

Name: _____

date: _____

period: _____

ch. 17, 20, 8.10, 19.7 equilibrium, electrochem, & thermo

test ⁶⁵ ~~70~~ ⁷⁰ points (100)

AP chemistry

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In problems involving any calculation, show your work in an organized manner, include (i) any relevant equation (or formula), (ii) conversion factor(s), (iii) put the proper units in your calculations and answer, and (iv) have the proper number of significant figures in your answer.

1. 50.0 mL 10.0 mM HNO₃ is by titrated by 25.0 mM KOH. What is ___ ? basis / rationale ? [20 points]

a. the pH at the volume of KOH = 0 mL

- HNO₃ is a strong acid, so

4pt

$$\begin{aligned} \text{pH} &= -\log[H^+] = -\log[HNO_3] \\ &= -\log(10 \cdot 10^{-3}) \\ &= 2.000 \end{aligned}$$

b. the pH at the volume of KOH = ∞

6pt

$$\begin{aligned} \text{pH} &= \text{pH of KOH} \text{ b/c } \dots \\ \text{pOH} &= -\log[OH^-] = -\log[KOH] \\ &= -\log(25 \cdot 10^{-3}) \\ &= 1.60 \end{aligned}$$

$$\text{pH} + \text{pOH} = 14$$

$$\text{pH} = 14 - \text{pOH} = 14 - 1.60 = 12.400$$

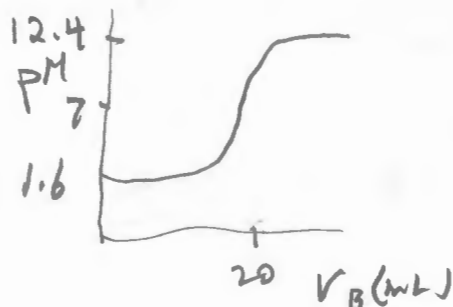
c. the pH and volume of KOH at the equivalence point

4pt

$$\begin{aligned} \text{(i)} \quad [A^-] V_A &= [B^+] V_B \\ 10 \text{ mM} (50 \text{ mL}) &= 25 \text{ mM} V_B \\ V_B &= 20 \text{ mL} \end{aligned}$$

(ii) pH = 7 b/c form neutral salt @ equivalence point & 3 no acid or base

d. based on the preceding information, sketch / label the titration curve

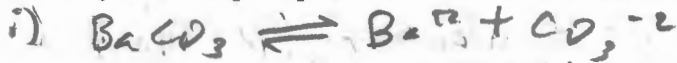


1 pt: graph, label & shape
 1 pt: V_B = 20 mL
 4 pt: pH = 6, 7, & 12.4

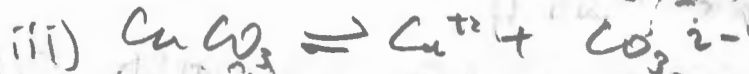
$Q > K_{sp}$

$\frac{1}{K}$

2. Sodium carbonate was slowly added to an aqueous solution of 1.0 mM Ba(NO₃)₂ and 0.1 mM Cu(NO₃)₂. Identify the first precipitate to be formed. Basis / rationale ? [10 points]



ii) $Q = [Ba^{2+}][CO_3^{2-}] > K_{sp} = 5.1 \cdot 10^{-9}$
 with $[CO_3^{2-}] > 5.1 \cdot 10^{-8} M$
 $[CO_3^{2-}] > 5.1 \cdot 10^{-6} M$



ii) $Q = [Cu^{2+}][CO_3^{2-}] > K_{sp} = 1.4 \cdot 10^{-10}$

$10^{-4} [CO_3^{2-}] > 1.4 \cdot 10^{-10}$
 $[CO_3^{2-}] > 1.4 \cdot 10^{-6} M$

2pt @ Cu is 1st ppt b/c $[CO_3^{2-}]$ to ppt $Cu^{2+} < Ba^{2+}$

3. What is the net ionic equation that describes how the addition of a strong ___ to a buffer containing lactic acid and sodium lactate. [10 points]

a. acid



b. base



4. How much time, in minutes, would be needed to generate 75 mL of oxygen gas at 25 °C with a pressure of 95 kPa in the electrolysis of water using a 250.0 mA current source ? [15 points]

i) $PV = nRT$
 $95 kPa \cdot \frac{75 mL}{101.3 kPa} = n \cdot (0.0821 L \cdot atm / mol \cdot K) (25 + 273) K$

$n_{O_2} = 0.002875 mol$



iii) $0.002875 mol O_2 \cdot \frac{4 mol e^-}{1 mol O_2} \cdot \frac{96,485 C/mol e^-}{1000} = 1110 C$

iv) $I = \frac{q}{t}$

$t = \frac{q}{I} = \frac{1110 C}{0.25 A} = 4439 sec \cdot \frac{min}{60 sec} = 7.4 min$

5. A galvanic cell contains a zinc electrode in an aqueous solution of zinc nitrate and an iron electrode in an aqueous solution of iron (II) nitrate. [20 points]

15

a. Write the net ionic equation for the spontaneous redox reaction. Justify / rationalize that it's spontaneous reaction.

