Today

Titration

determining something about an unknown by reacting it with a known solution

Polyprotic Acids

Titration

Why do a titration.

You have a solution with an unknown property

Unknown Concentration?
Unknown Ka (Kb)?
Both.

Slowly neutralize the solution by adding
a strong base (acid)
monitor the pH with each addition

Neutralize first
Then look at the neutralization from last class equilibrium

imagine a 100 mL solution with 0.1 M Acetic Acid (initial .01 moles)
we add 10 mL of 0.1M NaOH in each titration step (add 0.001 moles)

Initial (moles)			After Neutralization			Volume (L)	Equilibrium
HA	OH^-	A^-	HA	OH^-	A^-		pH
0.010	0.000	0.00	0.010	0.000	0.000	0.10	2.87

only HA $[H^+] = \sqrt{K_a C_a}$

Initial (moles)			After Neutralization			Volume (L)	Equilibrium
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0.010	0.001	0.00	0.009	0.000	0.001	0.11	3.79

Both HA & A^- Buffer $[H^+] = K_a \frac{C_a}{C_b}$

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0.009	0.001	0.00	0.008	0.000	0.002	0.12	4.15

keep adding OH^-

HA neutralizes to A^-

Buffer

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....							
0.006	0.001	0.005	0.005	0.000	0.005	0.15	4.75

$[HA] = [A^-]$

Equal

Buffer

$pH = pK_a$

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....							
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....							
0.001	0.001	0.009	0.000	0.000	0.010	0.15	8.78

HA all neutralized NOW all A^- weak base

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	....						
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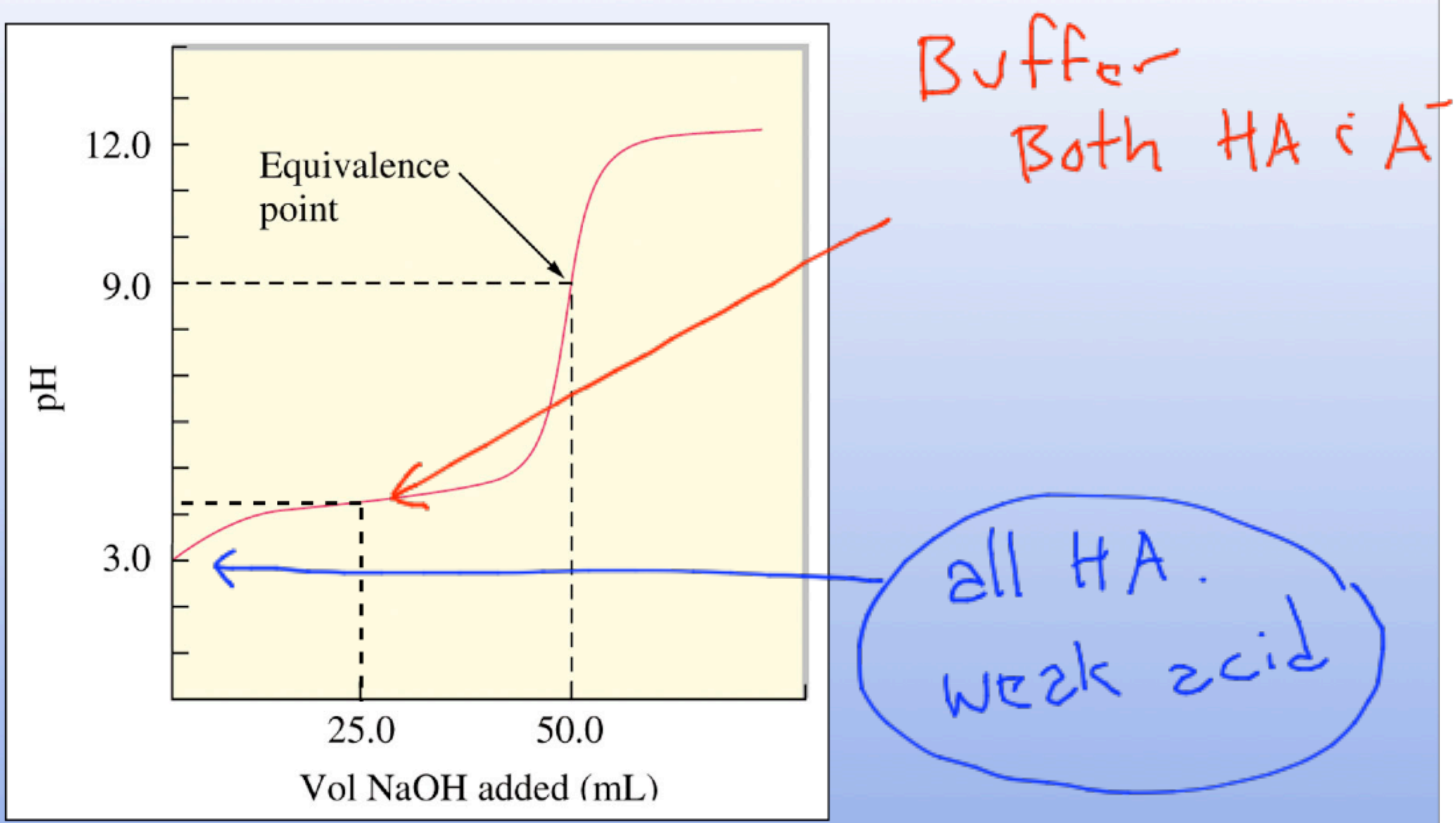
	....						
0.001	0.001	0.009	0.000	0.000	0.010	0.15	8.78
0.000	0.001	0.010	0.000	0.001	0.010	0.16	12.8

