N39 – Acid Base

Henderson-Hasselbalch
“He-Ha”

Buffered Solutions

Buffer - A solution that resists a change in pH when either hydroxide ions or protons are added.

Buffered solutions contain either:

- **A weak acid and its salt**
- **A weak base and its salt**

Acid/Salt Buffering Pairs

The salt will contain the anion of the acid, and the cation of a strong base (NaOH, KOH)

Weak Acid	Formula of the acid	Example of a salt of the weak acid
Hydrofluoric	HF	KF – Potassium fluoride
Formic	$HCOOH$	$KHCOO$ – Potassium formate
Benzoic	C_6H_5COOH	NaC_6H_5COO – Sodium benzoate
Acetic	CH_3COOH	NaH_3COO – Sodium acetate
Carbonic	H_2CO_3	$NaHCO_3$ - Sodium bicarbonate
Propanoic	$HC_3H_5O_2$	$NaC_3H_5O_2$ - Sodium propanoate
Hydrocyanic	HCN	KCN - potassium cyanide

Base/Salt Buffering Pairs

The salt will contain the cation of the base, and the anion of a strong acid (HCl, HNO_3)

Weak Base	**Formula of the base**	**Example of a salt of the weak acid**
Ammonia	NH_3	NH_4Cl - ammonium chloride
Methylamine	CH_3NH_2	CH_3NH_3Cl – methylammonium chloride
Ethylamine	$C_2H_5NH_2$	$C_2H_5NH_3NO_3$ - ethylammonium nitrate
Aniline	$C_6H_5NH_2$	$C_6H_5NH_3Cl$ – aniline hydrochloride
Pyridine	C_5H_5N	C_5H_5NHCl – pyridine hydrochloride

Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF. ($K_a = 7.2 \times 10^{-4}$)

A. 7.2×10^{-4} M

B. 2.0 M

C. 1.4×10^{-3} M

D. 0.20 M

E. none of these

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- D. 0.20 M
- E. none of these

$$HF \leftrightarrow H^+ + F^-$$

$$Ka = \frac{[H^+][F^-]}{HF}$$

F^- present when you start because of the salt!

Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF. ($K_a = 7.2 \times 10^{-4}$)

