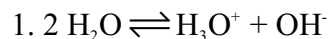


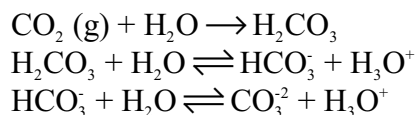
Laboratory #8 pH of Acids, Bases & Buffers

B. pH of distilled water:

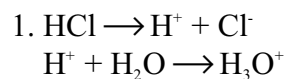


2. Expected pH 7.00

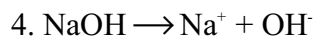
3. The acidic pH of distilled water is due to the absorption of CO_2 from the atmosphere:



C. pH of strong acids & bases:



2. 0.05 M HCl; $[\text{H}_3\text{O}^+] = 0.05 \text{ M}$; $\text{pH} = -\log(0.05) = 1.30$



5. 0.0050 M NaOH; $[\text{OH}^-] = 0.0050 \text{ M}$; $\text{pOH} = -\log(0.0050) = 2.30$
 $\text{pH} = 14.00 - 2.03 = 11.70$

D. pH of weak acids & bases:

1.

	HOAc	+	H ₂ O	⇌	OAc ⁻	+	H ₃ O ⁺
I	0.50				0		0
C	-x				+x		+x
E _x	0.50 - x				x		x
E	≈ 0.50						

$$K_a = \frac{[\text{OAc}^-][\text{H}_3\text{O}^+]}{[\text{HOAc}]} = 1.74 \times 10^{-5} = \frac{x^2}{0.50}; x = 0.0029$$

$$[\text{H}_3\text{O}^+] = 0.0029 \text{ M}; \text{pH} = -\log(0.0029) = 2.53$$

2. Expected pH: 2.53

4.

	NH_3	+	H_2O	\rightleftharpoons	NH_4^+	+	OH^-
I	0.10				0		0
C	-x				+x		+x
E_x	$0.10 - x$				x		x
E	≈ 0.10						

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = 1.74 \times 10^{-5} = \frac{x^2}{0.10}; x = 0.013$$

$$[\text{OH}^-] = 0.0013 \text{ M}; \text{pOH} = -\log(0.0013) = 2.88$$

$$\text{pH} = 14.00 - 2.88 = 11.12$$

5. Expected pH: 11.12

E. Hydrolysis of Salts of weak acids and bases

2. a)

	OAc^-	+	H_2O	\rightleftharpoons	HOAc	+	OH^-
I	0.50				0		0
C	-x				+x		+x
E_x	$0.50 - x$				x		x
E	≈ 0.50						

$$K_b = \frac{[\text{HOAc}][\text{OH}^-]}{[\text{OAc}^-]} = \frac{K_w}{K_a} = \frac{1.00 \times 10^{-14}}{1.74 \times 10^{-5}} = 5.75 \times 10^{-10}$$

$$5.75 \times 10^{-10} = \frac{x^2}{0.50}; x = 1.7 \times 10^{-5}$$

$$[\text{OH}^-] = 1.7 \times 10^{-5} \text{ M}; \text{pOH} = 4.77; \text{pH} = 14.00 - 4.77 = 9.23$$

Expected pH = 9.23

2. b)

	NH_4^+	+	H_2O	\rightleftharpoons	NH_3	+	H_3O^+
I	0.10				0		0
C	-x				+x		+x
E _x	0.10 - x				x		x
E	≈ 0.10						

$$K_a = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]} = \frac{K_w}{K_b} = \frac{1.00 \times 10^{-14}}{1.74 \times 10^{-5}} = 5.75 \times 10^{-10} = \frac{x^2}{0.10}$$

$$x = 7.6 \times 10^{-6}; [\text{H}_3\text{O}^+] = 7.6 \times 10^{-6} \text{ M}; \text{pH} = -\log(7.6 \times 10^{-6}) = 5.12$$

Expected pH = 5.12

2. c)

	SO_4^{2-}	+	H_2O	\rightleftharpoons	HSO_4^-	+	OH^-
I	0.10				0		0
C	-x				+x		+x
E _x	0.10 - x				x		x
E	≈ 0.10						

$$K_b = \frac{[\text{HSO}_4^-][\text{OH}^-]}{[\text{SO}_4^{2-}]} = \frac{K_w}{K_{a_2}} = \frac{1.00 \times 10^{-14}}{1.29 \times 10^{-2}} = 7.75 \times 10^{-13} = \frac{x^2}{0.10}$$

$$x = 2.78 \times 10^{-7}; [\text{OH}^-] = 2.78 \times 10^{-7} \text{ M}; \text{pOH} = -\log(2.78 \times 10^{-7}) = 6.56$$

