

Ch. 17: Additional Aqueous Equilibria

Ch. 18: Thermodynamics: Directionality of Chemical Reactions

Key Equations:

For weak acids alone in water: $[H^+] = \sqrt{K_a \times [WA]}$	For weak bases alone in water: $[OH^-] = \sqrt{K_b \times [WB]}$
$pZ = -\log Z$ General definition for p of anything	$pH + pOH = 14$
$[H^+][HO^-] = 1.00 \times 10^{-14}$	$K_a K_b = 1.00 \times 10^{-14}$ for conjugate acid/base pair
For Buffer: $pH = pK_a + \log[\text{base}]/[\text{acid}]$ Henderson-Hasselbalch Equation	$\Delta S^\circ = S^\circ (\text{products}) - S^\circ (\text{reactants})$
$\Delta G^\circ = G^\circ (\text{products}) - G^\circ (\text{reactants})$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ (T in Kelvin)

- Which of the following substances, when added to a 1L solution of 0.4M HF, could be used to prepare a buffer solution?
  - 0.4 moles of HCl only
  - 0.4 moles NaF only
  - 0.2 moles NaOH only
  - both 0.4 moles of NaF and 0.2 moles NaOH
  - 0.4 moles of NaCl
- Consider a solution prepared by adding 0.50 moles of  $CH_3COONa$  (sodium acetate) to 1.00 L of 1.00M  $CH_3COOH$  (acetic acid,  $K_a = 1.8 \times 10^{-5}$ ). If 0.050 moles of HCl is added to this buffer solution, the pH of the solution will drop slightly. The pH does not drastically decrease because the HCl reacts with the \_\_\_\_\_ present in the buffer solution.
  - $CH_3COONa$
  - $H^+$
  - $H_2O$
  - $CH_3COOH$
- For the following, in which case would the buffer capacity not be exhausted either by the addition of 0.5 moles of HCl or by the addition of 0.5 moles of NaOH?
  - 0.80 M HF and 0.20 M NaF
  - 0.80 M HF and 0.90 M NaF
  - 0.10 M HF and 0.20 M NaF
  - 0.10 M HF and 0.60 M NaF

4. Calculate the pH of a solution prepared by dissolving 0.15 mol of benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) and 0.30 mol of sodium benzoate ( $\text{C}_6\text{H}_5\text{COONa}$ ) in 1.00 L of solution. ( $K_a$  of  $\text{C}_6\text{H}_5\text{COOH} = 6.5 \times 10^{-5}$ )
- 2.51
  - 3.89
  - 4.49
  - 10.11
5. Consider a solution containing 0.100 M NaF and 0.126 M HF. Calculate the concentration of fluoride ion after addition of 5.00 mL of 0.100 M HCl to 25.0 mL of this solution.
- 0.0850 M
  - 0.00167 N
  - 0.0980 M
  - 0.0667 M
  - 0.00253 M
6. Calculate the final pH after 20.0 mL of 0.250 M NaOH solution is added to 50.0 mL of 0.200 M  $\text{HN}_3$  ( $K_a = 2.6 \times 10^{-5}$ ).
- 2.61
  - 8.79
  - 12.21
  - 4.59
  - 7.00
7. To prepare a buffer solution with  $\text{pH} = 4.70$ , how many moles of  $\text{NaN}_3$  should be added to a 1.0 L solution that is 0.40 M in  $\text{HN}_3$ ? ( $K_a$  for  $\text{HN}_3 = 2.6 \times 10^{-5}$ ).
- 0.12 moles
  - 0.31 moles
  - 0.40 moles
  - 0.52 moles
  - none of the above

