Some Review Problems for Exam 2 – Chem 1B

(Note: this selection of problems is NOT comprehensive!)

Useful Information:

$Ag^+ + e^- \rightarrow Ag$ $\quad E° = +0.799$ V

$Cr^{3+} + 3\ e^- \rightarrow Cr$ $\quad E° = -0.740$ V

$Au^{3+} + 3\ e^- \rightarrow Au$ $\quad E° = +1.498$ V

H_2CO_3 $K_{a1} = 4.3\times10^{-7}$, $K_{a2} = 5.6\times10^{-11}$

H_3PO_4 $K_{a1} = 7.5\times10^{-3}$, $K_{a2} = 6.2\times10^{-8}$, $K_{a3} = 4.2\times10^{-13}$

substance	$\Delta H_f°$, kJ/mol	$\Delta G_f°$, kJ/mol	S°, J/K•mol
$(CH_3)_2CO_{(g)}$	- 216.6	- 153.1	294.9
$(CH_3)_2CO_{(l)}$	- 247.6	- 155.7	200.04
$H_{2\,(g)}$	0	0	130.68
$CO_{(g)}$	- 110.5	- 137.2	197.7
$CH_{4(g)}$	- 74.6	- 50.5	186.3
$H_2O_{(g)}$	- 241.83	- 228.72	188.835
$H_2O_{(l)}$	- 285.83	- 237.1	69.95

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1. The indicator HX has a pK_a of 3.9. Its acid form is yellow and its base form is blue. What color will this indicator be in a solution of pH 5.0?
2. Oxalic acid ($H_2C_2O_4$) $K_{a1} = 5.9 \times 10^{-2}$, $K_{a2} = 6.4 \times 10^{-5}$
   You have a solution containing 0.020 moles of $HC_2O_4^-$ and 0.050 moles of $C_2O_4^{2-}$ in 500. mL of solution.
   a. How many moles of which buffer component must be added to change the pH to 3.80? How many grams, if it is in the form of its sodium salt?
   b. For the original buffer, what volume of 2.00 M HCl or 2.00 M NaOH must be added to change the pH to 3.80?
3. If 70.0 mL of 0.100 M HCl is added to 50.0 mL of 0.100 M Na_3PO_4, what is the pH of the resulting solution?
4. Describe three different ways of making 500. mL of a buffer with a pH of 7.00 in which the least concentrated buffer component is 0.20 M.
5. a. Calculate the pH at the 1/4 of the way point and at the 3/4 of the way point for the titration of 25.0 mL of 0.10 M CH_3NH_2 ($K_b = 5.0 \times 10^{-4}$) with 0.10 M HBr.
   b. Calculate the pH at the equivalence point.
   c. Calculate the pH after 30.0 mL of HBr has been added.
   d. What would be a good indicator to use for this titration? Explain.
6. What volume of 0.20 M HCl would you add to 100 mL of 0.10 M Na_2CO_3 to make a buffer with a pH of 10.00?
7. You have a solution that is 0.010 M Ag^+ and 0.010 M Ba^{2+}. If you slowly add Na_2SO_4, which will precipitate first?
   K_{sp} $Ag_2SO_4 = 1.4 \times 10^{-5}$, K_{sp} $BaSO_4 = 1.1 \times 10^{-10}$
   What is the concentration of the first cation when the second cation starts to ppt?
8. Determine the solubility of AgCl in 5.0 M NH_3.
   K_{sp} $AgCl = 1.8 \times 10^{-10}$, K_f $Ag(NH_3)_2^+ = 1.5 \times 10^7$

9. Find the overall equilibrium constant for : (see prob. #2 for K_a values)
$MgC_2O_{4\,(s)} + 2\ H_3O^+ \Leftrightarrow Mg^{2+} + H_2C_2O_4 + 2\ H_2O$
K_{sp} of $MgC_2O_4 = 8.5 \times 10^{-5}$

10. 50.0 mL of 0.20 M $MgSO_4$ is mixed with 50.0 mL of 0.20 M Na_3AsO_4. Will a precipitate form? K_{sp} $Mg_3(AsO_4)_2 = 2 \times 10^{-20}$
What are the ion concentrations afterward?

11. Determine the solubility of PbI_2 in 0.50 M NaI. $K_{sp} = 4.1 \times 10^{-8}$
Compare this to the solubility of PbI_2 in water.

12. a. Calculate $\Delta G°$ for the following reaction at 150.°C:
$3\ H_{2\,(g)} + CO_{(g)} \rightarrow CH_{4\,(g)} + H_2O_{(g)}$
Is it spontaneous under standard conditions at this temperature?
b. Is this reaction enthalpy-driven, entropy-driven, both, or neither?
c. How could you adjust the temperature to make this reaction as spontaneous as possible?
d. Calculate the equilibrium constant for this reaction at 150.°C.
e. If you mix together 0.010 atm hydrogen, 0.010 atm carbon monoxide, 5.0 atm methane, and 5.0 atm steam (at 150°C), which way will the reaction go to reach equilibrium?
f. Calculate the temperature at which this reaction should become nonspontaneous under standard conditions.
g. If you have 0.010 atm hydrogen, 5.0 atm methane, and 5.0 atm steam (at 150°C), what would the pressure of carbon monoxide need to be to make the reaction nonspontaneous?