Both A^- & OH^-

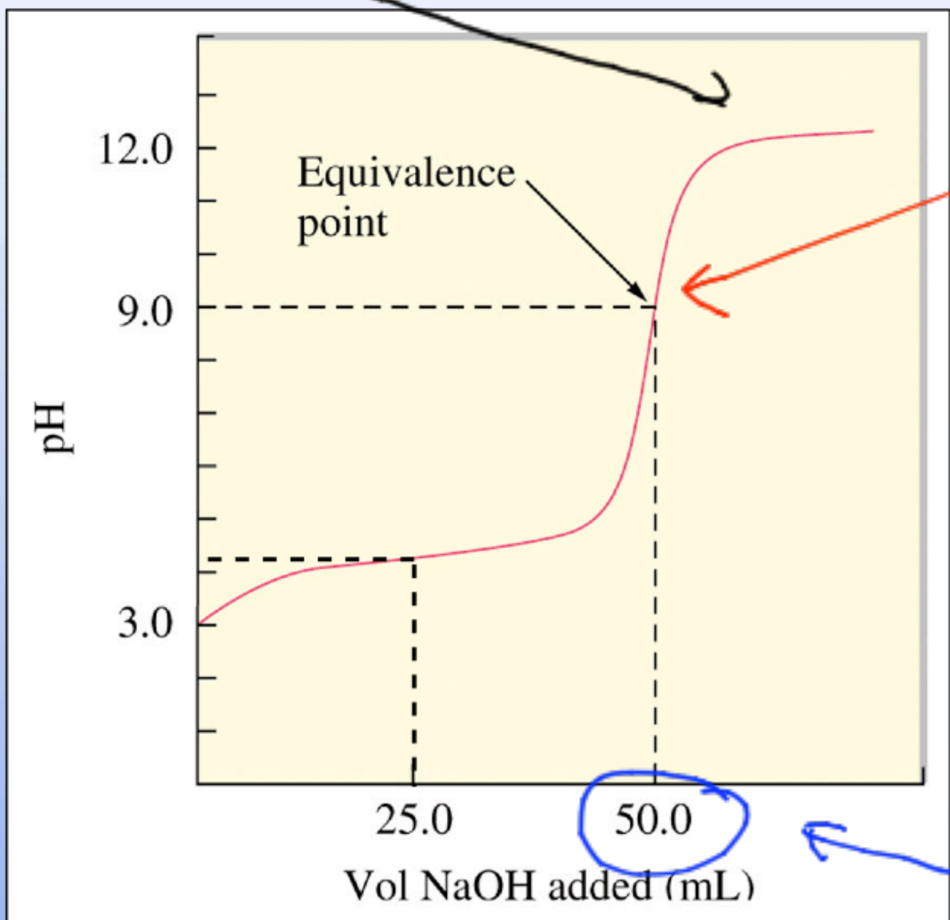
STRONG BASE

Titrating a weak acid



Titrating a weak acid

strong base

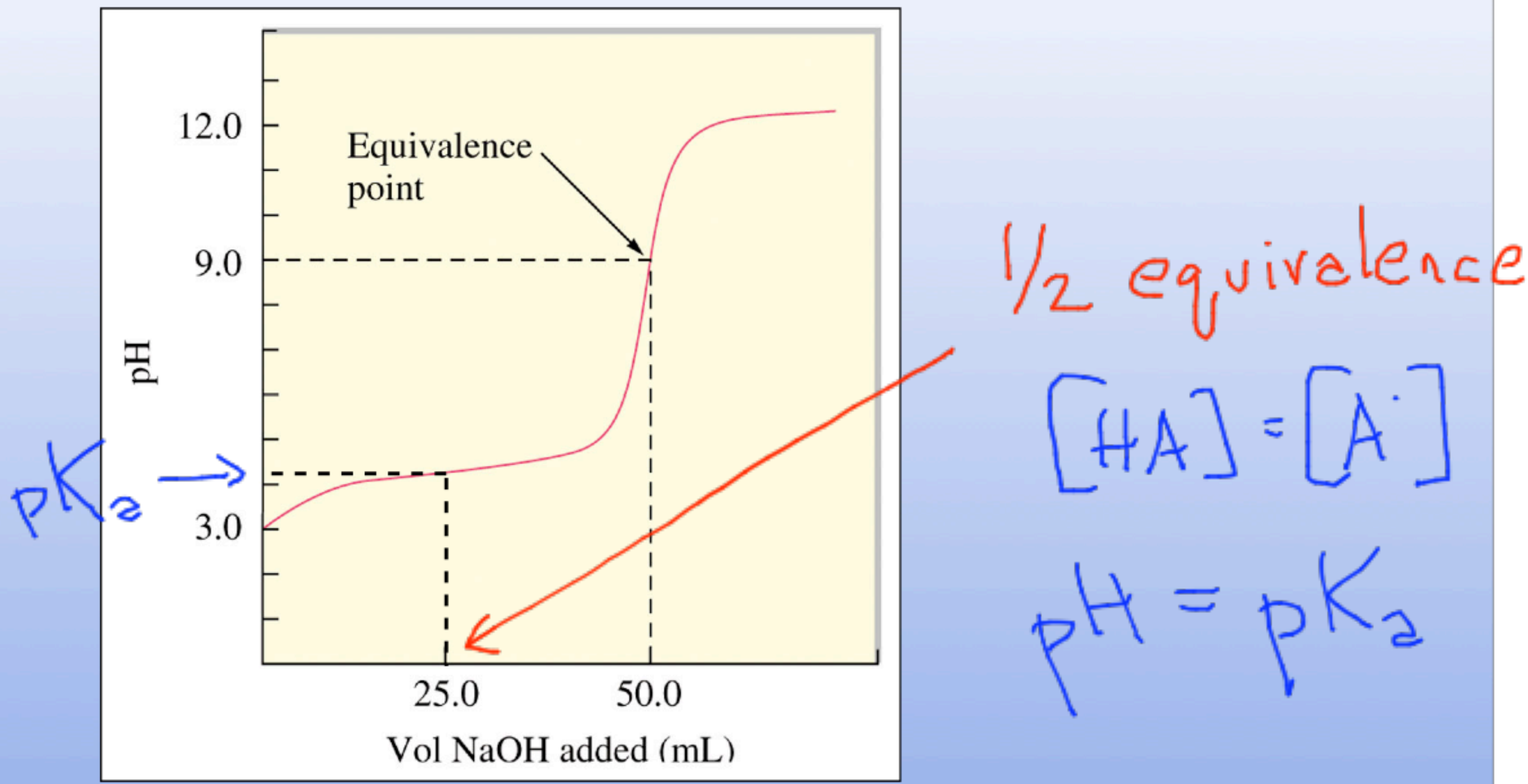


Equivalence Pt.
all HA neutralized to A^-

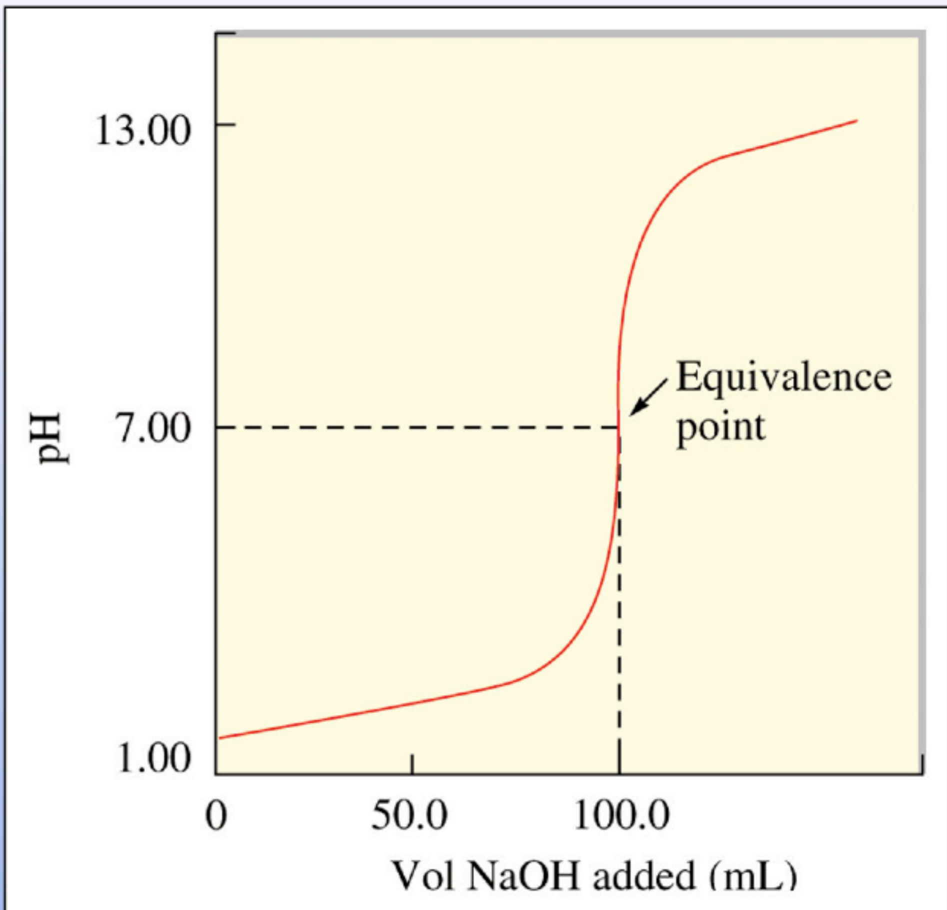
Equal moles
initial HA
added OH^-

information on concentration of initial sol'n

Titrating a weak acid



Easier Version   Strong Acid/Strong Base