A 7.2 x 10^{-4} M

B 2.0 M

C 1.4 x 10^{-3} M

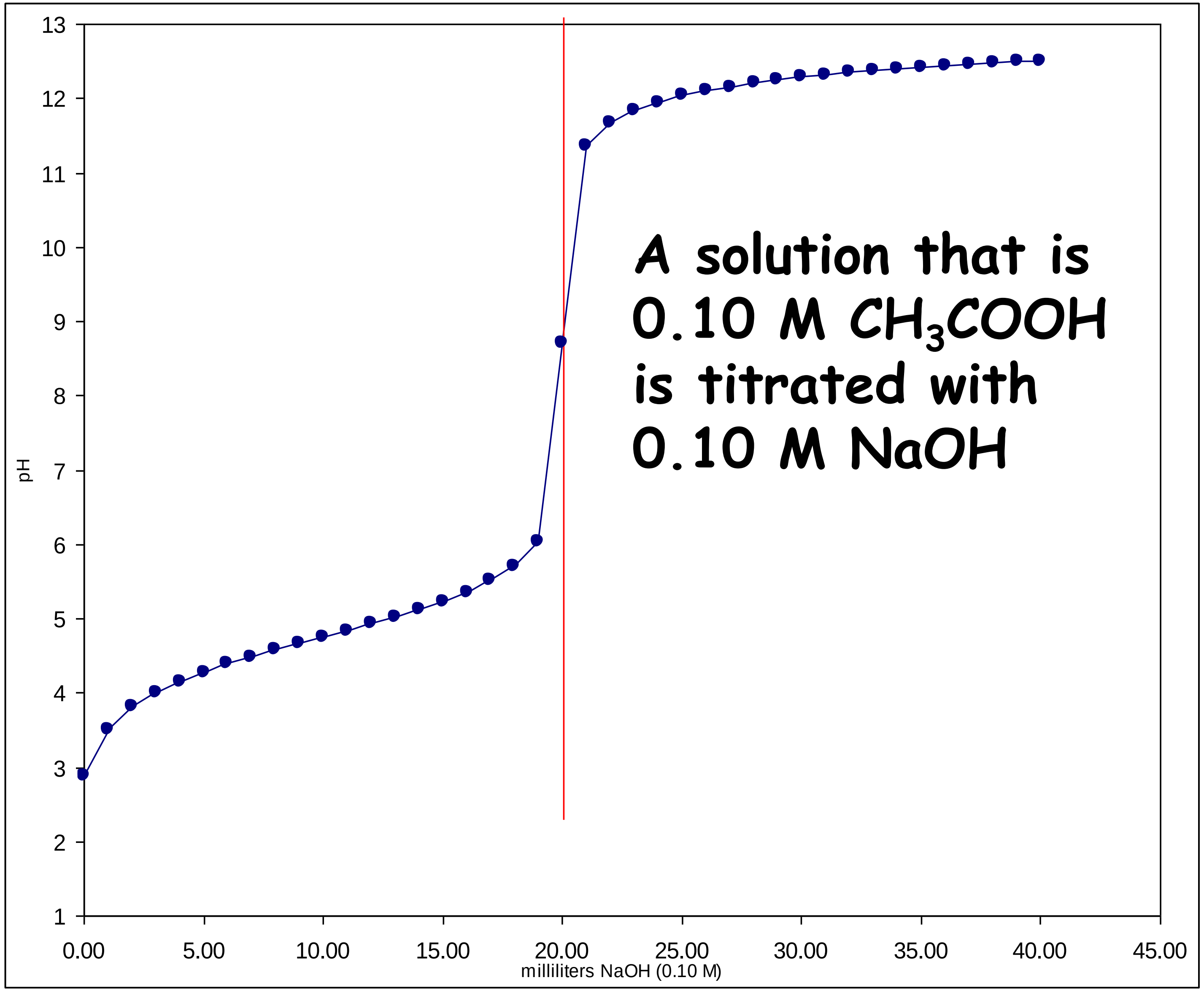
D 0.20 M

