Completion of equilibrium chapter

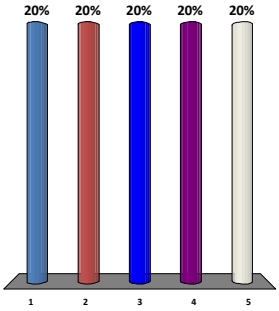
Ch 6 of Zumdahl

Problem #1, page 284

- With partner, set up the RICE process and get an expression for the equilibrium constant in terms of the change *x*.
- How can we solve this for x? –

What is the value of *x*?

1. 0.01 – 0.02 M
2. 0.02 – 0.03 M
3. 0.03 – 0.04 M
4. 0.04 – 0.05 M
5. None of the above



Problem 2, page 285

- Write the RICE table
- With your partner, find an expression for the equilibrium constant in terms of x.
- What is the expression for x?

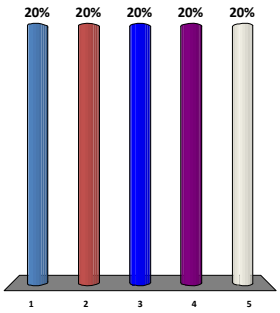
$$K_p = \frac{x}{(1.00-2x)^2} = 3.33$$

$$K_p = \frac{x}{(1.00-2x)^2} = 3.33$$

- How to solve for x?
- X = 0.34 atm

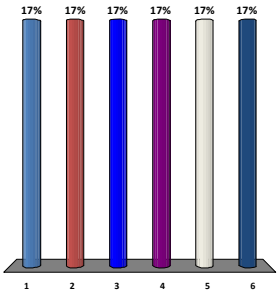
What is the partial pressure of NO_2

1. 0.16 atm
2. 0.17 atm
3. 0.32 atm
4. 0.34 atm
5. 0.68 atm



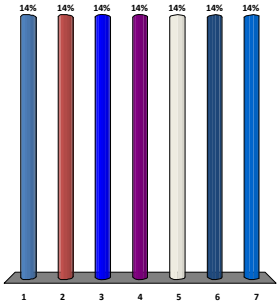
What is the partial pressure of N_2O_4 ?

1. 0.16 atm
2. 0.17 atm
3. 0.32 atm
4. 0.34 atm
5. 0.64 atm
6. 0.68 atm



What is the total pressure in the flask at equilibrium?

1. 0.32 atm
2. 0.34 atm
3. 0.66 atm
4. 1.00 atm
5. 1.32 atm
6. 1.34 atm
7. 1.66 atm

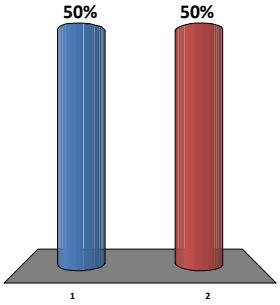


Problem #3, page 286

- Set up the RICE procedure
- 2.1% of the CO_2 decomposes
- What is the final pressure of carbon dioxide?
- What is the value of x?

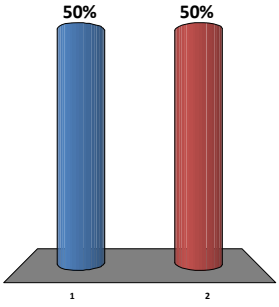
The equilibrium pressure of CO is 0.021 atm?

1. True
2. False



The equilibrium pressure of O_2 is 0.021 atm?

1. True
2. False

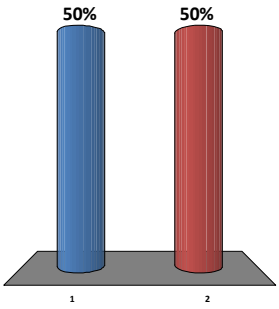


Problem 3

- Calculate the value of K_P
- 4.8×10^{-6}

Problem 4, p. 286. The expression for K is:

1. $P_{N2O}(P_{H2O})^2 / P_{NH4NO3}$
2. $P_{N2O}(P_{H2O})^2$



Hanson, Problem 4, page 286

- Work at the projector
- Reaction
  $NH_4NO_3(s) = N_2O(g) + 2\ H_2O\ (g)$ (R)
- At equilibrium $P_{tot} = 4.30$ atm
- Calculate K_P
- What are the Initial Partial Pressures? (I)
- What are the Changes (set up the x's) (C)
- Equilibrium Partial Pressures in terms of x ? (E)