HCl titrated with NaOH

No Buffer
(conjugate base is infinitely weak)

no ½ equiv.

only determine conc.

at the equivalence point we have
equal number of moles of acid and base

Neutralize first
Then look at the equilibrium

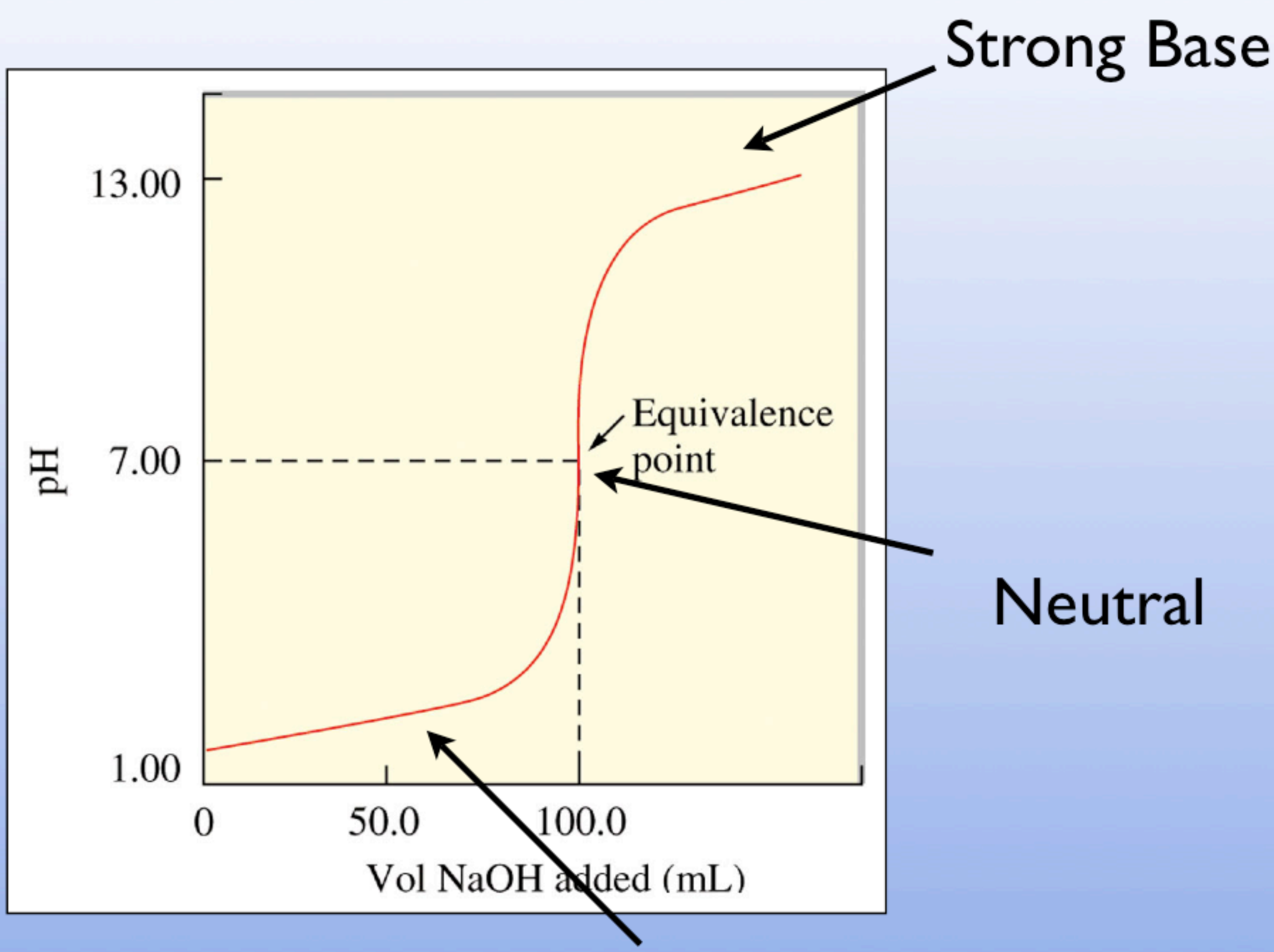
imagine a 100 mL solution with 0.1 moles of HCl
we add .01 moles of NaOH in each titration step (10 mL of 1M)