E none of these

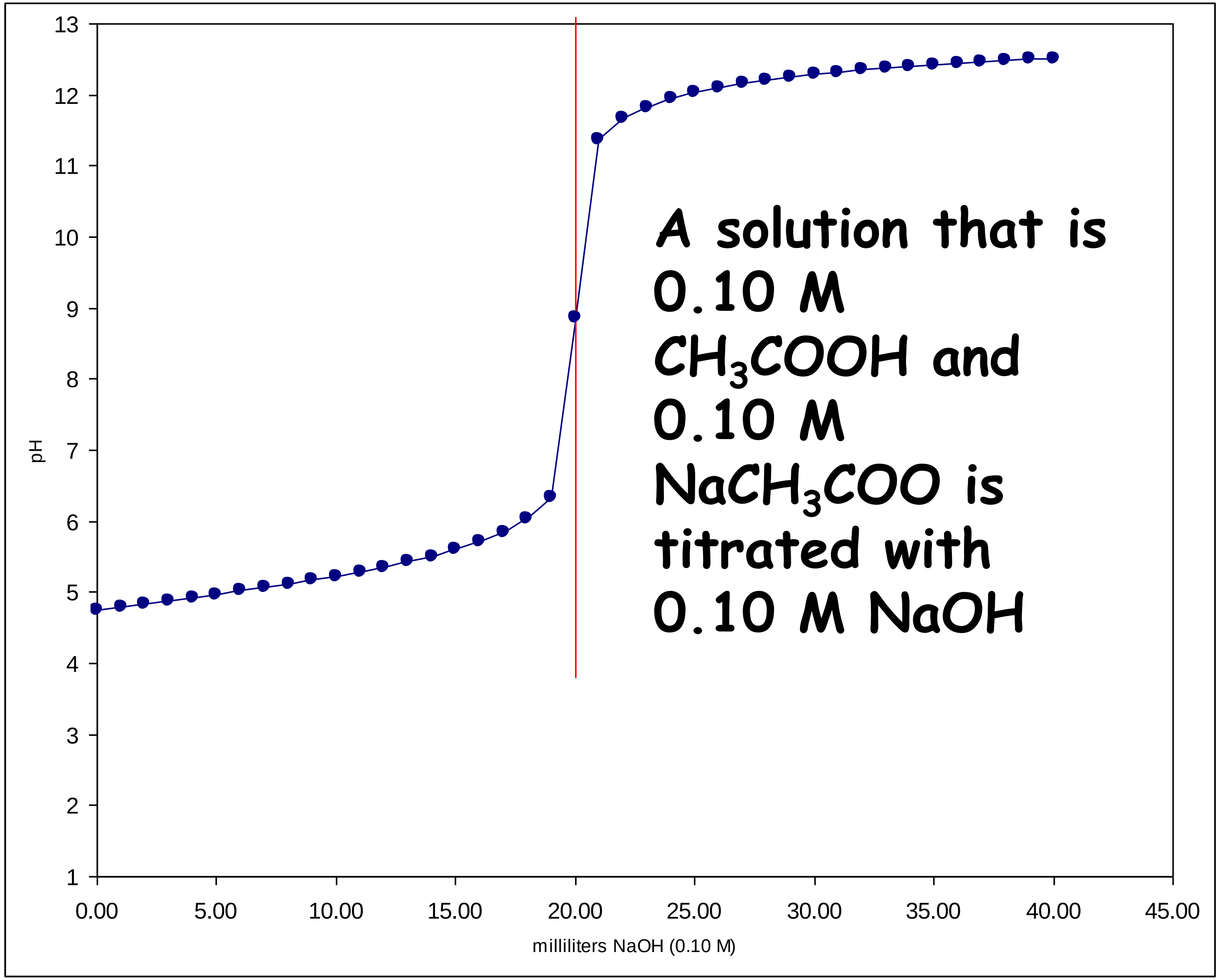
$$7.2\,x\,10^{-4} = \frac{[H^+][0.10]}{[0.2]};$$