8. What is the final pH when 0.56 moles of HCl is added to 1.0 L of 0.56M NaOCl solution. ( $K_a$  for HOCl =  $3.0 \times 10^{-8}$ ) (Assume the final volume is still 1.0 L).
- 7.77
  - 3.89
  - 4.76
  - 5.33
  - none of the above
9. If you start with 40.0 mL of 0.80 M HClO<sub>4</sub>, calculate the [H<sup>+</sup>] concentration after addition of 60.0 mL of 0.60 M KOH.
- $4.0 \times 10^{-2}$  M
  - $4.0 \times 10^{-3}$  M
  - $2.5 \times 10^{-12}$  M
  - $2.5 \times 10^{-13}$  M
  - none of the above
10. An initial pH of 1.00 and an equivalence point at pH 7.0 corresponds to a titration curve for
- A strong acid to which strong base is added
  - A strong base to which strong acid is added
  - A weak acid to which strong base is added
  - A weak base to which strong acid is added
  - A weak base to which weak acid is added
11. A weak acid HX has  $K_a = 4.0 \times 10^{-6}$ . What is the concentration of the anion X<sup>-</sup> in a solution in which 0.40M HX and 0.20M HCl are combined?
- $3.5 \times 10^{-3}$
  - $2.0 \times 10^{-3}$
  - $2.0 \times 10^{-6}$
  - $8.0 \times 10^{-6}$
  - none of the above
12. Which of the following combinations of chemicals in 1.0 L of water will give a solution with a basic pH?
- 1 mole of HCl and 1 mole of KN<sub>3</sub>
  - 1 mole of HCl and 1 mole of NaOH
  - 1 mole of HCl and 0.8 mole of NaOH
  - 1 mole of HCN and 1 mole of NaOH

13. What is the molarity of an HCl solution if 25.5 mL of this solution required 37.5 mL of 0.175 M NaOH to reach the equivalence point?
- 0.119
  - $1.83 \times 10^{-4}$
  - 0.257
  - 0.365
14. Which of the following combinations would give a pH of 7.00 at the “equivalence point” (when equal moles of each have been added)
- $\text{HClO}_4 + \text{NaF}$
  - $\text{HNO}_3 + \text{KOH}$
  - $\text{HCl} + \text{NH}_3$
  - $\text{HOCl} + \text{NaOH}$
  - None of the above
15. The solubility of which one of the following will not be affected by the pH of the solution?
- $\text{Na}_3\text{PO}_4$
  - NaF
  - $\text{KNO}_3$
  - $\text{Al}_2\text{S}_3$
  - $\text{Mn}(\text{OH})_2$
16. Zinc carbonate ( $\text{ZnCO}_3$ , 125.4 g/mol) has a  $K_{\text{sp}} = 1.4 \times 10^{-11}$ . How many grams of  $\text{ZnCO}_3$  can dissolve in 1.0 L of water?
- $4.69 \times 10^{-4}$  g/L
  - $3.74 \times 10^{-6}$  g/L
  - $6.39 \times 10^{-2}$  g/L
  - $5.43 \times 10^{-4}$  g/L
  - none of the above
17. The solubility of  $\text{Mn}(\text{OH})_2$  is  $2.2 \times 10^{-5}$  mol/L. What is the  $K_{\text{sp}}$  of  $\text{Mn}(\text{OH})_2$ ?
- $1.1 \times 10^{-14}$
  - $4.3 \times 10^{-14}$
  - $2.1 \times 10^{-14}$
  - $4.8 \times 10^{-10}$
  - none of the above

18. Consider the following table of  $K_{sp}$  values. Which one of the compounds shown in the table is the least soluble?