Initial		After Neutralization		Volume (L)	Equilibrium	
mol H^+	mol OH^-	mol H^+	mol OH^-		pH	pOH
0.1	0.01	0.09	0.00	0.11	0.09	13.91
0.09	0.01	0.08	0.00	0.12	0.18	13.82
0.08	0.01	0.07	0.00	0.13	0.27	13.76
....						
0.02	0.01	0.01	0.00	0.19	1.28	12.72
0.01	0.01	0.00	0.00	0.20	7.00	7.00
0.0	0.01	0.0	0.01	0.21	12.67	1.33
0.0	0.02	0.0	0.02	0.22	12.86	1.04

small changes

until all H^+ is neutralized

Strong Acid/Strong Base Titration



At the endpoint of your titration you have added 40 mL of a 1M NaOH solution to 200 mL of an unknown HCl solution. What was the concentration of the HCl?

A. 0.1 M

B. 0.2 M

C. 0.4 M

D. 1 M

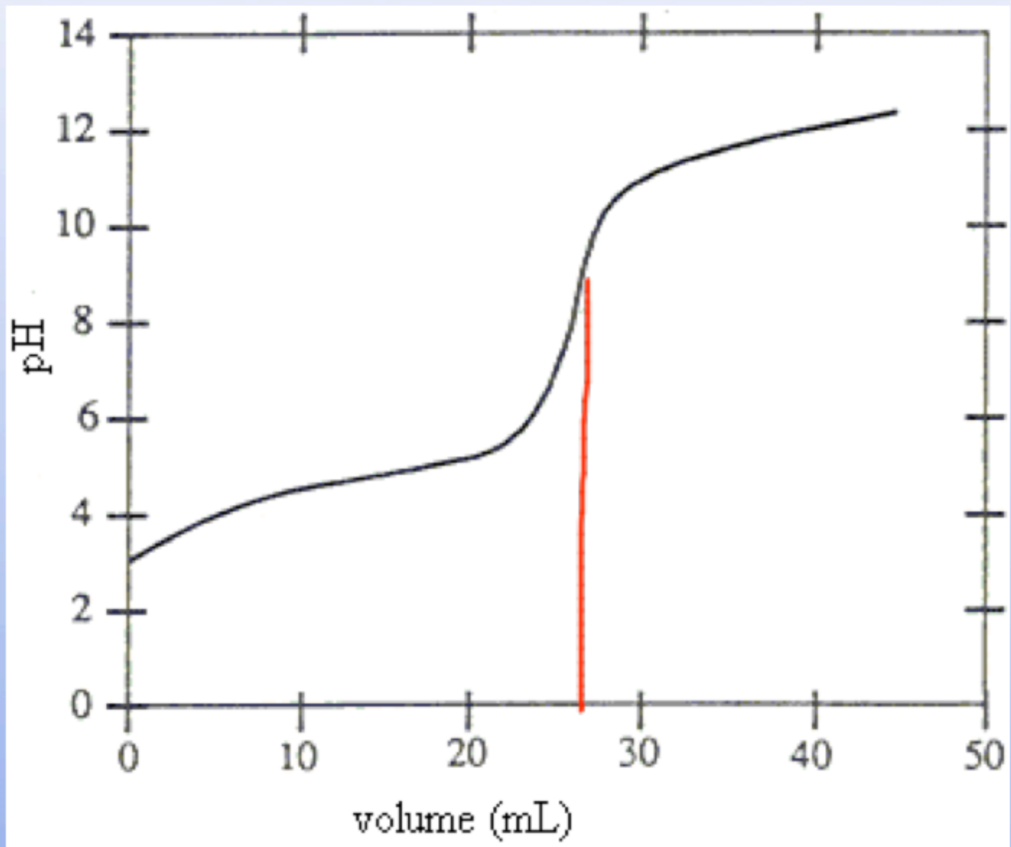
E. 2 M

At equiv. pt. Added OH^- = init. H^+

moles OH^- = (.04)(1 M) = .04

$$\frac{.04 \text{ moles}}{.2 \text{ L}} = .2 \text{ M}$$

The equivalence point in this titration is at



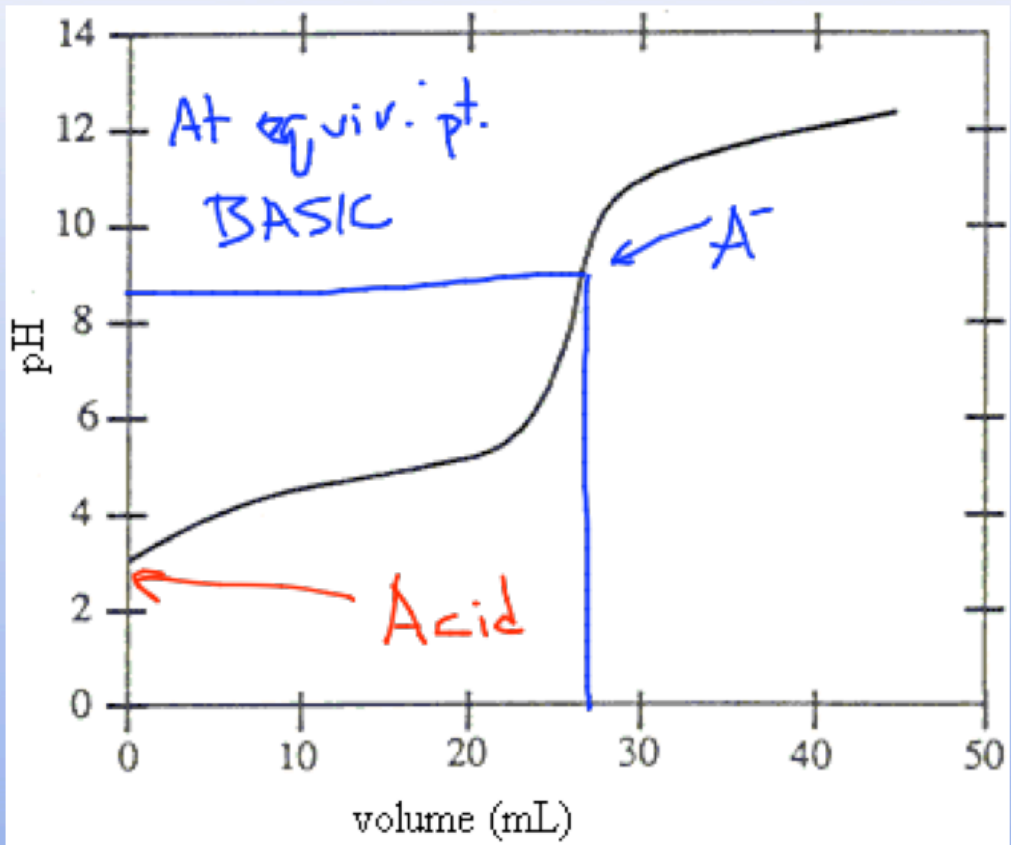
A. 5 mL

B. 14 mL

C. 28 mL

D. 44 mL

Below is a titration curve of a ______________



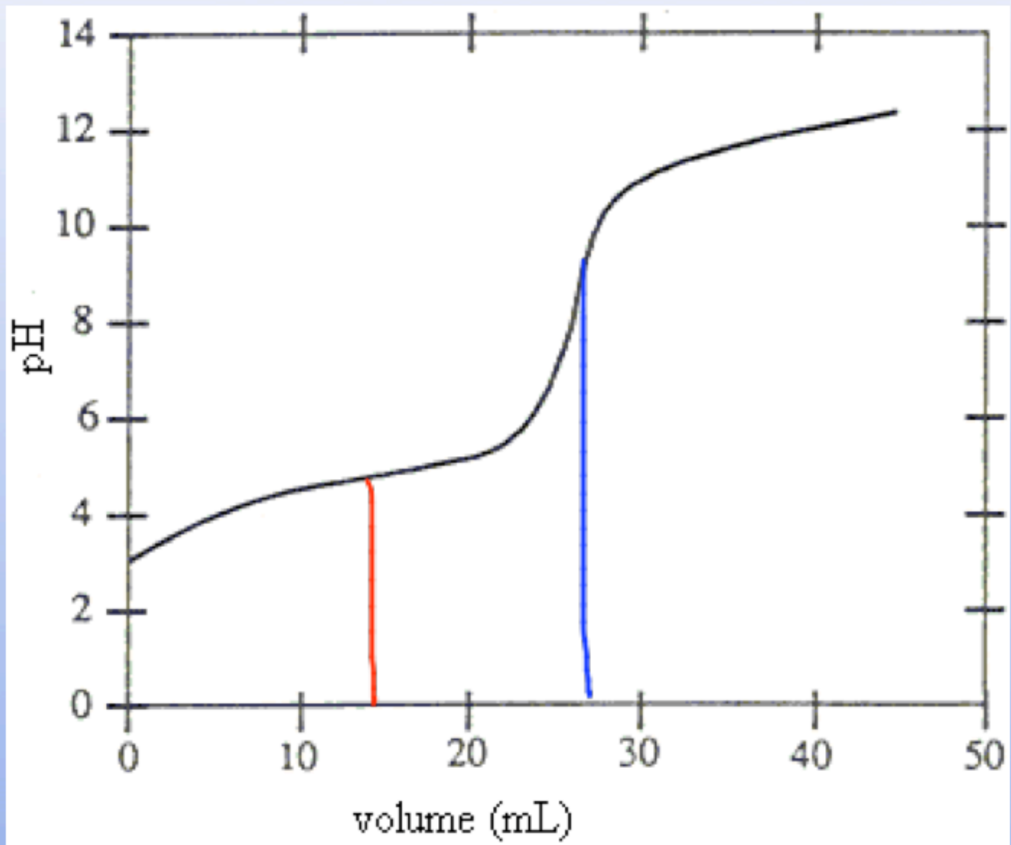
A. weak acid with a strong base

B. weak base with a strong acid

C. strong acid with a strong base

D. strong base with a strong acid

The half-equivalence point in this titration is at



