Classroom Activity Chapter 16 Number 1 — 24 February 2017

1. Determine the numerical value for each of these equilibria, given K_a for HA = 2.2×10^{-5}. Add arrows of appropriate length to each equilibria.

   (a) $HA + H_2O \rightleftharpoons H_3O^+ + A^-$ $K_a = 2.2 \times 10^{-5}$

   (b) $HA + OH^- \rightleftharpoons H_2O + A^-$ $K_n = \frac{1}{K_b} = \frac{K_a}{K_w} = 2.2 \times 10^{+9}$

   (c) $H_3O^+ + OH^- \rightleftharpoons 2\,H_2O$ $K_n = \frac{1}{K_w} = 1 \times 10^{+14}$

   (d) $A^- + H_2O \rightleftharpoons OH^- + HA$ $K_b = \frac{K_w}{K_a} = 4.5 \times 10^{-10}$

   (e) $2\,H_2O \rightleftharpoons H_3O^+ + OH^-$ 1×10^{-14}

   (f) $A^- + H_3O^+ \rightleftharpoons H_2O + HA$ $K_n = \frac{1}{K_a} = 4.5 \times 10^{+4}$

2. Suppose

   K_a for HA = 2.2×10^{-5} K_a for HB = 4.1×10^{-6}

   Calculate K for the reaction:

   $$HA + B^- \rightleftharpoons A^- + HB$$

   $HA + H_2O \rightleftharpoons H_3O^+ + A^-$ $K_a = 2.2 \times 10^{-5}$

   $B^- + H_3O^+ \rightleftharpoons H_2O + HB$ $K_n = 1/4.1 \times 10^{-6}$

   $HA + B^- \rightleftharpoons A^- + HB$ $K = 5.37$

3. Calculate K_c for the reaction:

   $$NH_4^+ + F^- \rightleftharpoons NH_3 + HF$$

   K_b for NH_3 = 1.8×10^{-5} and K_a for HF = 3.5×10^{-4}

   $NH_4^+ + OH^- \rightleftharpoons H_2O + NH_3$ $K = 1/K_b^{NH_3}$

   $F^- + H_3O^+ \rightleftharpoons H_2O + HF$ $K = 1/K_a^{HF}$

   $2H_2O \rightleftharpoons H_3O^+ + OH^-$ $K_w = 1 \times 10^{-14}$

   $NH_4^+ + F^- \rightleftharpoons NH_3 + HF$ $K_c = 1.6 \times 10^{-6}$

4a. What is the pH of a buffer prepared by dissolving 0.0100 mol $HC_2H_3O_2$ (pK_a = 4.74) and 0.0150 mol $C_2H_3O_2^-$ in enough water to dissolve the substances.

   Recipe 1

   $pH = 4.74 + \log\left(\frac{0.0150}{0.0100}\right)$

   $= 4.92$

4b. What is the pH of the previous buffer after 0.0030 mol NaOH were added?

   $pH = 4.75 + \log\left(\frac{0.015 + .003}{0.010 - .003}\right)$

   $= 5.16$

4c. Instead of adding NaOH as in Question 4b, suppose 0.0022 mol HCl were added instead to the buffer described in Question 4a. What is the pH?

   $pH = 4.75 + \log\left(\frac{0.015 - 0.0022}{0.010 + 0.0022}\right)$

   $= 4.77$

5. What is the pH of a buffer prepared by reacting 0.0155 mol NH_4Cl with 0.0080 mol NaOH?

   $K_b^{NH_3} = 1.8 \times 10^{-5}$ $pK_b = 4.74$

   $pK_a = 9.26$

   $pH = 9.26 + \log\left(\frac{0 + 0.0080}{0.0155 - 0.0080}\right)$

   $= 9.28$

6. How many grams of NaOH must be added to 500.0 mL 0.100 M $HC_2H_3O_2$ in order to prepare a buffer with a pH = 5.00? $K_a = 1.8 \times 10^{-5}$