Hanson, Problem 4, page 286

- How do we solve for x here? With partner
- X = 1.43 atm
- What is the value of K_P? With partner
- 11.8

Problem 6-23

- What do we know and what can we calculate easily?
- $K_C = 1.9\ mol^2/L^2$
- What is the relationship between K_c and K_P?
- $K_P = K(RT)^{\Delta n}$
- What is Δn here?
- What is RT here?
- What is $K_{P?}$
- $4.6 \times 10^3\ atm^2$

Problem 6-33

12.0 mol of SO_3 is placed in a 3.0 L container. Decomposition occurs:

$$2SO_3(g) = 2SO_2(g) + O_2(g)$$

At equilibrium 3.0 mol of SO_2 is present. Calculate K.

Problem 6-33

$2SO_3(g) = 2SO_2(g) + O_2(g)$ (R)

Initial concentrations?
$[SO_3] = 12.0\ mol/3.0\ L = 4.0\ M$ (I)

Changes (the x's)
SO_3: -2x; SO_2: +2x; O_2: x. (C)

Equilibrium concentrations
SO_3: 4.0M – 2x ; SO_2: 2x; O_2: x (E)

How can we determine x?

Problem 6-33

$2SO_3(g) = 2SO_2(g) + O_2(g)$ (R)

Equilibrium concentrations

SO_3: 4.0M – 2x ; SO_2: 2x; O_2: x (E)

How can we determine x?

At equilibrium: $[SO_2] = 3.0$ mol/3.0L = 1.0*M* = 2x

x = 0.5 *M*

At equilibrium: $[O_2] = x = 0.50$ *M*

$[SO_3] = 4.0M - 2x = 3.0$ *M*

Problem 6-33

$2SO_3(g) = 2SO_2(g) + O_2(g)$ (R)

At equilibrium: $[SO_2] = 3.0$ mol/3.0L = 1.0*M* = 2x

x = 0.5 *M*

At equilibrium: $[O_2] = x = 0.50$ *M*

$[SO_3] = 4.0M - 2x = 3.0$ *M*

Calculate K:

K = 0.056 mol/L

Problem 6-39a at Projector

- $H_2O(g) + Cl_2O(g) = 2\ HOCl(g)$
- 1.0 g of H_2O and 2.0 g of Cl_2O are mixed in a 1.0 L flask
- K = 0.090; what are the equilibrium concentrations?
- Strategy: know R;
- how to calculate initial concentrations? (I)

Problem 6-39a

- $H_2O(g) + Cl_2O(g) = 2\ HOCl(g)$
- 1.0 g of H_2O and 2.0 g of Cl_2O are mixed in a 1.0 L flask
- K = 0.090; what are the equilibrium concentrations?
- Strategy:
- What are the changes (the x's)?
- What are the equilibrium concentrations?

Problem 6-39a

- $H_2O(g) + Cl_2O(g) = 2\ HOCl(g)$
- 1.0 g of H_2O and 2.0 g of Cl_2O are mixed in a 1.0 L flask
- K = 0.090; what are the equilibrium concentrations?
- Strategy:
- What is the equilibrium constant expression? K = 0.090

Problem 6-39a

- $H_2O(g) + Cl_2O(g) = 2\ HOCl(g)$
- 1.0 g of H_2O and 2.0 g of Cl_2O are mixed in a 1.0 L flask
- K = 0.090; what are the equilibrium concentrations?
- Strategy:
- How to solve for x?