2pt

4+1b

4pt



E°



$0.763 \text{ V } E^\circ_{ox}$



$-0.44 \text{ V } E^\circ_{red}$

ii) $E^\circ_{cell} = E^\circ_{cath} + E^\circ_{an} > 0$

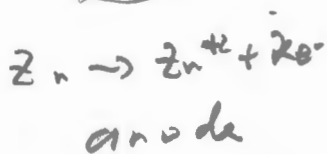
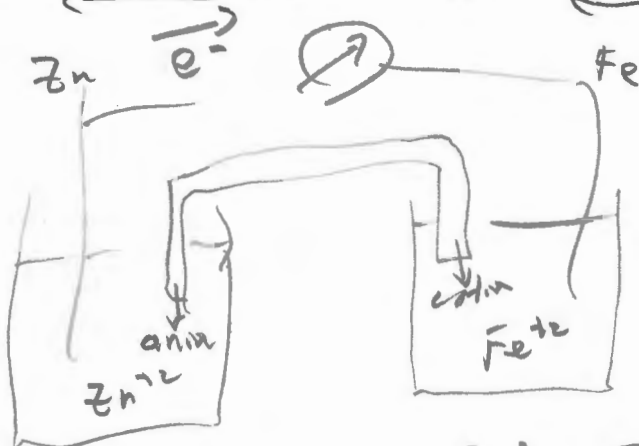
$\Delta G^\circ = -nFE^\circ < 0$

\therefore spontaneous rx

b. Sketch the electrochemical cell and label the electrode / electrolyte; the half-reaction at each electrode; cathode and anode; direction of the flow of electrons; direction of the ions in the salt bridge.

5pts

1+1e



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retest ⁶⁵ 90 points (5 ec)

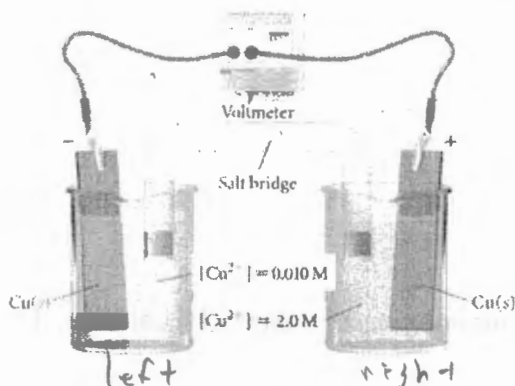
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1. In the below copper concentration cell, [15 points]



a. What is the redox half reactions on the ____ side of the above electrochemical cell ?

2 pt

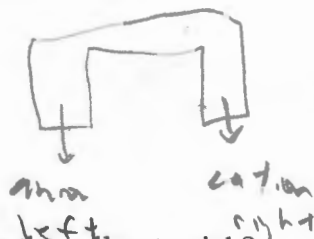


2



b. What is the direction of the ions in the salt bridge, which contains KCl ?

2



c. At 23 °C, what is the cell potential ?

3

$$E = E^{\circ} - \frac{RT}{nF} \ln \frac{[\text{Cu}^{2+}(\text{left})]}{[\text{Cu}^{2+}(\text{right})]}$$

3

$$= 0 - \frac{8.314 \text{ J mol}^{-1} \text{ K}^{-1} (23 + 273) \text{ K}}{2 (96,500) \text{ C mol}^{-1}} \ln \frac{0.01}{2}$$

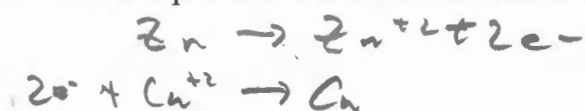
3

$$= + 0.01275 (5.298) = 0.068 \text{ V}$$

2. Sketch / label an electrolytic cell, where a carbon (or graphite) electrode is electroplated with copper, where the electrolytic cell has a carbon and copper electrodes are in an aqueous solution of copper (II) chloride. Clearly label the (i) cathode and anode and (ii) positive and negative terminal of the battery and write the half reaction at each electrode. [10 points]

3. In the electrochemical cell, where zinc metal is added to an aqueous solution of copper (II) chloride, [15 points]

- a. What is cell potential under standard conditions ?



$$E_{\text{ox}}^{\circ} = 0.763 \text{ V}$$

$$E_{\text{red}}^{\circ} = \underline{0.337 \text{ V}}$$

$$E_{\text{cell}}^{\circ} = 1.1 \text{ V}$$

- b. What is ΔG° at 300 K ?

$$\Delta G^{\circ} = -nF E^{\circ}$$

$$= 2 \left(96,500 \frac{\text{C/mol}}{\text{mol}} \right) 1.1 \text{ V} \frac{\text{J/Coul}}{\text{V}} \frac{\text{kJ}}{10^3 \text{ J}}$$

$$= -212 \frac{\text{kJ}}{\text{mol}}$$

- c. What is the numeric value of the equilibrium constant at 300 K ?

