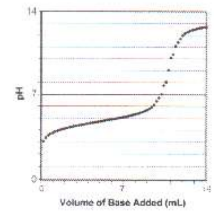
South Pasadena • AP Chemistry

Name Groves (KEY)
Period ___ Date ___/___/___

18 • Acids, Bases, & Buffers

STATION 1: INITIAL pH

"STANDARD ICE BOX PROBLEM"



In this Review, we will walk ourselves through the calculations needed to sketch the Titration Curve for a weak acid titrated with a strong base.

Acetic acid, is often abbreviated as HAc.. K_a acetic acid = 1.8×10^{-5}
SHOW YOUR WORK FOR EACH STEP.

What is the pH of a 0.15 M solution of HAc?

$HAc \rightleftharpoons H^+ + Ac^-$

	HAc	H^+	Ac^-
I	0.15 M	0 M	0 M
C	$-x$	$+x$	$+x$
E	$(0.15 - x)$	x	x

Assume $x << .15$
$\therefore (0.15 - x) \approx (0.15)$

$K_a = \frac{[H^+][Ac^-]}{[HAc]} = 1.8 \times 10^{-5}$

$= \frac{x^2}{(.15)} = 1.8 \times 10^{-5}$

$x = [H^+] = \sqrt{(.15)(1.8 \times 10^{-5})}$

$= \sqrt{2.7 \times 10^{-6}}$

$= 1.64 \times 10^{-3}$

$pH = -\log [H^+] = \boxed{2.78}$

Plot this point on your Titration Curve (Station 9). (mL KOH = 0mL, pH = 2.78)

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STATION 2: VM = VM

The acid is titrated with a 0.10 M solution of KOH.
Calculate the volume of base needed to neutralize a 10. mL sample of the 0.15 M HAc.

$V \cdot M = V \cdot M$

$\frac{(10.\,mL)(.15\,\cancel{M})}{.10\,\cancel{M}} = \frac{x\,(.10\,\cancel{M})}{(.10\,\cancel{M})}$

$\boxed{x = 15.\ mL\ KOH}$

Note that this is the volume of base at the equivalence point on your titration curve. Use with Station 4 to plot point.

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STATION 3: EQUIVALENCE POINT CHEMICALS

a) Write the balanced **net** equation for the neutralization of HAc by KOH:

$$HAc + OH^- \longrightarrow H_2O + Ac^-$$

b) What chemicals are in the flask at the endpoint (equivalence point) of this titration?

H_2O & Ac^- (and K^+)

c) How many moles of HAc are in the 10. mL of 0.15 M HAc that you used for the titration?

$(0.010\ L)(0.15\ M\ HAc) = 0.0015$ mol HAc * NOTE THIS ANSWER IS USED MULTIPLE TIMES.

d) How many ***moles*** of Ac^- are in the flask at the equivalence point?

** moles Ac^- = moles HAc initially = $\boxed{0.0015 \text{ mol } Ac^-}$

e) What is the total volume of solution (in Liters) at the equivalence point?

25 mL = 0.025 L (10. mL Acid + 15 mL base)

f) What is the ***concentration*** of Ac^- at the equivalence point? $[Ac^-]$ =

$$\frac{0.0015 \text{ mol } Ac^-}{0.025\ L} = \boxed{0.060\ M\ Ac^-}$$

** IMPT IDEA

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STATION 4: pH AT EQUIVALENCE POINT

Calculate the pH of a solution with the $[Ac^-]$ from Station 3. K_a of HAc = 1.8×10^{-5} "STANDARD ICE BOX PROBLEM"

$$Ac^- + H_2O \rightleftharpoons HAc + OH^-$$

	Ac^-	H_2O	HAc	OH^-
I	0.060 M		0 M	0 M
C	−x		+x	+x
E	(.060−x)		x	x

Assume x << .060
∴ (.060 − x) = (.060)

