Completion of acid/base/buffer chemistry

Chs 7-8 of Zumdahl

Hanson Activity 16-3

- Discuss Key Questions 1-4 of Activity 16-3, page 301, with your partner for three minutes.
- The clicker quiz will commence in 3 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Problem 55a

- Calculate the pH of a solution of 0.10 *M* HCl and 0.10 *M* HOCl (K_a= 3.5 x 10^{-8})
- What are the major species?
- What process controls the $[H^+]$? What is the pH
- pH = 1.00
- What would be the pH of 0.10 M HOCl by itself?
- $[H^+]$ = 5.9 x 10^{-5} *M* => pH = 4.2

Problem 55a

- Calculate the pH of a solution of 0.10 *M* HCl and 0.10 *M* HOCl (K_a= 3.5 x 10^{-8})
- What are the major species?
- What process controls the $[H^+]$? What is the pH
- pH = 1.00
- What is the concentration of OCl^-(aq) above?
- 3.5 x 10^{-8} *M*

Ex 2-3, p. 302

- Starting from $K_a = \frac{[H_3O^+][CN^-]}{[HCN]}$
- Rearrange to give expression for $[H_3O^+]$
- Take the log of both sides to give expression for -log $[H_3O^+]$ (*be careful)*
- Write it in terms of pH and pK

$$pH = pK_a + \log\left(\frac{[CN^-]}{[HCN]}\right)$$

Ex 5, p. 302

- 1.0 L of solution: 0.15 mol NaCN and 0.30 mol HCN (K_a=6.2 x 10^{-10}, pK_a = 9.21)
- Assume that the ionization of HCN is small compared to its concentration of 0.30 *M*.
- With your partner – what is the pH?

$$pH = pK_a + \log\left(\frac{[CN^-]}{[HCN]}\right) = 9.21 + \log\left(\frac{0.15M}{0.30M}\right) = 9.21 + \log(0.5) = 8.91$$

TABLE 7.2

Values of K_a for Some Common Monoprotic Acids

Formula	Name	Value of K_a
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}
$HClO_2$	Chlorous acid	1.2×10^{-2}
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}
HF	Hydrofluoric acid	7.2×10^{-4}
HNO_2	Nitrous acid	4.0×10^{-4}
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}
HOCl	Hypochlorous acid	3.5×10^{-8}
HCN	Hydrocyanic acid	6.2×10^{-10}
NH_4^+	Ammonium ion	5.6×10^{-10}
HOC_6H_5	Phenol	1.6×10^{-10}

↑ Increasing acid strength

Problem 7-54

- 1.0 *M* HF and 1.0 *M* HOC_6H_5 (phenol)
- Calculate pH and $[OC_6H_5^-]$ at equilibrium
- K_a (HF) = 7.2 x 10^{-4}; $K_a(HOC_6H_5)$ = 1.6 x 10^{-10}
- What is the strategy here?
- For HF alone, $[H^+]$ = 2.7 x 10^{-2} *M*
- Consider dissociation of phenol
- $[OC_6H_5^-]$ = 6.0 x 10^{-9} *M*, and pH = 1.57

Problem 58a,b

- Calculate the % dissocation in:
  - a) 0.50 *M* acetic acid (K_a = 1.8 x 10^{-5})
  - b) 0.050 *M* acetic acid(K_a = 1.8 x 10^{-5})
- For (a), calculate [H^+]=3.0 x 10^{-3}*M*
- % dissoc = 100 x (3.0x10^{-3}*M*)/(0.50*M*) = 0.6%
- For (b), calculate [H^+]=9.5 x 10^{-4}*M*
- % dissoc = 100 x (9.5x10^{-4}*M*)/(0.050*M*) = 1.9%

General observation: % dissociation increases as solution becomes more dilute.

Problem 53

- Aspirin tablet = 32.5 mg, $HC_9H_7O_4$
- Two tablets in 237 mL of solution.
- MW = 180.15 g/mol
- K_a= 3.3 x 10^{-4}
- What is the pH?
- 2.68

Polyprotic Acids

Table 7.4

Stepwise Dissociation Constants for Several Common Polyprotic Acids

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.8×10^{-13}
Arsenic acid	H_3AsO_4	5×10^{-3}	8×10^{-8}	6×10^{-10}
Carbonic acid*	H_2CO_3	4.3×10^{-7}	4.8×10^{-11}	
Sulfuric acid	H_2SO_4	Large	1.2×10^{-2}	
Sulfurous acid	H_2SO_3	1.5×10^{-2}	1.0×10^{-7}	
Hydrosulfuric acid†	H_2S	1.0×10^{-7}	$\approx 10^{-19}$	
Oxalic acid	$H_2C_2O_4$	6.5×10^{-2}	6.1×10^{-5}	
Ascorbic acid (vitamin C)	$H_2C_6H_6O_6$	7.9×10^{-5}	1.6×10^{-12}	

*This is really $CO_2(aq)$.