$$\Delta G^{\circ} = -RT \ln K$$

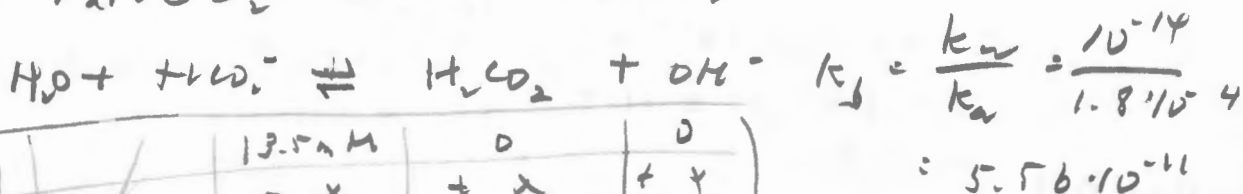
$$\ln K = -\frac{\Delta G^{\circ}}{RT} = \frac{212 \text{ kJ}}{8.314 \frac{\text{J}}{\text{mol K}} (300 \text{ K})} \frac{\text{kJ}}{10^3 \text{ J}}$$

$$= 84.997$$

$$K = e^{85} \sim 8.2 \cdot 10^{36}$$

4. An aqueous solution of potassium chloride is added to an aqueous solution of $1.0 \mu\text{M}$ silver nitrate and 1.0 mM lead (II) nitrate. What is the first precipitate to form? basis / rationale? For simplicity, assume that the addition of potassium chloride does not change the concentration of lead (II) nitrate and silver nitrate. [10 points]

What is the pH of 275 mL aqueous solution of 135 mM sodium formate, NaCOO^{H} ? [20 points]



		135 mM	0	0
		$-x$	$+x$	$+x$
K		$0.135 - x$	x	x

ii) $K_b = \frac{[\text{H}_2\text{CO}_2][\text{OH}^-]}{[\text{HCO}_2^-]}$

$5.56 \cdot 10^{-11} = \frac{x^2}{0.135 - x} \approx \frac{x^2}{0.135}$

$x = \sqrt{0.135 \cdot 5.56 \cdot 10^{-11}} = 2.74 \cdot 10^{-6}$

iii) $[\text{OH}^-][\text{H}^+] = 10^{-14}$

$2.74 \cdot 10^{-6} [\text{H}^+] = 10^{-14}$

$[\text{H}^+] = 3.65 \cdot 10^{-9}$

iv) $\text{pH} = -\log_{10} [\text{H}^+] = -\log_{10} (3.65 \cdot 10^{-9}) = 8.44$

6. At 25 °C, what is the pH of 75 mL of 125 mM sodium acetate and 75 mM acetic acid ? [5 points]

7. At 25 °C, what is the pH of 75 mL of 125 mM sodium acetate and 75 mM acetic acid mixed with 25 mL of _____. [20 points]

a. 35 mM HCl

6 pt i) $n_{NaAc} = [] V = \frac{125 \text{ mmol}}{10^3 \text{ mL}} \cdot 75 \text{ mL} = 9.375 \text{ mmol NaAc}$

$n_{HA} = [] V = \frac{75 \text{ mmol}}{10^3 \text{ mL}} \cdot 75 \text{ mL} = 5.625 \text{ mmol HA}$

$n_{HCl} = [] V = \frac{35 \text{ mmol}}{10^3 \text{ mL}} \cdot 25 \text{ mL} = 0.875 \text{ mmol HCl}$

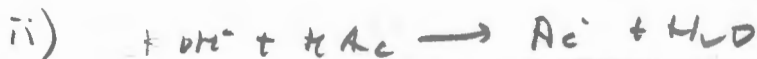


I	0.875	9.375	5.625	
C	-0.875	-0.875	+0.875	
E	0	8.5	6.5	

iii) $pH = pK_a + \log \frac{NaAc}{HAc}$
 $= -\log(4.8 \cdot 10^{-5}) + \log \left(\frac{8.5 \text{ mmol/L}}{6.5 \text{ mmol/L}} \right)$
 $= 4.745 + 0.117$
 $= \underline{4.86}$

b. 35 mM KOH

2 i) $n_{KOH} = [] V = \frac{35 \text{ mmol}}{10^3 \text{ mL}} \cdot 25 \text{ mL} = 0.875 \text{ mmol KOH}$



I	0.875	5.625	9.375
C	-0.875	-0.875	+0.875
E	0	4.75	10.25

3 iii) $pH = pK_a + \log \frac{A^-}{HA}$
 $= -\log(4.8 \cdot 10^{-5}) + \log \left(\frac{10.25}{4.75} \right)$
 $= 4.745 + 0.334$
 $= \underline{5.079}$