CH 302 Spring 2007 Worksheet 7

For all of the problems on this worksheet, use the following K values:

H_3PO_4: $pK_{a1} = 2$ $pK_{a2} = 6$ $pK_{a3} = 10$

H_2CO_3 : $pK_{a1} = 4$ $pK_{a2} = 10$

1. You drop 0.1 mol of KOH into 1 L of water. What is the pH of solution?

Answer: $pOH = -\log[OH^-] = -\log(C_b) = 1$ $pH = 13$

2. You drop 0.1 mol of KOH into a 1 L solution of 1 M H_3PO_4 and KH_2PO_4. What is the pH of the solution?

Answer: Neutralize; you have 0.9 M H_3A and 1.1 M H_2A^-.

$[H^+] = K_{a1}(C_a/C_b) = 10^{-2}(0.9/1.1) = 8.18 \times 10^{-3}$

$pH = 2.09$

3. You drop 0.1 mol of NaOH into a 1 L solution of 0.5 M $RbHCO_3$ and 0.5 M Na_2CO_3. What is the pH of the solution?

Answer: Neutralize; you have 0.4 M HA^- and 0.6 M A^{2-}.

$[H^+] = K_{a2}(C_a/C_b) = 10^{-10}(0.4/0.6) = 6.67 \times 10^{-11}$

$pH = 10.18$

4. You drop 0.5 mol of NaOH into a 1 L solution of 0.5 M $RbHCO_3$ and 0.5 M Na_2CO_3. What is the pH of the solution?

Answer: Neutralize; you have 1.0 M A^{2-}.

$[OH^-] = (K_{b1}C_b)^{1/2} = [(K_w/K_{a2})C_b)^{1/2} = (10^{-4} \times 1.0)^{1/2} = 10^{-2}$

$pOH = 2$ $pH = 12$

5. You drop 1.0 mol of NaOH into a 1 L solution of 0.5 M $RbHCO_3$ and 0.5 M Na_2CO_3. What is the pH of the solution?

Answer: Neutralize; you have 1.5 M A^{2-} and 0.5 M OH^-.

$[OH^-] = C_b = 0.5$ M

$pOH = 0.3$ $pH = 13.7$

For questions 6-13, 1.5 L 0.1 M H_3PO_4 is titrated with 1 M NaOH. Give the pH for the given amount of NaOH solution added to the H_3PO_4 solution.

	V_{NaOH}	pH
6.	0 mL	$[H^+] = (K_{a1}C_a)^{1/2} = (10^{-2}\text{x}0.1)^{1/2} = 10^{-1.5}$ **pH = 1.5**
7.	50 mL	Neutralize: 0.1 mol H_3A and 0.05 mol H_2A^-. $[H+] = K_{a1}(C_a/C_b) = 10^{-2}(0.1/0.05) = 2 \times 10^{-2}$ **pH = 1.7**
8.	150 mL	Neutralize: 0.15 mol H_2A^- $[H^+] = (K_{a1}K_{a2})^{1/2} = (10^{-2}10^{-6})^{1/2} = 10^{-4}$ **pH = 4.0**
9.	250 mL	Neutralize: 0.05 mol H_2A^- and 0.10 mol HA^{2-} $[H^+] = K_{a2}(C_a/C_b) = 10^{-6}(0.05/0.10) = 5 \times 10^{-7}$ **pH = 6.3**