   $5.00 = 4.74 + \log\left(\frac{0 + n_{OH^-}}{n_{wa} - n_{OH^-}}\right)$

   $\Sigma MV = 0.050$ mol

   $\frac{n_{OH^-}}{0.050\text{mol} - n_{OH^-}} = 1.80$

   $n_{OH^-} = 1.80 \times 0.050 - 1.8\,n_{OH^-}$

   $2.8\,n_{OH^-} = 0.090$

   $n_{OH^-} = 0.0321$ mol OH^-

   $= 0.0321$ mol NaOH

   $= 1.29$ g NaOH

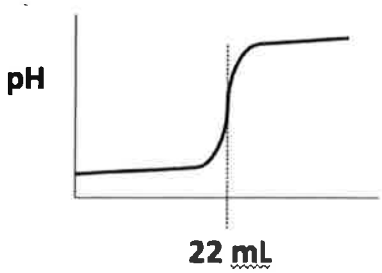
   $MM_{NaOH} = 40g/mol$

7. What will happen to the pH of any of the buffers in the previous problems if water is added?

8. What will happen to the pH of any of the buffers in the previous problems if strong acid is added?

Classroom Activity Chapter 16 Number 2 27 February 2017

1. This curve represents the titration of a strong acid with strong base. In this case, 25.00 mL of HNO_3 was titrated with 0.1184 M NaOH.



1a. How many moles of NaOH were added at the equivalence point?

$n = MV$
$= 0.1184 * 0.022$
$= 2.6 \times 10^{-3}$ mol

1b. Suppose the 25.00 mL acid sample came from a very large container. What is the concentration of the acid in the container?

$M_a V_a = M_b V_b$
$M_a \, .02500 = 2.605 \times 10^{-3}$
$[H_3O^+] = 0.1042$ M

1c. What is the pH of the solution after 18.00 mL NaOH(aq) has been added?

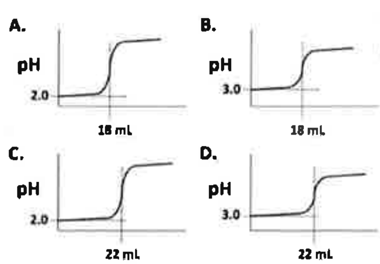
n	H_3O^+	+	OH^-
I	2.605×10^{-3}		2.13×10^{-3}
C	-2.13×10^{-3}		-2.13×10^{-3}
E	4.736×10^{-4}		~ 0

Using $n = MV$ $[H_3O^+] = \dfrac{4.736 \times 10^{-4} \text{ mol}}{0.043 L}$

total vol

$\boxed{pH = 1.96}$

2. Compare these four titration curves.

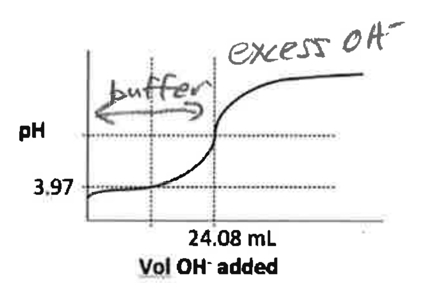


2a. Could any of them be the titration of a weak acid with OH^-? **Circle: Yes or No**

2b. Which two represent the least concentrated base? **Circle two: A B C D**

2c. Which two represent the least concentrated acid? **Circle two: A B C D**

3. This curve represents the titration of a weak acid with 0.1184 M NaOH. Suppose that 0.5050 g of a solid weak acid, HA, was dissolved in water to make 50.00 mL of solution and titrated to give the curve as shown.



3a. How many moles of NaOH were added at the equivalence point?

$n = 0.1184 * 0.02408$
$= 2.85 \times 10^{-3}$ mol

3b. How many moles of HA were originally present?

2.85×10^{-3} mol

3c. What is the molar mass of the acid?

$MM = \dfrac{m}{n} = \dfrac{0.5050 g}{2.85 \times 10^{-3} mol} = 177 g/mol$

3d. What is the K_a of the acid?

$pK_a = 3.97$
$K_a = 1.07 \times 10^{-4}$

3e. Indicate the "buffer region" in the titration curve. between 0 and 24.08 mL

3f. Indicate the region in which OH^- is in excess.

3g. What is the pH of the acid solution before any OH^- was added? (Hint: Chapter 15 MICE table, 400 Rule, etc.)