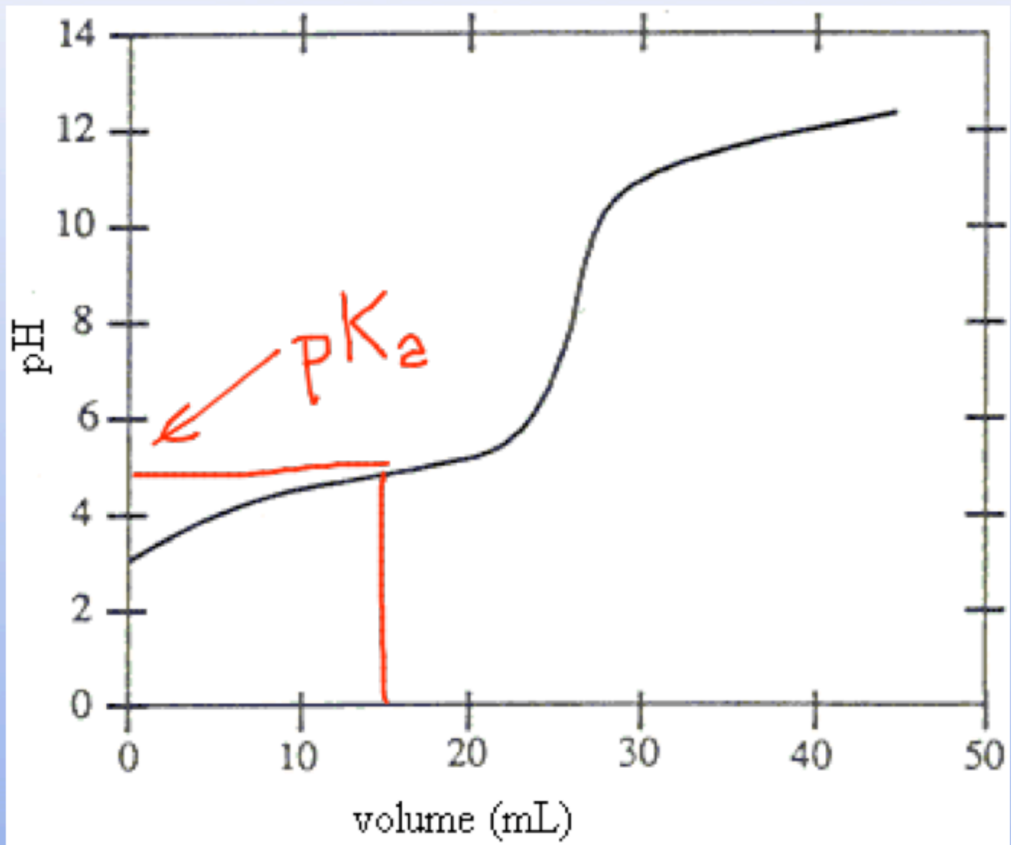
A. 5 mL

B. 14 mL = 28/2

C. 28 mL

D. 44 mL

The pKa of this weak acid is________



A. 3.1

B. 4.7

C. 8

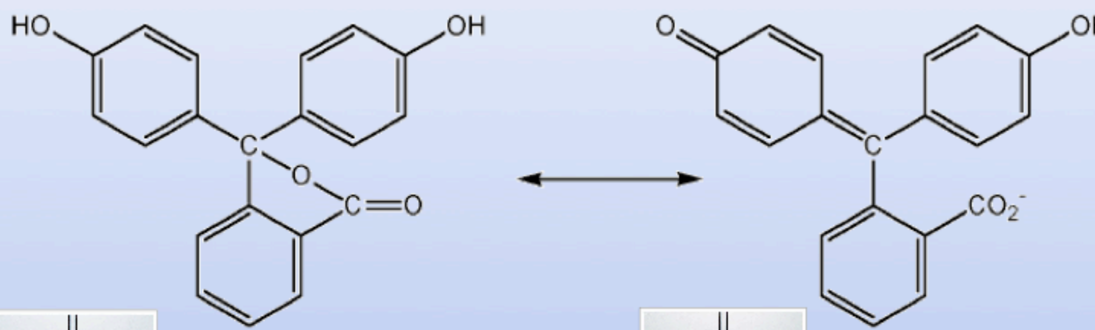
D. 12.1

Finding the endpoint (equivalence point)

Indicator dye

Phenolphthalein

$pKa = 8.2$ $K_a = 6.3 \times 10^{-9}$



amount of indicator is so small it doesn't affect the pH, but the equilibrium of the dye is strongly affected by the pH

Colourless
HA

Pink
A^-

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

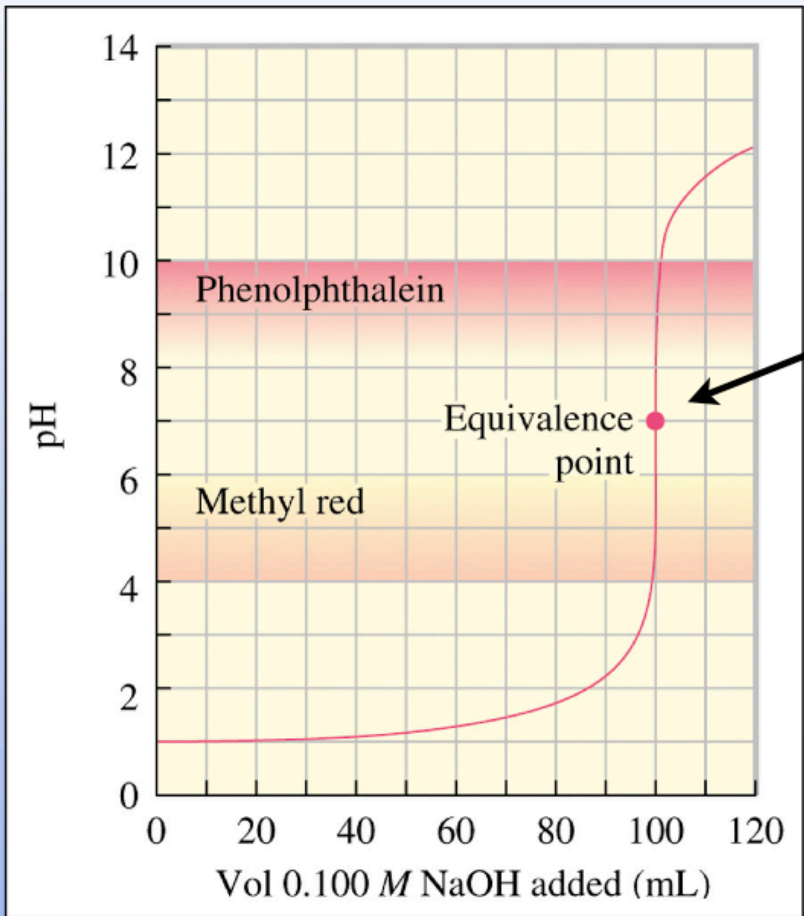
$$= [H^+] \times \frac{\text{Pink}}{\text{Clear}}$$