$$[H^+] = 1.44\,x\,10^{-3}\,M$$

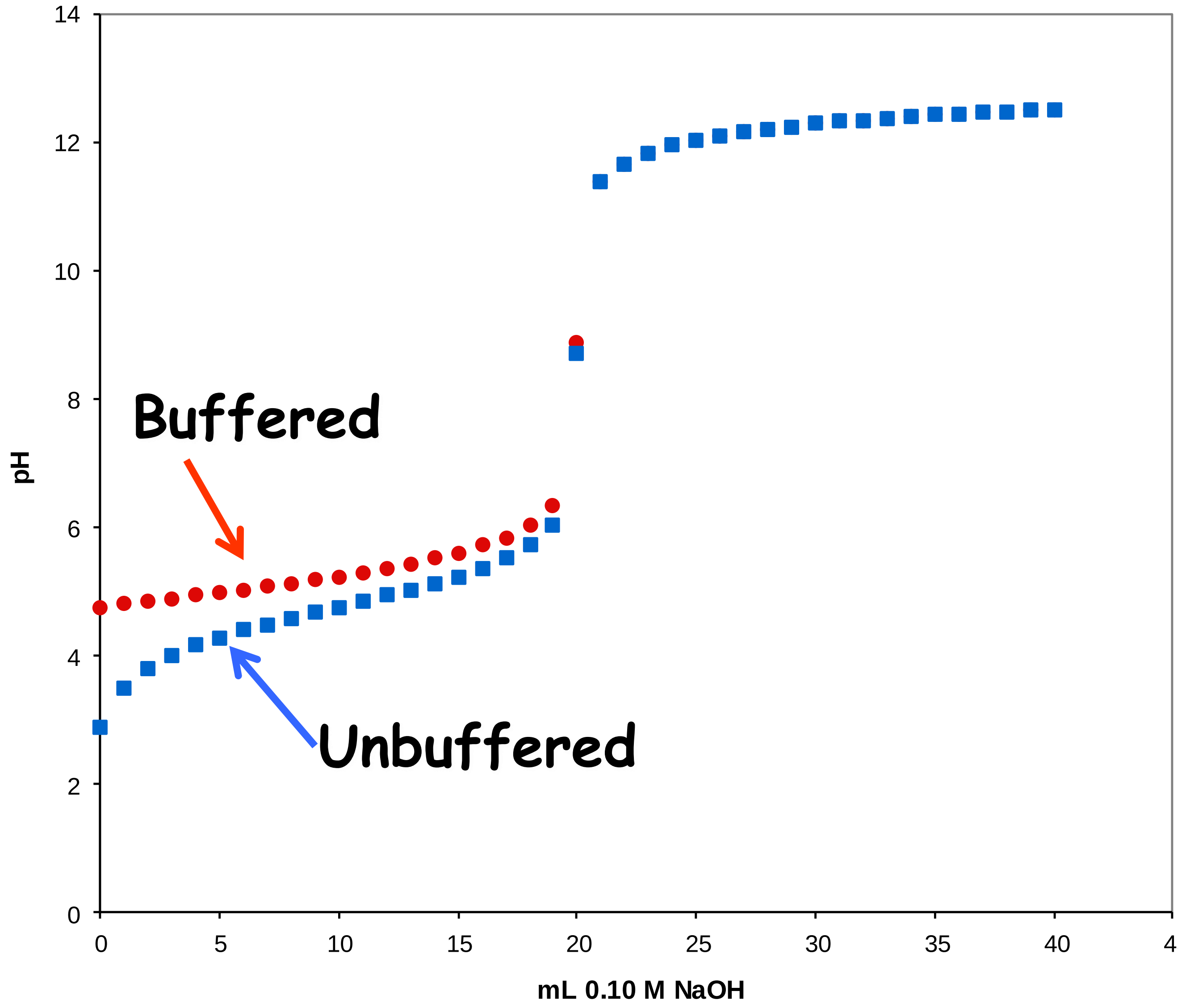
Titration of an Unbuffered Solution



Titration of a Buffered Solution

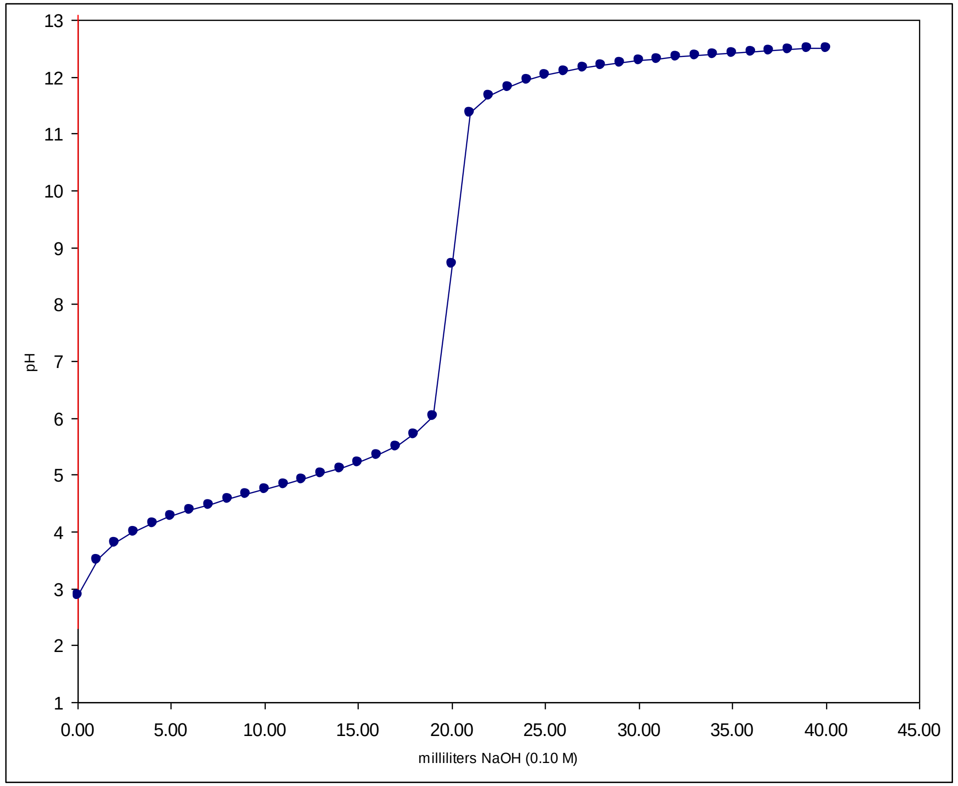


Comparing Results

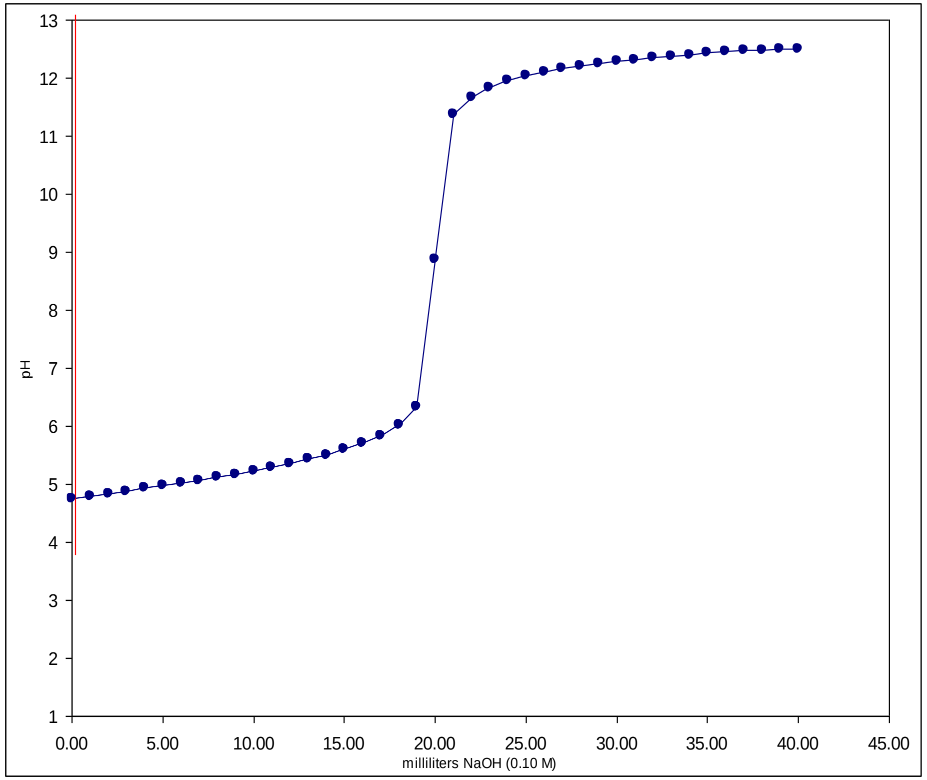


Comparing Results

Unbuffered



Buffered



- **In what ways are the graphs different?**
- **In what ways are the graphs similar?**

Henderson-Hasselbalch Equation

A really helpful shortcut equation to find the pH or pOH of a buffered solution.

You could do ICE Tables but those can be really time consuming.

Henderson-Hasselbalch Equation

$$pH = pK_a + log\left(\frac{A^-}{HA}\right) \qquad = pK_a + log\left(\frac{[Base]}{[Acid]}\right)$$

$$pOH = pK_b + log\left(\frac{BH^+}{B}\right) = pK_b + log\left(\frac{[Acid]}{[Base]}\right)$$

pKa = -log(Ka)
pKb = -log(Kb)

Just like pH = -log[H$^+$]

The acids or bases may be conjugates from the salt!

Other ways to think about He-Ha

Acid with a buffer:

$$pH = pK_a + log\left(\frac{[salt]}{[Acid]}\right) = pK_a + log\left(\frac{[conj.Base]}{[Acid]}\right)$$

Base with a buffer:

$$pOH = pK_b + log\left(\frac{[salt]}{[Base]}\right) = pKb + log\left(\frac{[conj.Acid]}{[Base]}\right)$$

Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF. ($K_a = 7.2 \times 10^{-4}$)

- A. $7.2E^{-4}$ M
- B. 2.0 M
- C. $1.4E^{-3}$ M
- D. 0.20 M
- E. none of these

Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF. ($K_a = 7.2 \times 10^{-4}$)

A. $7.2E^{-4}$ M

B. 2.0 M

C. $1.4E^{-3}$ M