†The K_{a_2} value for H_2S is quite uncertain. Its small size makes it very difficult to measure.

Polyprotic Acids: H_3PO_4

$$H_3PO_4(aq) = H^+(aq) + H_2PO_4^-(aq); K_{a1} = 7.5\times10^{-3}$$
$$H_2PO_4^-(aq) = H^+(aq) + HPO_4^{2-}(aq); K_{a2} = 6.2\times10^{-8}$$
$$HPO_4^{2-}(aq) = H^+(aq) + PO_4^{3-}(aq); K_{a3} = 4.8\times10^{-13}$$

- Which ionization will determine the hydrogen ion concentration?
- What will be the major species?
- What are the ratios of the successive equilibrium constants?

Problem 85: H_3AsO_4

$$H_3AsO_4(aq) = H^+(aq) + H_2AsO_4^-(aq); K_{a1} = 5\times10^{-3}$$
$$H_2AsO_4^-(aq) = H^+(aq) + HAsO_4^{2-}(aq); K_{a2} = 8\times10^{-8}$$
$$HAsO_4^{2-}(aq) = H^+(aq) + AsO_4^{3-}(aq); K_{a3} = 6\times10^{-10}$$

- What is the pH in 0.2*M* arsenic acid?
- $[H^+] = [H_2AsO_4^-] =$ 2.9 x 10^{-2} *M, pH = 1.54*
- $K_{a2} << K_{a1}$

Problem 85: H_3AsO_4

$$H_3AsO_4(aq) = H^+(aq) + H_2AsO_4^-(aq); K_{a1} = 5\times10^{-3}$$
$$H_2AsO_4^-(aq) = H^+(aq) + HAsO_4^{2-}(aq); K_{a2} = 8\times10^{-8}$$
$$HAsO_4^{2-}(aq) = H^+(aq) + AsO_4^{3-}(aq); K_{a3} = 6\times10^{-10}$$

- $[H^+] = [H_2AsO_4^-] =$ 2.9 x 10^{-2} *M, pH = 1.54*
- *What is the concentration of $HAsO_4^{2-}$?*

$$K_{a2} = \frac{[HAsO_4^{2-}][H^+]}{[H_2AsO_4^-]} = \frac{(2.9\times10^{-2})[HAsO_4^{2-}]}{2.9\times10^{-2}} = 8\times10^{-8}$$

Hanson Activity 16-3

- Discuss Key Questions 5-8 of Activity 16-3, page 304, with your partner for three minutes.
- The clicker quiz will commence in 3 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Ex 7, p.304

- Calculate the pOH of a 0.30 M solution of NaOH.
- 0.52
- What is the pH?
- 13.48

Ex 8, p.305

- Calculate the pOH of 0.30 M NH_3 (K_b=1.8 x 10^{-5})
- 2.63
- The pH?
- 11.37

Problem 69

- Calculate the concentration of a $Ba(OH)_2$ solution with pH = 10.50.
- 1.6 x 10^{-4} *M*

Problem 71

- Hydrazine N_2H_4 is a weak base in water (K_b=3.0x 10^{-6})
- It reacts as:

$$H_2NNH_2(aq) + H_2O(l) = H_2NNH_3^+(aq) + OH^-(aq)$$

- Calculate the concentration of all species in a 2.0 M solution of hydrazine.
- What is the pH?
- 11.38

Problem 79 a,b

- What is percent ionization in
  a) 0.10 M NH_3
  b) 0.010 M NH_3
  c) 1.3%
  d) 4.2%

Hanson Activity 16-3

- Discuss Key Questions 9-10of Activity 16-3, page 306, with your partner for three minutes.
- The clicker quiz will commence in 3 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Exercise 9, p.307

- With your partner, examine the example for HCN
- Work out one example with your partner:
  - Rows 1-2: NH_4^+
  - Rows 3-4: H_2CO_3
  - Rows 5-6: H_3O^+
  - Row 7: H_2O

Problem 93 a,b

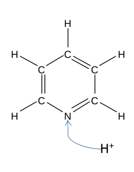
Rank the following 0.10 M solutions in order of increasing pH:

a) HI, HF, NaF, NaI
b) NH_4Br, HBr, KBr, NH_3

Problem 95 a,c

Are these acidic, basic, or neutral? Why?

- $Sr(NO_3)_2$
- C_5H_5NHF (look at Table 7.3)



Problem 95 a,c

Are these acidic, basic, or neutral? Why?