$[H^+] > 6.3 \times 10^{-9}$
$pH < 8.2$

$$\frac{\text{Pink}}{\text{Clear}} < 1$$

$[H^+] < 6.3 \times 10^{-9}$
$pH > 8.2$

$$\frac{\text{Pink}}{\text{Clear}} > 1$$



color just barely changing for Phenolpthalein

Better yet just use a pH meter

Bromophenol Blue has a pK_a of around 4. When it is protonated (HA form) it is green, when it is deprotonated (A^- form) it is blue.

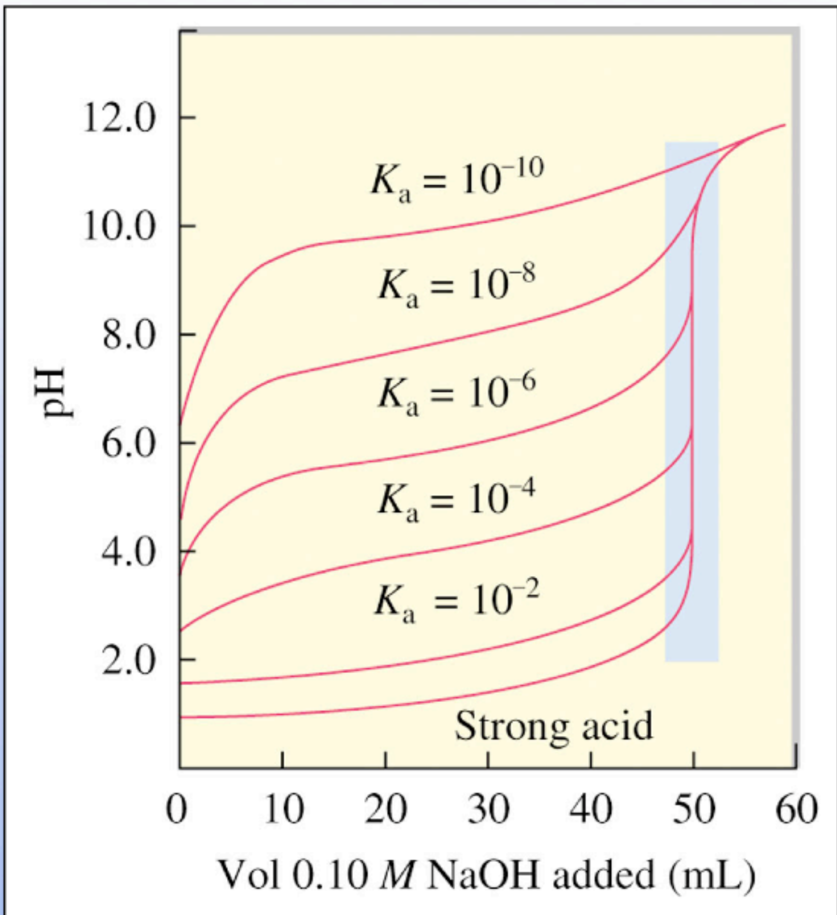
What color would in be in a solution in which the pH was 8?