13. a. For the process: $(CH_3)_2CO_{(g)} \rightarrow (CH_3)_2CO_{(l)}$
Predict the signs of $\Delta H°$ and $\Delta S°$.
b. Is this process enthalpy-driven, entropy-driven, both, or neither?
c. Is the reverse process ($(CH_3)_2CO_{(l)} \rightarrow (CH_3)_2CO_{(g)}$) enthalpy-driven, entropy-driven, both, or neither?
d. Estimate the normal boiling point of acetone, $(CH_3)_2CO$. (The actual bp is 56°C.)
e. Estimate the vapor pressure of acetone at 30.°C.
f. At what temperature would acetone have a vapor pressure of 600. torr?

14. If a reaction is endothermic and the sign of ΔS is positive, under what conditions of temperature will the reaction be spontaneous: at all temperatures, no temperatures, high temperatures, or low temperatures? Explain.

15. All S° (entropy) values for substances listed in the appendix are positive values. Explain why, in light of the third law of thermodynamics.

16. For the reaction: $3\ H_{2\,(g)} + N_{2\,(g)} \rightarrow 2\ NH_{3\,(g)}$
$K = 5.89 \times 10^5$ at 25°C and $K = 6.87 \times 10^{-5}$ at 500.°C.
a. Predict the signs of $\Delta H°$ and $\Delta S°$.
b. Use this information to calculate $\Delta H°$ and $\Delta S°$ for this reaction.

17. Is Li^+ a good reducing agent?

18. $Ni^{2+} + 2\ e^- \rightarrow Ni$ $\quad E° = -0.28$ V
Is this spontaneous?

19. Balance the following redox reaction. It occurs in basic solution.
$P_4 \rightarrow H_2PO_2^- + PH_3$

20. Balance the following redox reaction. It occurs in acidic solution.
$MnO_4^- + C_2O_4^{2-} \rightarrow Mn^{2+} + CO_2$

Identify the substance oxidized, the substance reduced, the oxidizing agent, and the reducing agent. (#20 continued)

21. What is the best oxidizing agent and the best reducing agent in the following list:
Na, Na^+, Br_2, Br^-, Co, Co^{2+}, Fe, Fe^{2+}, Fe^{3+}, H_3O^+, H_2, Au, Au^{3+}
22. Does solid iron react with acid? Does solid gold react with acid?
23. If a Ag/Ag^+ half-cell is connected to a Cr^{3+}/Cr half-cell,
a. What is the cell voltage under standard conditions?
b. Sketch the cell. Label the sketch.
c. How could you adjust the concentrations of Ag^+ and Cr^{3+} to increase the voltage?
d. Calculate the cell voltage if $[Ag^+] = 2.0\times10^{-4}$ M and $[Cr^{3+}] = 0.80$ M.
e. Calculate $\Delta G°$ and K for the overall reaction.
f. If the cell voltage = 1.413 V when $[Cr^{3+}] = 0.50$ M, what is the $[Ag^+]$?
24. If $\Delta G°$ for a reaction is positive at a particular temperature, does the reaction go forward at all? What might it depend on?
25. 500. mL of a buffer contains 0.153 moles of $H_2PO_4^-$ and 0.266 moles of HPO_4^{2-}. If 50. mL of 0.65 M HCl is added to this solution, what is the resulting pH?
26. For the reaction: $PbCl_{2\,(s)} \leftrightarrows Pb^{2+}_{(aq)} + 2\ Cl^-_{(aq)}$ $\Delta H°$ is positive and (even though this is counterintuitive) ΔS is negative. Will this solid be more soluble, less soluble, or equally soluble in warmer water? Explain your reasoning.

Answers:

1. blue
2. a. 0.10 mol $HC_2O_4^-$, 12 g $NaHC_2O_4$ b. 0.030 mol HCl, 15 mL HCl
3. 7.38
4. a. Mix 0.10 mol HPO_4^{2-} and 0.16 mol $H_2PO_4^-$
b. Mix 0.26 mol HPO_4^{2-} and 0.16 mol HCl
c. Mix 0.26 mol $H_2PO_4^-$ and 0.10 mol NaOH
(can now convert these numbers of moles to g or mL, as appropriate.)
5. a. 11.18, 10.22 b. 6.00 c. 2.0
6. 32 mL
7. $BaSO_4$, $[Ba^{2+}] = 7.9 \times 10^{-10}$ M
8. 34 g/L
9. K = 23
10. a. yes b. $[Na^+] = 0.30$ M, $[SO_4^{2-}] = 0.10$ M, $[AsO_4^{3-}] = 0.033$ M, $[Mg^{2+}] = 2.6 \times 10^{-6}$M.
11. In 0.50 M NaI, 7.6×10^{-5} g/L. In water, 1.0 g/L
12. a. –115.2 kJ, yes
b. enthalpy-driven
c. lower T
d. 2×10^{14}
e. forward (ΔG -)
f. 687 °C
g. 1.5×10^{-7} atm
13. a. both negative
b. enthalpy
c. entropy
d. 54°C
e. 310 mm Hg
f. 47°C
14. high T
16. a. both negative
b. $\Delta H° = -92$ kJ
$\Delta S° = -199$ J/K
17. No – can't be oxidized
18. Can't tell

20. Mn is reduced, C is oxidized, MnO_4^- is ox. agent, $C_2O_4^{2-}$ is red. agent
21. Best ox agent: Au^{3+}
    Best red agent: $Na_{(s)}$
22. yes, no
23. a. 1.539 V
    c. increase $[Ag^+]$, decrease $[Cr^{3+}]$
    d. 1.322 V
    e. – 382.7 kJ/mol
    f. 6×10^{-3} M Ag^+
24. yes – depends on what you start with.
25. pH = 7.31
26. more soluble