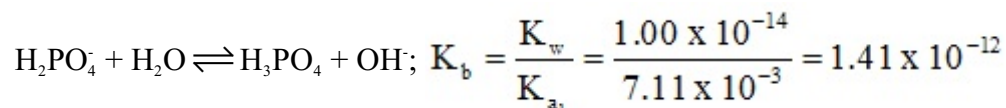
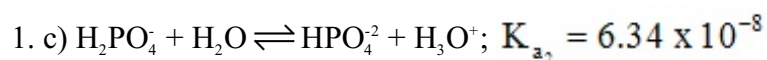
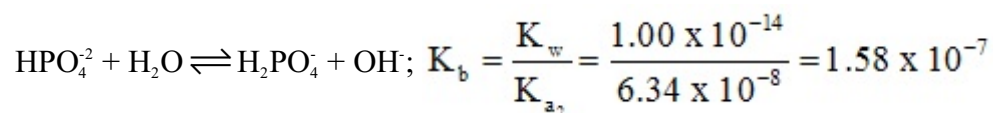
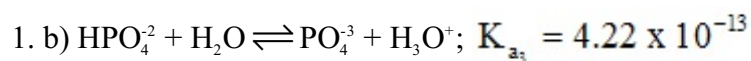
$$\text{pH} = 14.00 - 6.56 = 7.44$$

Expected pH = 7.44

F. pH of amphoteric (half-acid) compounds:

$$1. \text{ a) } \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{CO}_3^{2-} + \text{H}_3\text{O}^+; K_{a_2} = 5.6 \times 10^{-11}$$

$$\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-; K_b = \frac{K_w}{K_{a_1}} = \frac{1.00 \times 10^{-14}}{4.2 \times 10^{-7}} = 2.38 \times 10^{-8}$$



2. a) since $K_b > K_a$ solution will be basic and $\text{pH} > 7$

b) since $K_b > K_a$ solution will be basic and $\text{pH} > 7$

c) since $K_a > K_b$ solution will be acidic and $\text{pH} < 7$

H. A balanced buffer solution:

1.

$$\frac{10.0 \text{ mL}}{1} \times \frac{0.50 \text{ mmol HOAc}}{\text{mL}} \times \frac{1}{20.0 \text{ mL}} = \frac{0.25 \text{ mmol HOAc}}{\text{mL}}$$

$$\frac{10.0 \text{ mL}}{1} \times \frac{0.50 \text{ mmol NaOAc}}{\text{mL}} \times \frac{1}{20.0 \text{ mL}} = \frac{0.25 \text{ mmol NaOAc}}{\text{mL}}$$

	HOAc	+	H ₂ O	⇌	OAc ⁻	+	H ₃ O ⁺
I	0.25				0.25		0
C	-x				+x		+x
E _x	0.25 - x				0.25 + x		x
E	≈ 0.25				≈ 0.25		

$$K_a = \frac{[\text{OAc}^-][\text{H}_3\text{O}^+]}{[\text{HOAc}]} = 1.74 \times 10^{-5} = \frac{0.25x}{0.25}$$

$$x = 1.74 \times 10^{-5}; [\text{H}_3\text{O}^+] = 1.74 \times 10^{-5} \text{ M}; \text{pH} = -\log(1.74 \times 10^{-5}) = 4.76$$

2. reaction of buffer with strong base: $\text{HOAc} + \text{OH}^- \rightleftharpoons \text{OAc}^- + \text{H}_2\text{O}$

reaction of buffer with strong acid: $\text{OAc}^- + \text{H}_3\text{O}^+ \rightleftharpoons \text{HOAc} + \text{H}_2\text{O}$

