\text{O}^+]$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+] = -\log[1.77 \times 10^{-5}] = 4.75$$

OR using Henderson-Hasselbalch Eqn

$$\text{pH} = \text{pK}_a + \log \frac{[\text{conj base}]}{[\text{Acid}]}$$

$$= \text{pK}_a + \log \frac{[\text{acetate}]}{[\text{acetic acid}]}$$

$$\text{pH} = \text{pK}_a + \log \frac{1}{1}$$

$$\text{pH} = \text{pK}_a + \log 1$$

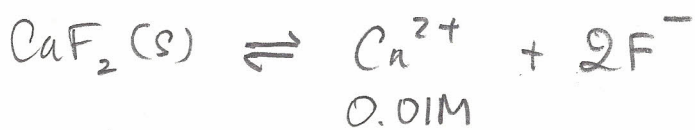
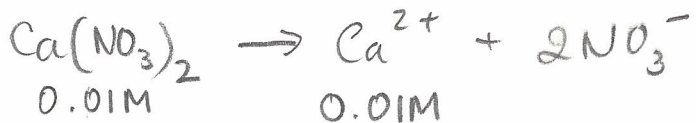
$$= \text{pK}_a + 0$$

$$\text{pH} = \text{pK}_a = -\log K_a$$

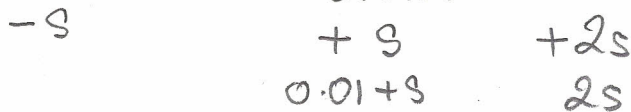
$$\text{pH} = -\log(1.77 \times 10^{-5}) = 4.75$$

5) Calculate the molar solubility of CaF_2 at 25°C in a solution that is 0.010 M in $\text{Ca}(\text{NO}_3)_2$. K_{sp} for $\text{CaF}_2 = 3.9 \times 10^{-11}$. Show your calculation with ICE chart. (8 pts.)

5) _____



I
C
E



$$K_{\text{sp}} = [\text{Ca}^{2+}][\text{F}^-]^2 = 3.9 \times 10^{-11}$$

$$\Rightarrow (0.01+s)(2s)^2 = 3.9 \times 10^{-11}$$

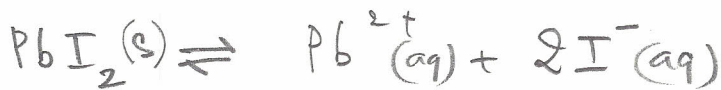
$$\Rightarrow 4s^2 \approx \frac{3.9 \times 10^{-11}}{0.01}$$

$$\Rightarrow s^2 = 9.75 \times 10^{-10}$$

$$\Rightarrow s = 3.12 \times 10^{-5} \text{ (M)}$$

6) Calculate the concentration of iodide ions in a saturated solution of lead (II) iodide. The solubility product constant of PbI_2 is 1.4×10^{-8} (8 pts.).

6) _____



$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{I}^-]^2 = 1.4 \times 10^{-8}$$

$$\Rightarrow s \cdot (2s)^2 = 1.4 \times 10^{-8}$$

$$\Rightarrow 4s^3 = 1.4 \times 10^{-8}$$

$$\Rightarrow s^3 = 3.5 \times 10^{-9}$$

$$\Rightarrow s = 1.52 \times 10^{-3} \text{ (M)}$$

$$[\text{I}^-] = 2s = 2 \times 1.52 \times 10^{-3} = 3.04 \times 10^{-3}$$

-3

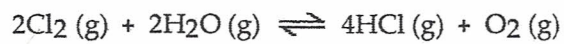
$$pH = pK_a$$

MULTIPLE CHOICE. Select the one alternative that best completes the statement or answers the question (4 pts each).

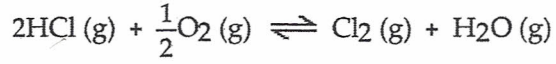
- 7) In a solution, when the concentrations of a weak acid and its conjugate base are equal, 7) B
 A) the system is not at equilibrium.
 B) the $-\log$ of the $[H^+]$ and the $-\log$ of the K_a are equal. = 0
 C) the buffering capacity is significantly decreased.
 D) all of the above are true.