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Problem 6-39a

- $H_2O(g) + Cl_2O(g) = 2\ HOCl(g)$
- 1.0 g of H_2O and 2.0 g of Cl_2O are mixed in a 1.0 L flask
- K = 0.090; what are the equilibrium concentrations?
- Strategy:
- What are the x values?
- 4.6 x 10^{-3}*M and* -6.4x10^{-3}*M (which is correct?)*

Nature of Acids/Bases

Ch 7 of Zumdahl

Hanson Activity 16-1

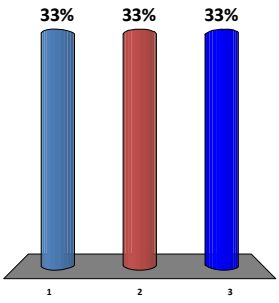
- Discuss Key Questions 1-5 of Activity 16-1, page 288, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

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

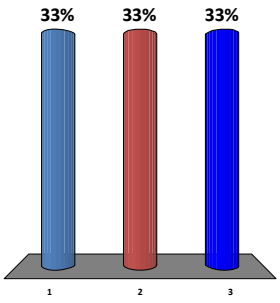
If you are given the logarithm of a number:

1. The number = $10^{-logarithm}$
2. The number = $10^{logarithm}$
3. The number = logarithm x 10



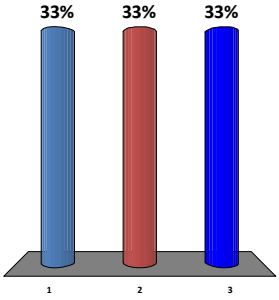
If you are given the pH of a solution:

1. $[H_3O^+] = 10^{-pH}$
2. $[H_3O^+] = 10^{pH}$
3. $[H_3O^+] = pH \times 10^{14}$

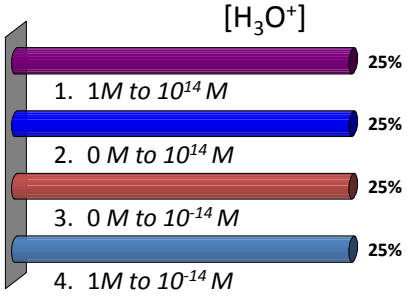


If you are given the hydronium ion concentration $[H_3O^+]$

1. pH = -log$[H_3O^+]$
2. pH = log$[H_3O^+]$
3. pH = $10^{14}/[H_3O^+]$



The pH scale ranges from 0 to 14. What is the corresponding range of $[H_3O^+]$



Exercise 1, p. 288

- Get out your calculators!

Hanson Activity 16-1

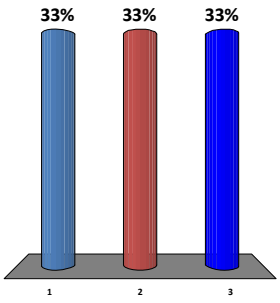
- Discuss Key Questions 6-9 of Activity 16-1, page 289, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

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

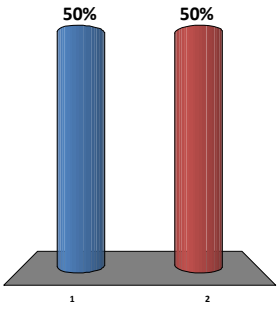
Compared to a neutral solution, a solution with pH of 2.7 has:

1. A lower hydronium concentration
2. A higher hydronium concentration
3. The same hydronium concentration



Compared to a neutral solution, a basic solution will have:

1. A higher pH
2. A lower pH

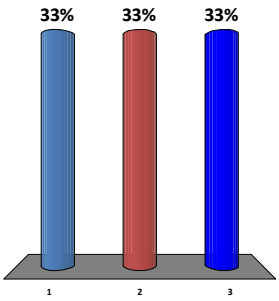


Questions about the Key Questions?

- Now quickly do Exercises 3-5, page 290 with your partner

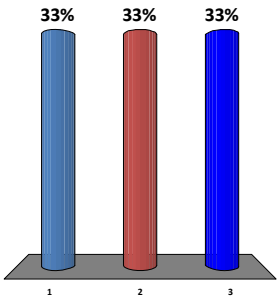
Ex3: Which has the highest hydronium ion concentration?

1. Milk
2. Pickle juice
3. Oven Cleaner



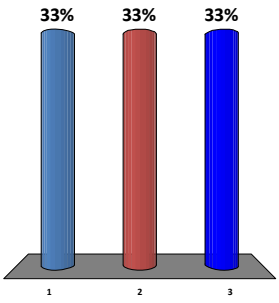
Which is the most acidic?