10. 300 mL Neutralize: 0.15 mol HA^{2-}

$[H^+] = (K_{a2}K_{a3})^{1/2} = (10^{-6}10^{-10})^{1/2} = 10^{-8}$

pH = 8.0

11. 400 mL Neutralize: 0.05 mol HA^{2-} and 0.10 mol A^{3-}

$[H^+] = K_{a3}(C_a/C_b) = 10^{-10}(0.05/0.10) = 5 \times 10^{-11}$

pH = 10.3

12. 450 mL Neutralize: 0.15 mol A^{2-}

$K_{b1} = K_w/K_{a3} = 10^{-4}$

$C_b = (0.15 \text{ mol})/(1.5 \text{ L} + 0.450 \text{ L}) = 0.077 \text{ M}$

$[OH^-] = (K_{b1}C_b)^{1/2} = 2.8 \times 10^{-3}$

pOH = 2.6 **pH = 11.4**

13. 500 mL Neutralize: 0.05 mol OH^- and 0.15 mol A^{2-}

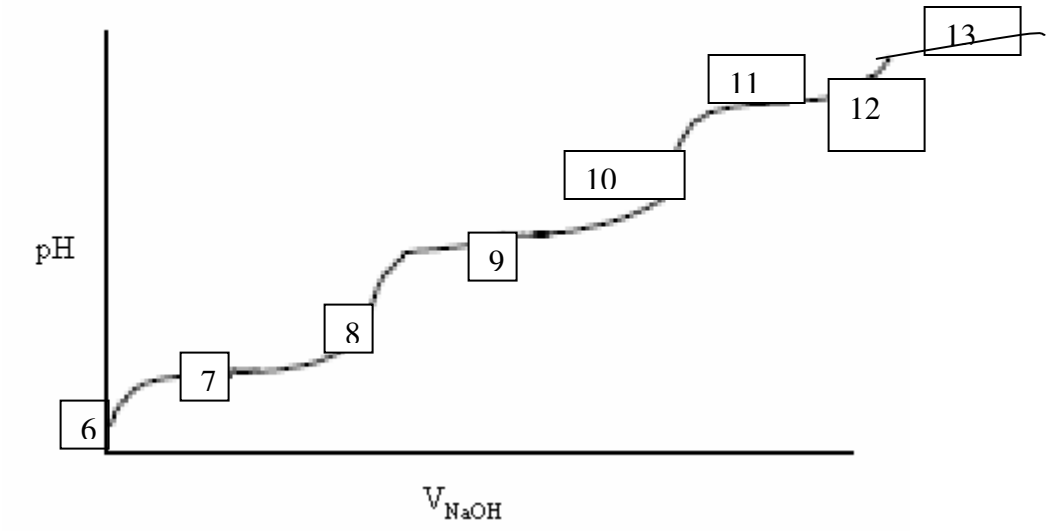
$C_b = (0.05 \text{ mol})/(1.5 \text{ L} + 0.5 \text{ L}) = 0.025 \text{ M}$

$pOH = -\log[OH^-] = -\log(C_b) = 1.6$

pH = 12.4

14. Sketch the titration curve for a triprotic acid such as H_3PO_4.

15. Place the numbers 6 through 13 on the curve indicating the area of the titration curve corresponding to the calculation.



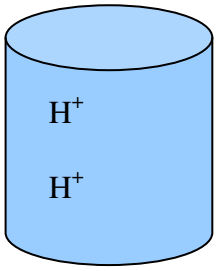
The 11 questions below represent the important areas of a triprotic acid titration curve. For each mixture, explain where you are on the curve after neutralization, provide the equation you would use for the calculation, and estimate the correct pH for the given mixture. DON'T USE A CALCULATOR. To guide you, draw the equilibrium species essential to determining the pH in the beaker provided (AFTER NEUTRALIZATION.) Hints: Assume there are no K_w contribution in the calculations use these numbers a lot: *Phosphoric acid values: $pKa_1 = 2$ $pKa_2 = 6$ $pKa_3 = 10$*

16. 1M HCl and 1 M H_3PO_4

Where are you on a titration curve? Strong acid excess

Equation used to determine the pH. C_a

Estimated pH. 0

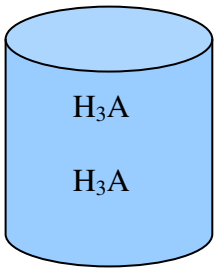


17. 1 M H_3PO4

Where are you on a titration curve? Beginning of weak acid titration

Equation used to determine the pH. $H^+ = (K_{a1}C_a)^{0.5}$

Estimated pH. 1 (this is a bad approximation because K_{a1} is so large)