- 8) How does the reaction quotient of a reaction (Q) differ from the equilibrium constant (K_{eq}) of the same reaction? 8) B
 A) K does not depend on the concentrations or partial pressures of reaction components.
 B) Q is the same as K_{eq} when a reaction is at equilibrium. ✓
 C) Q does not depend on the concentrations or partial pressures of reaction components.
 D) K_{eq} does not change with temperature, whereas Q is temperature dependent.
 E) Q does not change with temperature.

- 9) The K_{eq} for the equilibrium below is 7.52×10^{-2} at $480^\circ C$. 9) C



What is the value of K_{eq} at this temperature for the following reaction?

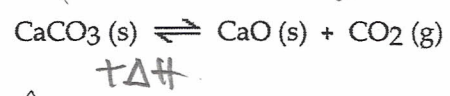


- A) 13.3
 B) 0.274
 C) 3.65
 D) -0.0376
 E) 5.66×10^{-3}

$$K_2 = \frac{1}{(K_1)^{1/2}}$$

revers
 chia 2

- 10) For the endothermic reaction 10) C



Le Chatelier's principle predicts that _____ will result in an increase in the number of moles of CO_2 .

- A) removing some of the $CaCO_3(s)$
 B) decreasing the temperature
 C) increasing the temperature
 D) increasing the pressure
 E) adding more $CaCO_3(s)$

↓ T pink ←
 ↑ T blue

11) The equilibrium reaction $\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ (Pink) + $4 \text{Cl}^-(\text{aq}) \rightleftharpoons \text{CoCl}_4^{2-}(\text{aq})$ (Blue) + $6 \text{H}_2\text{O}(\text{l})$ turns pink when placed in ice water mixture but turns blue in hot water. The reaction, as shown, is: 11) B

↓ T ↑ T

A) Nonthermic B) Endothermic
 C) Exothermic D) Insufficient data

12) In which of the following aqueous solutions would you expect AgBr to have the lowest solubility? 12) D

A) 0.10 M AgNO_3
 B) 0.15 M KBr
 C) 0.10 M LiBr
 D) 0.20 M NaBr
 E) pure water

$\text{AgBr} \rightleftharpoons \text{Ag} + \text{Br}$
0.1 s

13) The pH of a solution prepared by mixing 50.0 mL of 0.125 M KOH and 50.0 mL of 0.125 M HCl is _____ 13) C

A) 8.11 B) 5.78 C) 7.00 D) 0.00 E) 6.29

0.25×10^{-3} $0.1 - s$ s 6.25×10^{-3}

14) Which one of the following pairs cannot be mixed together to form a buffer solution? 14) E

A) $\text{NaC}_2\text{H}_3\text{O}_2$, HCl ($\text{C}_2\text{H}_3\text{O}_2^-$ = acetate)
 B) NH_3 , NH_4Cl
 C) KOH , HF
 D) H_3PO_4 , KH_2PO_4 ✓
 E) RbOH , HBr

15) Which below best describe(s) the behavior of an amphoteric hydroxide in water? 15) C

A) With conc. aq. HCl , its clear solution forms a precipitate.
 B) With conc. aq. NaOH , its suspension dissolves.
 C) With both conc. aq. NaOH and conc. aq. HCl , its suspension dissolves.
 D) With conc. aq. HCl , its suspension dissolves.
 E) With conc. aq. NaOH , its clear solution forms a precipitate.

99

16) Given K_{sp} for $\text{Zn}_3(\text{PO}_4)_2(\text{s})$ is 9.0×10^{-33} and that K_f for $[\text{Zn}(\text{OH})_4]^{2-}$ is 4.6×10^{17} for the formation of the complex from Zn^{2+} and OH^- , calculate the K_{net} for the following reaction: 16) A

$\text{Zn}_3(\text{PO}_4)_2(\text{s}) + 12 \text{OH}^-(\text{aq}) \rightleftharpoons 3 [\text{Zn}(\text{OH})_4]^{2-}(\text{aq}) + 2 \text{PO}_4^{3-}(\text{aq})$ K_{sp}

$3 [\text{Zn}(\text{OH})_4]^{2-} \rightleftharpoons 3 \text{Zn}^{2+} + 12 \text{OH}^-$ K_f

A) 8.76×10^{20} B) 8.76×10^{-16} C) 4.14×10^{15} D) 4.14×10^{-15}

TRUE/FALSE. Circle 'A' if the statement is true and 'B' if the statement is false (2 pts each) and then provide a short explanation (2 pts. each).

