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Chemistry 1210 Spring 2023 Test 2

Wednesday, March 1, 2023 Time: 1 hour 50 minutes

Name: ANSWERS Student #: _____

*This test consists of **six** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **37** marks available. Good luck!*

1) **[2 marks]** The molar solubility of $Ca_3(PO_4)_2$ in water is 1.14×10^{-7}. The K_{sp} of $Ca_3(PO_4)_2$ should therefore be:

a) 1.92×10^{-35}
b) 6.9×10^{-34}
c) 2.07×10^{-33}
d) 1.3×10^{-14}
e) 7.78×10^{-14}

2) **[2 marks]** The K_{sp} of Ag_3PO_4 is 8.89×10^{-17}, and the molar mass of Ag_3PO_4 is 418.6 grams. The number of grams of Ag_3PO_4 that will dissolve in 1 litre of 0.010 M $AgNO_3$ is therefore:

a) 3.0×10^{-15}
b) 8.9×10^{-15}
c) 3.3×10^{-12}
d) 3.7×10^{-12}
e) 8.9×10^{-11}
f) 3.7×10^{-8}

3) **[4 marks]** A solution contains $[S^{2-}] = 1.0 \times 10^{-10}$ M and $[PO_4^{3-}] = 1.0 \times 10^{-2}$ M. Solid $AgNO_3$ is added carefully to separate the two ions. The K_{sp}s of the two compounds formed are 8.89×10^{-17} (Ag_3PO_4) and 1.6×10^{-49} (Ag_2S).

a) Which ion will precipitate first?

S^{2-}: $1.6 \times 10^{-49} = [Ag^+]_e^2 \cdot 1 \times 10^{-10} \Rightarrow [Ag^+]_e = 4 \times 10^{-20}$ M

PO_4^{3-}: $8.89 \times 10^{-17} = [Ag^+]_e^3 \cdot 1 \times 10^{-2} \Rightarrow [Ag^+]_e = 2.07 \times 10^{-5}$

So S^{2-} precipitates first

b) At the point of maximum separation, what will be the percent remaining of the first ion to precipitate?

$(2.07 \times 10^{-5})^2 \cdot [S^{2-}]_e = 1.6 \times 10^{-49}$

$\Rightarrow [S^{2-}]_e = 3.728 \times 10^{-40}$ M

↑ small! ↑ wow!

% remaining: $\frac{3.728 \times 10^{-40}}{1 \times 10^{-10}} \times 100 = 3.728 \times 10^{-28}\%$

↑ wow! ↑ small!

4) **[4 marks]** Give the oxidation number of the oxygen atom in each of the following compounds:

a) F_2O +2 b) Na_2O_2 −1 c) NaOF 0 d) FOOF +1

5) **[7 marks total]** Given the following (unbalanced) redox reaction, occurring in **basic** solution:

$C_6H_6 + ClO_4^{-1} \longrightarrow CO_2 + Cl_2$

a) **[4 marks]** Balance the reaction.

$(12H_2O + C_6H_6 \longrightarrow 6CO_2 + 30H^+ + 30e^-) \times 7$

$(14e^- + 16H^+ + 2ClO_4^- \longrightarrow Cl_2 + 8H_2O) \times 15$

$84H_2O + 7C_6H_6 + 240H^+ + 30ClO_4^- \longrightarrow 42CO_2 + 210H^+ + 15Cl_2$

$+ 120H_2O$

$7C_6H_6 + 30H^+ + 30ClO_4^- \longrightarrow 42CO_2 + 15Cl_2 + 36H_2O$

$30H_2O \longrightarrow 30H^+ + 30OH^-$

$7C_6H_6 + 30ClO_4^- \longrightarrow 42CO_2 + 15Cl_2 + 6H_2O + 30OH^-$

b) **[1 mark]** Identify the reducing agent. C_6H_6

c) **[1 mark]** Identify the species which is oxidized. C_6H_6

d) **[1 mark]** How many electrons are transferred in the overall process?

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6) **[5 marks total]** Given the following half-reactions:

$2IO_3^{-1} + 12H^+ + 10e^{-1} \longrightarrow I_2 + 6H_2O$ $\quad \varepsilon° = 1.20\ V$

$I_2 + 2e^{-1} \longrightarrow 2I^{-1}$ $\quad \varepsilon° = 0.54\ V$

a) **[2 marks]** Write the reaction for the disproportionation of I_2.