D. 0.20 M

E. none of these

Acid solution with a salt added.

- HF = acid
- NaF = salt

The salt has the conjugate base of the acid.

- F^-

$$pH = pKa + Log\frac{[Base]}{[Acid]};$$

Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF. ($K_a = 7.2 \times 10^{-4}$)

A 7.2E^{-4} M

B 2.0 M

C 1.4E^{-3} M

D 0.20 M

E none of these

$$pH = pKa + Log\frac{[Base]}{[Acid]};$$

$$pH = -log[7.2E^{-4}] + log\frac{[0.1M]}{[0.2M]}$$

$$= 2.84$$

$[H^+] = 10^{-pH} = 10^{-2.84} = 0.00144M$

Another good equation

Rearrange your Law of Mass Action:

$$Ka = \frac{[H^+][A^-]}{[HA]} \rightarrow \boxed{[H^+] = Ka\frac{[HA]}{[A^-]}} \rightarrow\ = Ka\frac{[Acid]}{[conj.Base]}$$

$$Kb = \frac{[BH^+][OH^-]}{[B]} \rightarrow \boxed{[OH^-] = Kb\frac{[B]}{[BH^+]}} \rightarrow\ = Kb\frac{[Base]}{[conj.Acid]}$$

Suggestions…

Pick a method and stick to it. They all have pros and cons.

- **Ice tables**

  Pro = familiar   Con = takes forever, lots of steps

- **He-Ha**

  Pro = fast, on the AP eq. sheet   Con = Have to recognize to use it, not always solving for pH

- **Rearranging Law of Mass Action**

  Pro = simple   Con = Have to recognize to use it, extra step to get to pH or pOH

Suggestions…

Make sure to practice ALL methods once in a while.

You never know which info they will give you…

You want to be able to solve any variety of problems!

YES it is fine if I used one method on a key and you used another method. No big deal.

Just make sure you are careful about rounding issues.