- C_5H_5NHF (look at Table 7.3)
  - Dissolves as C5H5NH$^+$ (aq) + F^-(aq)
  - C_5H_5N (pyridine) is a weak base, K_b=1.7 x 10^{-9}
  - HF is a weak acid (K_a=7.2 x 10^{-4})
  - What is K_a of the conjugate acid?
  - What is K_b of F^- ?

Problem 99

- 0.050 M solution of NaB(aq), pH = 9.00. (find K_b)
- What is the pH of 0.010 M HB(aq) ? (find K_a)
- 3.66

Chapter 8 - buffers

Hanson Activity 17-1

- Discuss Key Questions 1-7 of Activity 17-1, page 306, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Ex 2, p.371

- Calculate pH of solution 0.150 M in HAc (K_a=1.8x10^{-5}) and 0.300 M in NaAc
- Use the equation under Beaker B of the model
- pH = 5.05

Ex 3, p. 311

- For ammonia/ ammonia chloride buffer, what ratio of $[NH_3]/[NH_4^+]$ is needed for pH = 8.55?
- K_a= 5.6 x 10^{-10}
- $[NH_3]/[NH_4^+]$ = .2/1 or 1/5

Ex 4, p. 311

- Are these buffers?

a) 0.10 M KNO_3 and 0.1 M HNO_3
b) 0.10 M $NaNO_2$ and 0.1 M HNO_2
c) 0.10 M HCl and 0.1 M NH_3 (what reaction takes place?)
d) 0.20 M HCl and 0.1 M NH_3
e) 0.10 M HCl and 0.2 M NH_3

Problem 21d

- Calculate the pH of 0.100 M $HC_3H_5O_2$ (K_a=1.3 x10^{-5}) and 0.100 M $NaC_3H_5O_2$.
- 4.89

Problem 31

- 25.1 g of $HC_7H_5O_2$ (MW = 122.12 g/mol) and 37.7 g of $NaC_7H_5O_2$ (MW = 144.10 g/mol) in 200.0 mL of solution. What is the pH?
- 4.37

Problem 35

- Given a 1.0 L solution of 1.0 *M* sodium acetate, $NaC_2H_3O_2$, how many moles of HCl must be added to produce a pH=4.20 buffer?
- K_a for acetic acid = 1.8 x 10^{-5}, pK_a= 4.74
- What ratio of acetic acid to acetate ion is needed?
- 0.78 mol

Problem 47

- In Table 7.2, which acid is best choice for making a 7.00 buffer?
- Use HOCl - could add NaOCl to adjust the acid/base ratio to get exactly 7.00.

Table 7-2

Table 7.2

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Formula	Name	Value of K_a
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$HClO_2$	Chlorous acid	1.2×10^{-2}
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}
HF	Hydrofluoric acid	7.2×10^{-4}
HNO_2	Nitrous acid	4.0×10^{-4}
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}
HOCl	Hypochlorous acid	3.5×10^{-8}
HCN	Hydrocyanic acid	6.2×10^{-10}
NH_4^+	Ammonium ion	5.6×10^{-10}
HOC_6H_5	Phenol	1.6×10^{-10}

↑ Increasing acid strength

Table 7-3

Table 7.3

Values of K_b for Some Common Weak Bases

Name	Formula	Conjugate Acid	K_b
Ammonia	NH_3	NH_4^+	1.8×10^{-5}
Methylamine	CH_3NH_2	$CH_3NH_3^+$	4.38×10^{-4}
Ethylamine	$C_2H_5NH_2$	$C_2H_5NH_3^+$	5.6×10^{-4}
Aniline	$C_6H_5NH_2$	$C_6H_5NH_3^+$	3.8×10^{-10}
Pyridine	C_5H_5N	$C_5H_5NH^+$	1.7×10^{-9}

Table 7-4

Table 7.4

Stepwise Dissociation Constants for Several Common Polyprotic Acids

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.8×10^{-13}
Arsenic acid	H_3AsO_4	5×10^{-3}	8×10^{-8}	6×10^{-10}
Carbonic acid*	H_2CO_3	4.3×10^{-7}	4.8×10^{-11}	
Sulfuric acid	H_2SO_4	Large	1.2×10^{-2}	
Sulfurous acid	H_2SO_3	1.5×10^{-2}	1.0×10^{-7}	
Hydrosulfuric acid†	H_2S	1.0×10^{-7}	$\approx 10^{-19}$	
Oxalic acid	$H_2C_2O_4$	6.5×10^{-2}	6.1×10^{-5}	
Ascorbic acid (vitamin C)	$H_2C_6H_6O_6$	7.9×10^{-5}	1.6×10^{-12}	

*This is really $CO_2(aq)$.

†The K_{a_2} value for H_2S is quite uncertain. Its small size makes it very difficult to measure.