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} = 5.5\bar{5}\times10^{-10}$$

$$= \frac{[HAc][OH^-]}{[Ac^-]} = 5.5\bar{5}\times10^{-10}$$

$$= \frac{x^2}{.060}$$

$$x = [OH^-] = \sqrt{(.060)(5.5\bar{5}\times10^{-10})}$$

$$= 5.77\times10^{-6}$$

$$pOH = -\log[OH^-] = 5.23856$$

$$pH = 14 - pOH$$

$$= \boxed{8.76}$$

EQUIVALENCE POINT PLOTTED at (15 mL, 8.76)

Plot the pH at the equivalence point on your titration curve using the info from Stations 2 and 4.

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STATION 5: HALF-WAY TO EQUIVALENCE POINT

a) What volume of base is half-way to the equivalence point? 7.5 mL

b) What do you know about the pH half-way to the equivalence point? pH = pKa

c) What is the pH half-way to the equivalence point? 4.74 $-\log(1.8\times10^{-5}) = 4.74$

d) Plot this third point on your titration curve (Station 9).

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STATION 6: BEFORE HALF-WAY

When 6.5 mL of KOH has been added to the solution:

a) How many moles of HAc are in 10. mL of 0.15 M HAc? (0.010 L)(.15 M) = .0015 mol

b) How many moles of OH- are in 6.5 mL of 0.10 M KOH? (0.0065 L)(.10 M) = .00065 mol

c) What is the total volume (in Liters)? 16.5 mL = .0165 L

d) Fill in this NEUTRALLIZATION chart using Molarities

HAc	+ OH⁻	→ $H_2O(l)$	+ Ac^-
$\frac{.0015\text{ mol}}{.0165\text{ L}}$ = .0909 M	$\frac{.00065\text{ mol}}{.0165\text{ L}}$ = .0394 M	0	0 M
− .0394	−.0394		+ .0394
.0515 M	0		.0394 M

e) Fill in this EQUILIBRIUM chart:

HAc	+ $H_2O(l)$	⇆ H_3O^+	+ Ac^-
.0515 M		0	.0394 M
−x		+x	+x
.0515 − x		x	.0394 + x

Assume x << .0394 ∴ (.0515 − x) ≈ (.0515) & (.0394 + x) ≈ (.0394)

f) Write the equilibrium expression for HAc.

Substitute the equilibrium values into the expression and compute the $[H_3O^+]$ concentration and pH.

$$K_a = \frac{[H_3O^+][Ac^-]}{[HAc]} = 1.8\times10^{-5} = \frac{(x)(.0394)}{(.0515)}$$

$$[H^+] = x = \frac{(1.8\times10^{-5})(.0515)}{(.0394)} = 2.35\times10^{-5}$$

$$pH = -\log[H^+] = \boxed{4.63}$$

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STATION 7: AFTER HALF-WAY

When 8.5 mL of KOH has been added to the solution:

a) How many moles of HAc are in 10. mL of 0.15 M HAc? .0015 mol HAc

b) How many moles of OH- are in 8.5 mL of 0.10 M KOH? (.0085L) (.10M) = .00085 mol OH-

c) What is the total volume (in Liters)? 18.5 mL = .0185L

d) Fill in this NEUTRALIZATION chart using Molarities

HAc	+ OH^-	→ $H_2O(l)$	+ Ac^-
$\frac{.0015 \text{ mol}}{.0185 \text{ L}} = .0811$ M	$\frac{.00085 \text{ mol}}{.0185 \text{ L}} = .0459$ M		0
−.0459	−.0459		+.0459
.0352	0		.0459

e) Fill in this EQUILIBRIUM chart:

HAc	+ $H_2O(l)$	⇆ H_3O^+	+ Ac^-
.0352		0	.0459
−x		+x	+x
.0352 − x		x	.0459 + x

Assume $x \ll .0352$ ∴ $(.0352 - x) \approx (.0352)$ & $(.0459 + x) \approx (.0459)$

f) Write the equilibrium expression for HAc.
Substitute the equilibrium values into the expression and compute the $[H_3O^+]$ concentration and pH.