1. Milk
2. Pickle juice
3. Oven Cleaner



Which has the highest pH?

1. Milk
2. Pickle juice
3. Oven Cleaner



Exercises 6-9, p. 290

- Begin filling in this table with your partner
- For pH = 5.3, what is the calculated $[H_3O]$?
- For $[OH^-] = 2 \times 10^{-9} M$, what calculated pOH?
- What is the pH + pOH in column 2?
- What is the $[OH^-] \times [H_3O]$ in column 2?

$HA(aq) + H_2O(l) = H_3O^+(aq) + A^-(aq)$

- H_3O^+ (aq) is the same as $H^+(aq)$
- In the forward reaction, what acts as an acid?
- In the forward reaction, what acts as a base?
- In the reverse reaction, what acts as a base? (conjugate base)
- In the reverse reaction, what acts as an acid? (conjugate acid)

$HA(aq) + H_2O(l) = H_3O^+(aq) + A^-(aq)$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Strong Acids have:
- Large K_a values
- Equilibrium shifted far to the right
- $[H_3O^+] \approx [HA]_0$ (initial HA concentration)
- Conjugate base strength: much weaker than water

$HA(aq) + H_2O(l) = H_3O^+(aq) + A^-(aq)$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

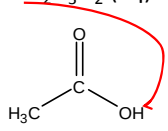
Weak Acids have:
- Small K_a values
- Equilibrium shifted far to the left
- $[H_3O^+] << [HA]_0$ (initial HA concentration)
- Conjugate base strength: much stronger than water

Examples of Strong Acids

- HCl (aq)
- H_2SO_4(aq) (both H's are bonded to oxygens)
- HNO_3(aq) (H is bonded to oxygen)
- $HClO_4$(aq) (H is bonded to oxygen)

Examples of Weak Acids

- H_3PO_4 (aq) $K_{a1} = 7.5 \times 10^{-3}$
- HSO_4^{-1}(aq) $K_a = 1.2 \times 10^{-2}$
- $HC_2H_3O_2$ (aq) $K_a = 1.8 \times 10^{-5}$



- HOCl(aq) $K_a = 3.5 \times 10^{-8}$

Free Energy Change for Weak Acid

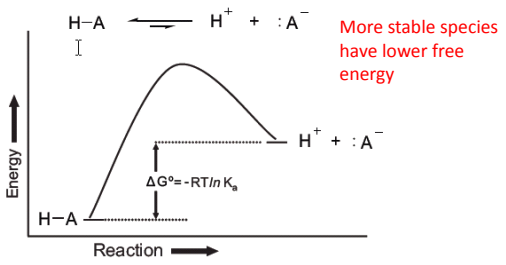


TABLE 7.2

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

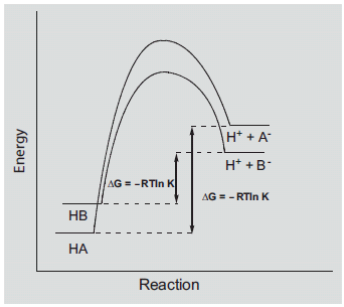
Hanson Activity 16-2

- Discuss Key Questions 1 and 3 of Activity 16-2, page 293, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

Clicker quiz

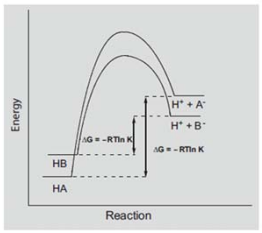
- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Exercise 2: HB is a stronger weak acid than is HA



In Exercise 2, which is the stronger base:

1. $A^-(aq)$
2. $B^-(aq)$

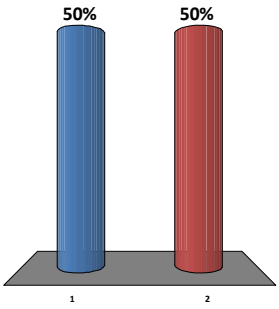


$pK_a = -\log K_a$

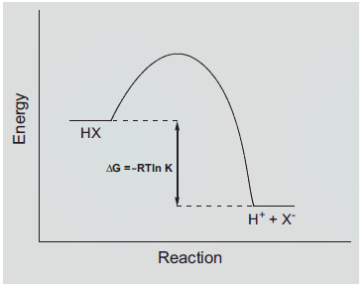
- For H-A, $pK_a = 5.2$
- For H-B, $pK_a = 7.4$
- With your partner, decide which is the stronger weak acid.