M	HA	+ H_2O ⇌	H_3O^+	+ A^-
I	0.0570		0	0
C	$-x$		$+x$	$+x$
E				

$\dfrac{x^2}{0.0570} = 1.07 \times 10^{-4} \Rightarrow x = 2.47 \times 10^{-3}$

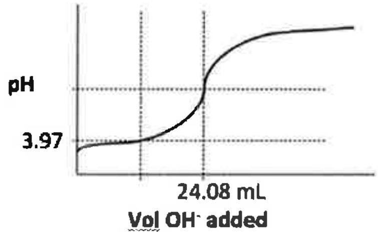
pH = 2.61

$\dfrac{2.85 \times 10^{-3} mol}{0.05000 L}$

400 Rule
is $\dfrac{0.0570}{1.07 \times 10^{-4}} > 400$
It is 533

Classroom Activity Chapter 16 Number 3 1 March 2017

3. This is a continuation of the question asked on worksheet Number 2. The curve represents the titration of 50.00 mL weak acid, HA, with 0.1184 M NaOH.



3h. What is the pH at the equivalence point? $K_b^{A^-} = 9{,}35\times10^{-11}$ 400 Rule Good

wb

M $A^- + H_2O \rightleftharpoons OH^- + HA$

I

C

E

$[A^-] = \frac{n_{wb}}{V_{tot}} = \frac{2{,}85\times10^{-3}\text{ mol}}{.07408\text{ L}} = 3{,}84\times10^{-2}\text{ M}$

$\frac{x^2}{3{,}84\times10^{-2}} = 9{,}35\times10^{-11}$

$x = [OH^-] = 3{,}72\times10^{-7}$ pH = 7,57

3i. What is the pH after 30.00 mL NaOH(aq) have been added? Excess OH^- nICE

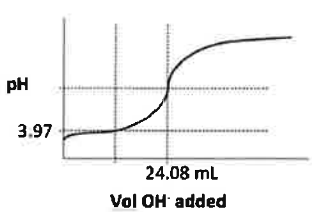
n	HA	+	OH^-	→
I	$2{,}85\times10^{-3}$		$n = MV$ $= ,1184 \cdot ,0300$ $= 3{,}55\times10^{-3}$	
C	$-2{,}85\times10^{-3}$		$-2{,}85\times10^{-3}$	
	~0		$7{,}02\times10^{-4}$	

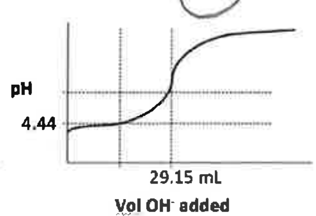
$[OH^-] = \frac{7{,}02\times10^{-4}\text{ mol}}{,0800\text{ L}} = 8{,}775\times10^{-3}$

V_{tot}

pH = 11,94

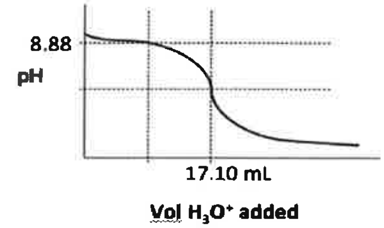
4a. Which acid is the stronger weak acid, HA, shown at left or HB, shown at right? Both acids were titrated with 0.100 M NaOH(aq). **Circle HA or HB**





4b. Which acid is the more concentrated weak acid, HA or HB? Both acids were titrated with 0.100 M NaOH(aq). **Circle HA or HB**

5a. What is being titrated here? Example: "Strong acid with strong base." The second item listed is in the buret.



wb + H_3O^+

5b. What is the significance of pH = 8.88? Could it be used to determine pK_b? If so, do it.

It is pKa

pKb is 14−8,88 = 5,12

6. What volume of 5.00×10^{-3} M HNO_3 is needed to titrate 100.00 mL of 5.00×10^{-3} M $Ca(OH)_2$ to the equivalence point?

A. 12.5 mL B. 50.0 mL

C. 100. mL D. 200. mL

7. What is the pH of a solution made by mixing 30.00 mL of 0.10 M HCl with 40.00 mL of 0.10 M KOH? Assume that the volumes of the solutions are additive.

A. 0.85 B. 1.85

C. 12.15 D. 13.15

8. What is the pH at the equivalence point of a weak acid-strong base titration?

A. pH < 7 B. pH = 7

C. pH > 7 D. pH = 14.00

9. What is the approximate pH at the equivalence point of a weak acid-strong base titration if 25 mL of aqueous formic acid requires 29.80 mL of 0.0567 M NaOH? $K_a = 1.8 \times 10^{-4}$ for formic acid.

A. 2.46 B. 5.88

C. 8.12 D. 11.54