Compound	$K_{sp}$
CdS	$8.0 \times 10^{-27}$
CuS	$6.3 \times 10^{-36}$
PbS	$8.0 \times 10^{-28}$
MnCO <sub>3</sub>	$1.8 \times 10^{-11}$

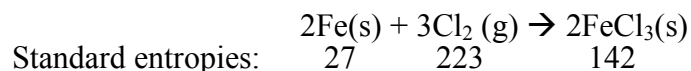
- a. CdS  
 b. CuS  
 c. PbS  
 d. MnCO<sub>3</sub>
19. What is the solubility (in moles/liter) of PbCl<sub>2</sub> in a solution that is 0.15 M solution in HCl? ( $K_{sp}$  PbCl<sub>2</sub> =  $1.6 \times 10^{-5}$ )

- a.  $2.0 \times 10^{-3}$   
 b.  $1.1 \times 10^{-4}$   
 c.  $1.8 \times 10^{-4}$   
 d.  $7.1 \times 10^{-4}$   
 e. none of the above

20. Which of the following statements is true regarding the impact of additional chemicals on the solubility of a saturated solution of CaCO<sub>3</sub>?

- a. CaCl<sub>2</sub> will decrease it's solubility, NaOH will increase it's solubility  
 b. HCl will decrease it's solubility, CaCl<sub>2</sub> will increase it's solubility  
 c. CaCl<sub>2</sub> will decrease it's solubility, HCl will increase it's solubility  
 d. NaCl will decrease it's solubility, HCl will increase it's solubility

21. Calculate  $\Delta S^\circ$  (at 25°C in J/mol•K) for the following reaction, given the standard entropies shown (in J/mol•K):



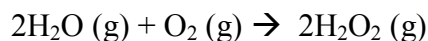
- a. -439  
 b. +108  
 c. -108  
 d. -380  
 e. +380

22. Which of the following reactions would have a positive value for  $\Delta S^\circ$ ?

- a.  $\text{Ba(OH)}_2 (\text{s}) + \text{CO}_2 (\text{g}) \rightarrow \text{BaCO}_3 (\text{s}) + \text{H}_2\text{O} (\text{l})$
- b.  $\text{N}_2 (\text{g}) + 3\text{H}_2 (\text{g}) \rightarrow 2 \text{NH}_3 (\text{g})$
- c.  $2\text{SO}_3 (\text{g}) \rightarrow 2\text{SO}_2 (\text{g}) + \text{O}_2 (\text{g})$
- d.  $\text{AgNO}_3 (\text{aq}) + \text{HCl} (\text{aq}) \rightarrow \text{AgCl} (\text{s}) + \text{HNO}_3 (\text{aq})$

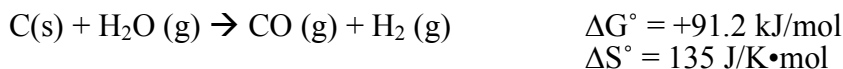
23. Determine the value of  $\Delta G^\circ$  (in kJ/mol) for the following reaction using data from the table below.

Substance	$\Delta G_f^\circ$ (kJ/mol)
$\text{H}_2\text{O} (\text{g})$	-228
$\text{H}_2\text{O}_2 (\text{g})$	-105



- a. -246
- b. 666
- c. 246
- d. -666

24. What is the value for  $\Delta H^\circ$  for this reaction at  $25^\circ\text{C}$ ?



- a. 40 kJ/mol
- b. 226 kJ/mol
- c. 91 kJ/mol
- d. 131 kJ/mol

25. Based on your knowledge of chemical reactions, which of the following processes has a negative standard free energy change at  $25^\circ\text{C}$ ?

- a.  $\text{CH}_4 (\text{g}) + 2\text{O}_2 (\text{g}) \rightarrow \text{CO}_2 (\text{g}) + 2\text{H}_2\text{O} (\text{g})$  only
- b.  $2\text{Na} (\text{s}) + 2\text{H}_2\text{O} (\text{l}) \rightarrow 2\text{NaOH} (\text{aq}) + \text{H}_2 (\text{g})$  only
- c.  $2\text{H}_2\text{O} (\text{l}) \rightarrow 2\text{H}_2 (\text{g}) + \text{O}_2 (\text{g})$
- d. both  $\text{CH}_4 (\text{g}) + 2\text{O}_2 (\text{g}) \rightarrow \text{CO}_2 (\text{g}) + 2\text{H}_2\text{O} (\text{g})$  and  $2\text{Na} (\text{s}) + 2\text{H}_2\text{O} (\text{l}) \rightarrow 2\text{NaOH} (\text{aq}) + \text{H}_2 (\text{g})$