A. blue

B. green

C. a mix of blue and green

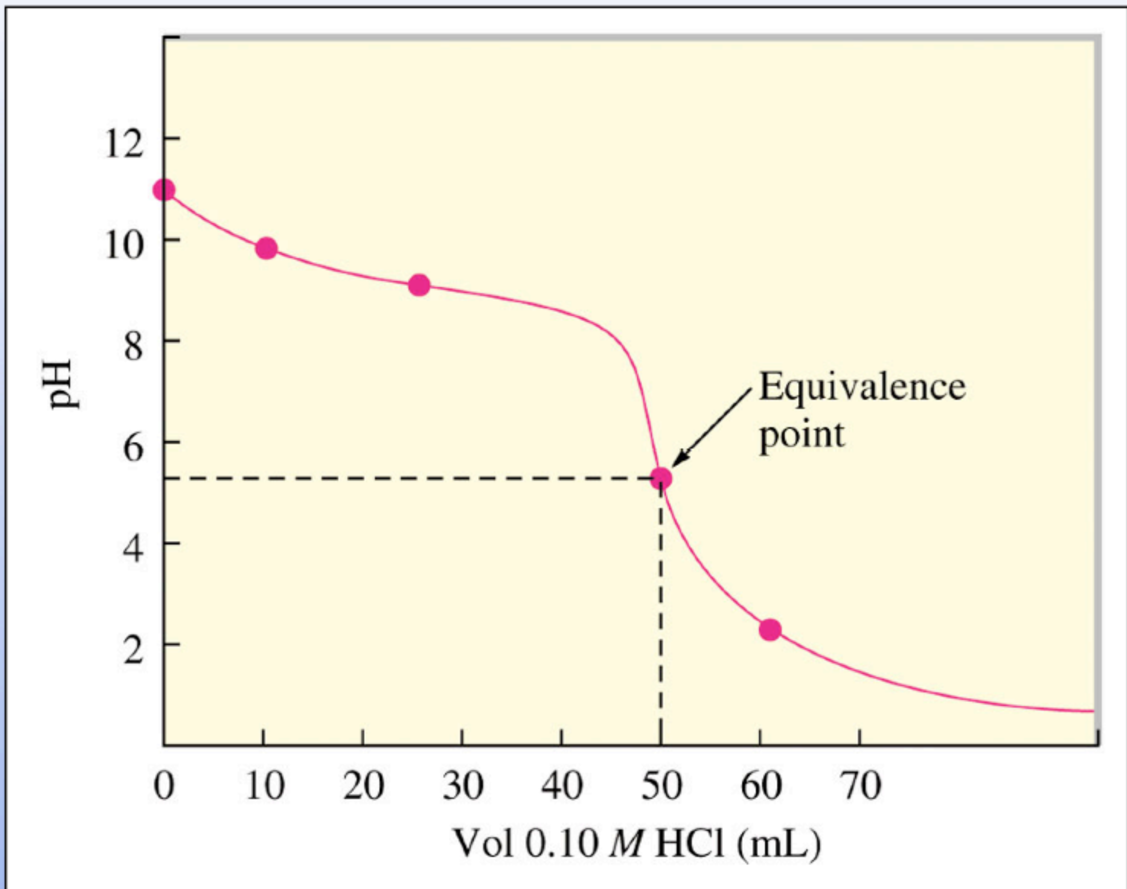
More Basic than pK_a → A^- predominates



½ equiv. pt.
↳ pK_a

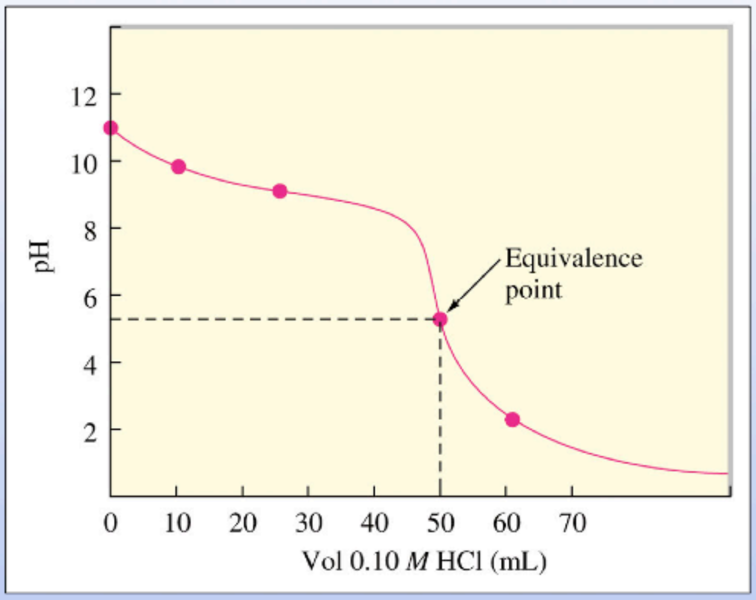
Example of 6 acids with different Ka's but
the same concentration
Same concentration will produce the
same equivalence point

Weak base titrated with strong acid



Basic solution starts at high pH (basic) goes to low (acid)

Weak base titrated with strong acid



Original Base solution had a volume of 100 mL.
What is the concentration?

A. 0.05 M

B. 0.1 M

C. 0.15 M

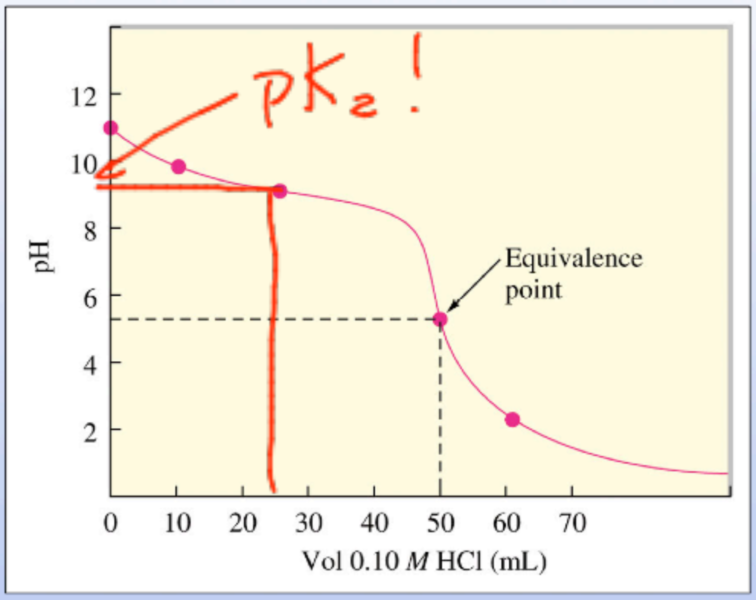
D. 0.20 M

moles added H^+ = init. base

$(.1 M)(.05 L) = .005$ moles

$\frac{.005}{.1} = 0.05 M$

Weak base titrated with strong acid



What is the Kb of the base?

$$K_b = \frac{K_w}{K_a}$$

$$pK_a + pK_b = 14$$

A. 1×10^{-3}

B. 1×10^{-5}

C. 1×10^{-8}

D. 1×10^{-9}

$pK_a = 9$ $\quad K_a = 1 \cdot 10^{-9}$

$K_b = 1 \cdot 10^{-5}$

Polyprotic Acids

Acids that have more than one proton to lose

Now we need to keep track of all the "forms" of the acid

Monoprotic HA , A^-

Diprotic H_2A, HA^-, A^{2-}

Triprotic H_3A, H_2A^-, HA^{2-}, A^{3-}