- 17) The solubility product of a compound is numerically equal to the product of the concentration of the ions involved in the equilibrium, each multiplied by its coefficient in the equilibrium reaction. T or F F ✓

- not equal

-1 - multiplied by its coefficient in the equilibrium is not correct. *then what?*

- 18) The solubility of slightly soluble salts containing basic anions is proportional to the pH of the solution. T or F F ✓

it is a buffer solution. NO

-2 ⇒ resist the change of pH if adding slightly soluble salts containing basic anions.

- 19) At constant temperature, reducing the volume of a gaseous equilibrium mixture causes the reaction to shift in the direction that increases the number of moles of gas in the system. T or F F ✓

$$C_M = \frac{n}{V} \text{ if } V \downarrow \Rightarrow C_M \uparrow$$

⇒ to re equilibrium. the rxn has to shift in the direction that decreasing the number of moles of gas.

- 20) The effect of a catalyst on a chemical reaction is to react with product, effectively removing it and shifting the equilibrium to the right. T or F F ✓

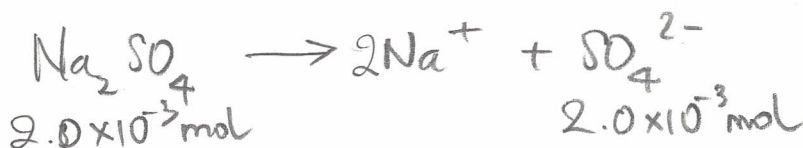
catalyst does not react with reactants or products.

It decrease E_a of reaction.

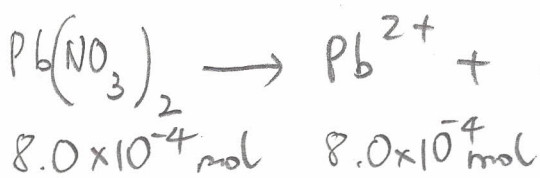
Show your calculation with set up and units (when appropriate)

21) Extra point question: Show your calculation to predict if a precipitate will form when 0.10 L of $8.0 \times 10^{-3} \text{ M Pb(NO}_3)_2$ is added to 0.40 L of $5.0 \times 10^{-3} \text{ M Na}_2\text{SO}_4$ solution. K_{sp} of $\text{PbSO}_4 = 6.3 \times 10^{-7}$. Calculate $[\text{Pb}^{2+}]$ in the mixture (2 pts.) calculate $[\text{SO}_4^{2-}]$ in the mixture (2 pts.); calculate Q (2 pts.); state reason if precipitate will form or not (2 pts.). (Total 8 pts.)

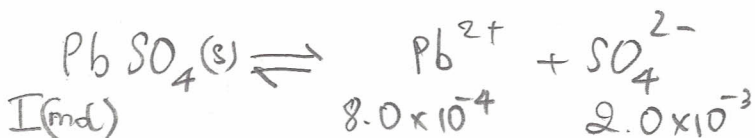
21) _____



$$\begin{aligned} \text{mole Na}_2\text{SO}_4 &= 5.0 \times 10^{-3} \times 0.4 \text{ L} \\ &= 2.0 \times 10^{-3} \text{ mol} \end{aligned}$$



$$\begin{aligned} \text{mole Pb(NO}_3)_2 &= 8.0 \times 10^{-3} \times 0.1 \text{ L} \\ &= 8.0 \times 10^{-4} \text{ mol} \end{aligned}$$



$$[\text{Pb}^{2+}] = \frac{8.0 \times 10^{-4} \text{ mol}}{(0.1 + 0.4) \text{ L}} = 1.6 \times 10^{-3} \text{ M}$$

$$[\text{SO}_4^{2-}] = \frac{2.0 \times 10^{-3} \text{ mol}}{(0.1 + 0.4) \text{ L}} = 4 \times 10^{-3} \text{ M}$$

$$\begin{aligned} Q &= [\text{Pb}^{2+}][\text{SO}_4^{2-}] = 1.6 \times 10^{-3} \times 4 \times 10^{-3} \\ &= 6.4 \times 10^{-6} > K_{sp} (6.3 \times 10^{-7}) \end{aligned}$$

$$\Rightarrow Q > K_{sp}$$

\Rightarrow rxn shifts to the left

\Rightarrow the precipitate will form ✓