In Exercise 4, the stronger acid is HB

1. True
2. False



Ex 6. Sketch a reaction profile similar to the model for a strong acid HX.

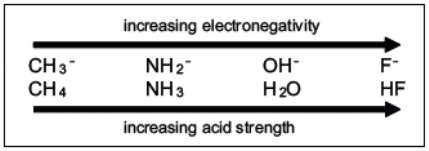


Factors that affect acid strength

- Charge. Conjugate bases can be destabilized by large negative charges
- H_2SO_4 is a stronger acid than HSO_4^-

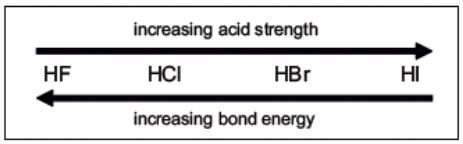
Factors that affect acid strength

- Electronegativity. Conjugate bases with negative charge can be stabilized by more electronegative atoms.



Factors that affect acid strength

- Bond Strength. An acid with stronger bonds will be stabilized relative to one with weaker bonds.



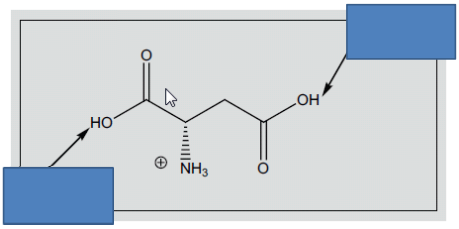
Appl #1, p. 297. Why is H_2O a stronger acid than NH_3?

- Which conjugate base is more stable: OH^- or NH_2^-?

Appl 2, p. 297. Why is ethanol more acidic than ethane?

- Which conjugate base is more stable?

Appl 5, p. 297. Which acid group is more acidic (K_a= 2.1 and 3.9)



Calculate the pH of 1.00 M HF

- $K_a = 7.2 \times 10^{-4}$
- Apply the RICE procedure
- Consider simplification x << 1.0 (5% rule).
- $x = 2.7 \times 10^{-2}$

Problem 7-33c

- At 40 °C, $K_w = 2.92 \times 10^{-14}$
- If $[OH^-]$ = 0.10 *M*, what is the pH?
- 12.54

Is the dissociation of water exothermic or endothermic?

- $K_w = 1.0 \times 10^{-14}$ at 25°C
- $K_w = 2.92 \times 10^{-14}$ at 40°C

Problem 43a

- List the major species present in 0.250 *M* HNO_2 and find the pH
- $K_a = 4.0 \times 10^{-4}$
- pH = 2.00

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})
- pH = 1.00
- What is the concentration of OCl^-(aq)
- 3.5 x 10^{-8} *M*

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 51

- 0.56 g of benzoic acid, $C_6H_5CO_2H$, in 1.0 L of solution. (MW = 122.1 g/mol)
- K_a=6.4 x 10^{-5}
- Calculate [$C_6H_5CO_2H$], [$C_6H_5CO_2^-$],[H^+], and pH
- 3.29
- [$C_6H_5CO_2H$] = 4.1 x 10^{-3} *M*, [$C_6H_5CO_2^-$]=[H^+] = 5.1 x 10^{-4}*M*,

Problem 55

- A formic acid HCOOH solution has a pH of 2.70
- K_a=1.8 x 10^{-4}
- Calculate the initial concentration of formic acid
- 0.024 *M*

Problem 53

- Aspirin tablet = 32.5 mg, $HC_9H_7O_4$
- Two tablets in 237 mL of solution.
- $K_a = 3.3 \times 10^{-4}$
- What is the pH?
- 2.68

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?
- $[H^+] = [H_2AsO_4^-] = 2.9 \times 10^{-2}$ *M, pH = 1.54*
- $K_{a2} << K_{a1}$

Problem 85: H_3AsO_4

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

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

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