$I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+ + 10e^-$ $\quad \varepsilon° = -1.20V$

$(I_2 + 2e^- \longrightarrow 2I^-) \times 5$ $\quad \varepsilon° = 0.54V$

$6I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+ + 10I^-$

$\Downarrow \div 2$

$\boxed{3I_2 + 3H_2O \longrightarrow IO_3^- + 6H^+ + 5I^-}$

b) **[1 mark]** Will I_2 disproportionate under standard conditions? How do you know? (No marks for guessing. 😊)

$0.54 - 1.20 = -0.66V$ for $\varepsilon°$

$\varepsilon° < 0$, so $\boxed{NO}$

c) **[2 marks]** Calculate K_c for the disproportionation. You may assume a temperature of 25°C.

$0 = -0.66 - \frac{0.059159}{5} \log K$ ← b/c divided by 2 above.

$\Rightarrow \boxed{K = 1.65 \times 10^{-56}}$

(If didn't $\div 2$, get 2.73×10^{-112})

7) **[9 marks total]** A battery was constructed using the following half-reactions:

$PbO_2(s) + 4H^+(aq, 6\ M) + 2e^{-1} \longrightarrow Pb^{2+}(aq, 0.010\ M) + 2H_2O(l)$ $\quad \varepsilon° = 1.46\ V$

$Al^{3+}(aq, 0.20\ M) + 3e^{-1} \longrightarrow Al(s)$ $\quad \varepsilon° = -1.66\ V$

The battery was run at 25°C, and 2 litres of solution were used in each half-cell. Platinum electrodes were available for use as necessary.

a) **[1 mark]** Which electrode will be the anode? $Al(s)$

b) **[1 mark]** Give the cell notation for the battery.

$Al(s) \mid Al^{3+}(aq, 0.2M) \parallel H^+(aq, 6M), Pb^{2+}(aq, 0.01M) \mid PbO_2(s) \mid Pt(s)$

c) **[1 mark]** What is the overall reaction occurring in the battery?

$(PbO_2 + 4H^+ + 2e^- \longrightarrow Pb^{2+} + 2H_2O) \times 3 \quad \varepsilon° = 1.46V$

$(Al \longrightarrow Al^{3+} + 3e^-) \times 2 \quad \varepsilon° = 1.66V$

$3PbO_2 + 12H^+ + 2Al \longrightarrow 3Pb^{2+} + 6H_2O + 2Al^{3+}$

d) **[1 mark]** What voltage will the battery produce under standard conditions?

$1.46 + 1.66 = \boxed{3.12\ V}$

e) **[2 marks]** What voltage will the battery produce under the conditions given?

$$\varepsilon = 3.12 - \frac{0.059159}{6} \log\left(\frac{0.01^3 \cdot 0.2^2}{6^{12}}\right)$$

$$= \boxed{3.285\ V}$$

f) **[3 marks]** A current of 0.50 A was drawn from the battery for 3 hours and 13 minutes. What was the concentration of the Al^{3+} at the end of this time?

$$0.5\ \frac{coul}{s} \times 11580s \times \frac{1\ mole^-}{96{,}485\ coul} \times \frac{1\ Al^{3+}}{3e^-}$$

$$= 0.02\ mol\ Al^{3+}\ created$$

$$\frac{2L \times 0.2\ \frac{moles}{L} + 0.02\ mol}{2L} = \boxed{0.21\ M}$$

8) **[4 marks]** A concentration cell was assembled based on the following half-reaction:

$Ag^+(aq) + e^{-1} \longrightarrow Ag(s)$

One half cell contained a 0.10 M solution of $AgNO_3$, and the other held a saturated solution of Ag_2CO_3. The cell, when run at 35.17°C, produced 0.157 volts. What is the K_{sp} of Ag_2CO_3 at 35.17°C?

$Ag^+(0.1) + e^- \longrightarrow Ag$

$Ag \longrightarrow Ag^+(x) + e^-$

$Ag^+(0.1) \longrightarrow Ag^+(x)$

$Q = \frac{x}{0.1}$

$Ag_2CO_3 \rightarrow 2Ag^+ + CO_3^{2-}$

$2.71\times10^{-4}\quad 1.35\times10^{-4}$

$K_{sp} = (2.71\times10^{-4})^2(1.35\times10^{-4})$

$= \boxed{1\times10^{-11}}$

$$0.157 = 0 - \frac{(8.314)(308.32)}{1 \cdot 96{,}485\ldots} \ln Q$$

$\Rightarrow Q = 2.71\times10^{-3}$; $[Ag^+] = 2.71\times10^{-4}$