$$K_a = \frac{[H_3O^+][Ac^-]}{[HAc]} = 1.8\times10^{-5} = \frac{(x)(.0459)}{(.0352)} \qquad x = [H_3O^+] = \frac{(1.8\times10^{-5})(.0352)}{(.0459)}$$

$$= 1.3785\times10^{-5} \qquad pH = \boxed{4.86}$$

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STATION 8: AFTER THE EQUIVALENCE POINT

When 20. mL of KOH have been added to the solution:

a) How many moles of HAc are in 10. mL of 0.15 M HAc? .0015 mol

b) How many moles of OH^- are in 20. mL of 0.10 M KOH? .0020 mol

c) How many moles of excess OH^- are in solution? .0020 − .0015 = .00050 mol OH-

d) What is the total volume (in Liters)? 30.0 mL = .030 L

e) What is the concentration of OH-, the pOH, and the pH of the solution?

$$[OH^-] = \frac{.00050 \text{ mol}}{.030 \text{ L}} = 1.67\times10^{-2} M \qquad pOH = 1.78 \qquad pH = 14 - pOH = \boxed{12.22}$$

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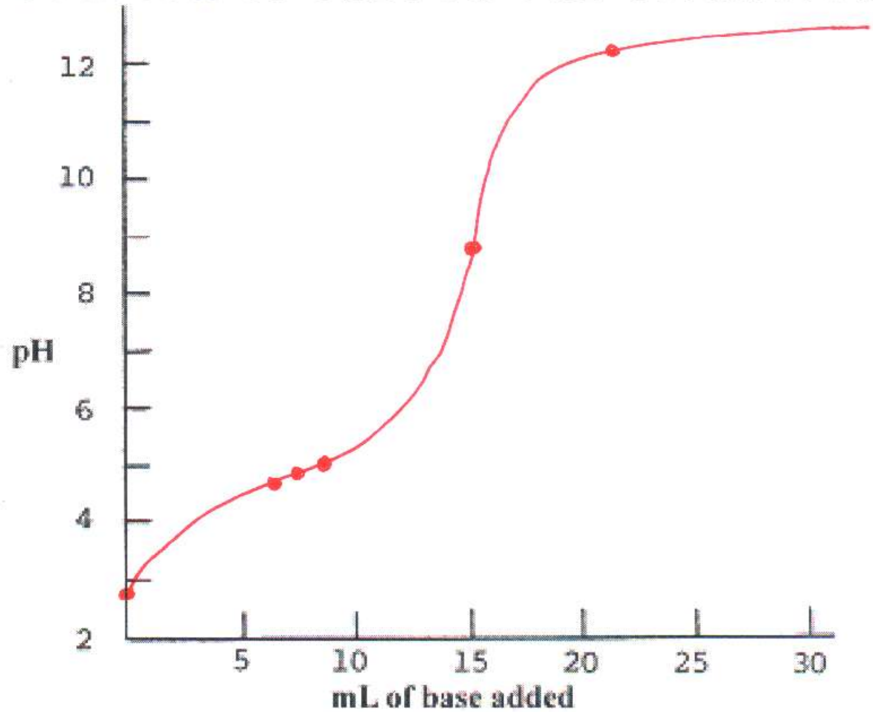
STATION 9: SKETCH THE TITRATION CURVE



FYI: Formulas from the AP Exam:

EQUILIBRIUM

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

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \ @\ 25°C$$
$$= K_a \times K_b$$

$$pH = -\log[H^+],\ pOH = -\log[OH^-]$$

$$14 = pH + pOH$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$pOH = pK_b + \log\frac{[HB^+]}{[B]}$$

$$pK_a = -\log K_a,\ pK_b = -\log K_b$$

$$K_p = K_c(RT)^{\Delta n},$$

where Δn = moles product gas − moles reactant gas