26. Which one of the following has the greatest entropy?

- a.  $\text{HCl} (\text{l})$
- b.  $\text{HCl} (\text{s})$
- c.  $\text{HCl} (\text{g})$
- d. These are all the same

27. When a reaction is found by thermodynamics to be product-favored,
- It will be always be very rapid as written
  - Once it starts, it is possible for it to proceed as written without outside intervention
  - It is also reactant-favored
  - The equilibrium position lies very far to the left

28. Under which temperature conditions will the following reaction be product-favored?



- Above  $54^\circ\text{C}$
  - Above  $327^\circ\text{C}$
  - Below  $54^\circ\text{C}$
  - Below  $159^\circ\text{C}$
  - Always
29. The entropy of the universe is
- constant
  - continually decreasing
  - continually increasing
  - zero
30. What are the signs for  $\Delta H$  and  $\Delta S$  for a reaction that is product-favored at low temperature but reactant -favored at high temperature?
- $\Delta H$  is positive,  $\Delta S$  is positive
  - $\Delta H$  is negative,  $\Delta S$  is negative
  - $\Delta H$  is positive,  $\Delta S$  is negative
  - $\Delta H$  is negative,  $\Delta S$  is positive
31. Consider the following product-favored reaction occurring in an automobile engine ( $\text{C}_8\text{H}_{18}$  is gasoline). The signs for  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$  would be:
- $$2 \text{C}_8\text{H}_{18}(\text{l}) + 25 \text{O}_2(\text{g}) \rightarrow 16 \text{CO}_2(\text{g}) + 18 \text{H}_2\text{O}(\text{g})$$
- , +, +
  - +, -, -
  - +, +, -
  - , +, -

32. "Ice", frozen water, melts at 0°C. What are the signs for  $\Delta G$ ,  $\Delta H$  and  $\Delta S$  when ice is melting at 0°C?
- $\Delta G$  is negative,  $\Delta H$  is negative, and  $\Delta S$  is positive
  - $\Delta G$  is positive,  $\Delta H$  is positive, and  $\Delta S$  is positive
  - $\Delta G = 0$ ,  $\Delta H$  is negative, and  $\Delta S$  is negative
  - $\Delta G = 0$ ,  $\Delta H$  is positive, and  $\Delta S$  is positive
  - none of the above
33. Solid Ammonium nitrate is highly soluble in water. When it dissolves the solution gets very cold. Based on this experimental data alone, what must be the signs for  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$  for the process, and is the process enthalpy driven, entropy driven, both, or neither?
- +, +, +      Neither
  - +, -, -      Both
  - +, +, -      Entropy driven
  - , -, -      Enthalpy driven
34. Which of the following statements is false?
- When a reaction is exothermic, this results in dispersal of energy and in an increase in the entropy of the surrounding
  - Both the dispersal of energy and the dispersal of matter tend to be favorable things
  - All exothermic reactions are product-favored
  - Gaseous molecules tend to have higher entropy than solid molecules

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Answers, Test3  
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|-------|-------|
| 1. D  | 20. C |
| 2. A  | 21. A |
| 3. B  | 22. C |
| 4. C  | 23. C |
| 5. D  | 24. D |
| 6. D  | 25. D |
| 7. D  | 26. C |
| 8. B  | 27. B |
| 9. D  | 28. A |
| 10. A | 29. C |
| 11. D | 30. B |
| 12. D | 31. D |
| 13. C | 32. D |
| 14. B | 33. C |
| 15. C | 34. C |
| 16. A |       |
| 17. B |       |
| 18. B |       |
| 19. D |       |