3. Strong base addition: $\text{HOAc} + \text{OH}^- \rightarrow \text{OAc}^- + \text{H}_2\text{O}$

$$\frac{2.0 \text{ mL}}{1} \times \frac{0.25 \text{ mmol HOAc}}{\text{mL}} \times \frac{1 \text{ mmol NaOH}}{1 \text{ mmol HOAc}} \times \frac{1 \text{ mL}}{1.0 \text{ mmol NaOH}} \times \frac{1 \text{ drop}}{0.05 \text{ mL}}$$

$$= 10 \text{ drops}$$

Strong acid addition: $\text{OAc}^- + \text{H}_3\text{O}^+ \rightarrow \text{HOAc} + \text{H}_2\text{O}$

$$\frac{2.0 \text{ mL}}{1} \times \frac{0.25 \text{ mmol OAc}^-}{\text{mL}} \times \frac{1 \text{ mmol HCl}}{1 \text{ mmol OAc}^-} \times \frac{1 \text{ mL}}{1.0 \text{ mmol HCl}} \times \frac{1 \text{ drop}}{0.05 \text{ mL}}$$

$$= 10 \text{ drops}$$

5. 10 drops NaOH calculated

10 drops HCl calculated

I. An unbalanced buffer solution:

1.

$$\text{pH} = 5.30; [\text{H}_3\text{O}^+] = \text{anti log}(-5.30) = 5.0 \times 10^{-6} \text{ M}$$

$$K_a = \frac{[\text{OAc}^-][\text{H}_3\text{O}^+]}{[\text{HOAc}]} = 1.74 \times 10^{-5}; \frac{[\text{OAc}^-]5.0 \times 10^{-6}}{[\text{HOAc}]} = 1.74 \times 10^{-5}$$

$$\frac{[\text{OAc}^-]}{[\text{HOAc}]} = 3.5$$

$$[\text{OAc}^-] = \frac{0.50 \text{ mmol OAc}^-}{\text{mL}} \times \frac{X \text{ mL}}{20.0 \text{ mL}} = \frac{0.50}{20.0} X$$

$$[\text{HOAc}] = \frac{0.50 \text{ mmol HOAc}}{\text{mL}} \times \frac{Y \text{ mL}}{20.0 \text{ mL}} = \frac{0.50}{20.0} Y$$

$$X + Y = 20.0; X = 20.0 - Y; [\text{OAc}^-] = \frac{0.50}{20.0} (20.0 - Y)$$

$$\frac{\frac{0.50}{20.0} (20.0 - Y)}{\frac{0.50}{20.0} Y} = 3.5; \frac{20.0 - Y}{Y} = 3.5; 20.0 - Y = 3.5Y$$

$$4.5Y = 20.0; Y = 4.4; X = 20.0 - 4.4 = 15.6$$

Take 4.4 mL HOAc and 15.6 mL NaOAc

3. Strong base addition: $\text{HOAc} + \text{OH}^- \rightarrow \text{OAc}^- + \text{H}_2\text{O}$

Strong acid addition: $\text{OAc}^- + \text{H}_3\text{O}^+ \rightarrow \text{HOAc} + \text{H}_2\text{O}$

$$\frac{4.4 \text{ mL}}{1} \times \frac{0.50 \text{ mmol HOAc}}{\text{mL}} \times \frac{1}{20.0 \text{ mL}} = \frac{0.11 \text{ mmol HOAc}}{\text{mL}}$$

$$\frac{2.0 \text{ mL}}{1} \times \frac{0.11 \text{ mmol HOAc}}{\text{mL}} \times \frac{1 \text{ mmol NaOH}}{1 \text{ mmol HOAc}} \times \frac{1 \text{ mL}}{1.0 \text{ mmol NaOH}} \times \frac{1 \text{ drop}}{0.05 \text{ mL}} = 4.4 \text{ drops}$$

$$\frac{15.6 \text{ mL}}{1} \times \frac{0.50 \text{ mmol OAc}^-}{\text{mL}} \times \frac{1}{20.0 \text{ mL}} = \frac{0.39 \text{ mmol OAc}^-}{\text{mL}}$$

$$\frac{2.0 \text{ mL}}{1} \times \frac{0.39 \text{ mmol OAc}^-}{\text{mL}} \times \frac{1 \text{ mmol HCl}}{1 \text{ mmol OAc}^-} \times \frac{1 \text{ mL}}{1.0 \text{ mmol HCl}} \times \frac{1 \text{ drop}}{0.05 \text{ mL}} = 15.6 \text{ drops}$$

5. 4.4 drops of NaOH

15.6 drops of HCl