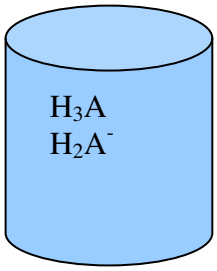


18. 1M H_3PO4 and 1 M NaH_2PO_4

Where are you on a titration curve? First buffer region where pH = pK_1

Equation used to determine the pH. $H^+ = K_{a1}C_a / C_b$

Estimated pH. 2

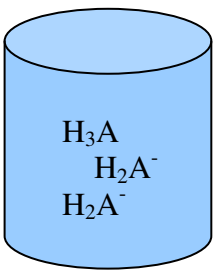


19. 1M H_3PO4, 1 M NaH_2PO_4 and .002M NaOH

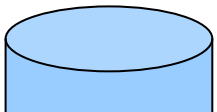
Where are you on a titration curve? First buffer region

Equation used to determine the pH. $H^+ = K_{a1}C_a / C_b$

Estimated pH. Slightly more basic than pH 2



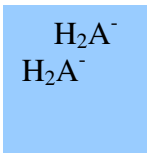
20. 1 M NaH_2PO_4



Where are you on a titration curve? First equivalence point

Equation used to determine the pH. $H^+ = (K_{a1}K_{a2})^{0.5}$

Estimated pH. 4

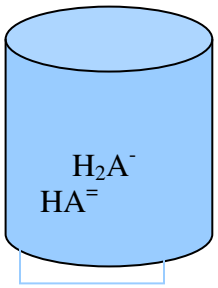


21. 1 M NaH_2PO_4 and 1M Li_2HPO_4

Where are you on a titration curve? Second buffer region where $pH = pK_2$

Equation used to determine the pH. $H^+ = K_{a2}C_a / C_b$

Estimated pH. 6

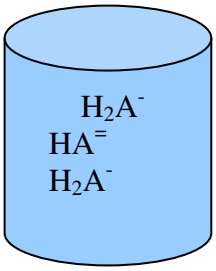


22. 1 M NaH_2PO_4, Li_2HPO_4 and 0.002 HCl

Where are you on a titration curve? Second buffer region

Equation used to determine the pH. $H^+ = K_{a2}C_a / C_b$

Estimated pH. Slightly more acidic than pH 6

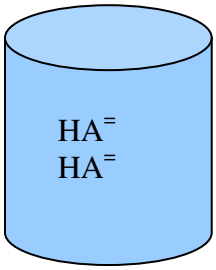


23. 1M Li_2HPO_4

Where are you on a titration curve? Second equivalence point

Equation used to determine the pH. $H^+ = (K_{a2}K_{a3})^{0.5}$

Estimated pH. 8

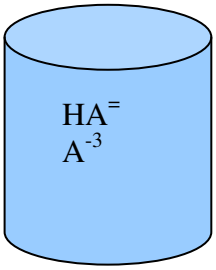


24. 1M Li_2HPO_4 and 1M $NaLiRbPO_4$

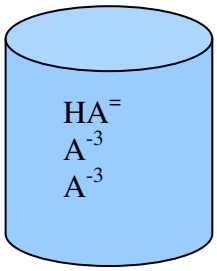
Where are you on a titration curve? Third buffer region where $pH = pK_3$

Equation used to determine the pH. $H^+ = K_{a3}C_a / C_b$

Estimated pH. 10



25. 1M Li_2HPO_4 and 1M $NaLiRbPO_4$ and .002M NaOH

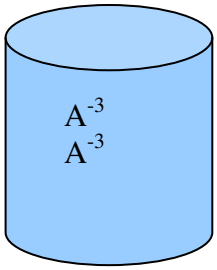


Where are you on a titration curve? Third buffer region

Equation used to determine the pH. $H^+ = K_{a3}C_a / C_b$

Estimated pH. Slightly more basic than pH 10

26. 1M $NaLiRbPO_4$

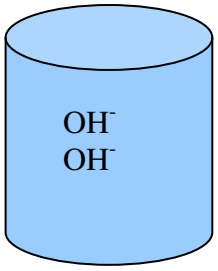


Where are you on a titration curve? Third equivalence point, all weak base

Equation used to determine the pH. $OH^- = (K_w/K_{a3}C_b)^{0.5}$

Estimated pH. 12

27. 1M $NaLiRbPO_4$ and 1M NaOH



Where are you on a titration curve? Excess strong base

Equation used to determine the pH. C_b

Estimated pH. 14