

## Acids &amp; Bases # 2

Due Tuesday, Nov 16th, 1999

Table 1. Dissociation Constants for some Acids.

Acid	pK <sub>a</sub> Value	Acid	pK <sub>a</sub> Value	Acid	pK <sub>a</sub> Value
CH <sub>4</sub>	24	H <sub>2</sub> S	7.0	H <sub>3</sub> PO <sub>4</sub>	2.1
CF <sub>3</sub> COOH	-2	Benzoic	4.2	HPF <sub>6</sub>	-10

1. (5 pts) Circle the following acid that will have a pH closest to 7 for a 0.1 M aqueous solution?

- a) CF<sub>3</sub>COOH      b) benzoic      c) H<sub>3</sub>PO<sub>4</sub>      **d) CH<sub>4</sub>**      e) HPF<sub>6</sub>

The acid that will have its pH closest to 7 will be the weakest acid. This will be the one with the largest pK<sub>a</sub> value. The strongest acid will have the most acidic pH, which for a 0.1 M solution would be pH = 1.

2. (5 pts) Circle the following acid that when reacted with an equivalent amount of NaOH will form a solution with a pH closest to 7?

- a) H<sub>2</sub>S      b) benzoic      c) H<sub>3</sub>PO<sub>4</sub>      d) CH<sub>4</sub>      **e) HPF<sub>6</sub>**

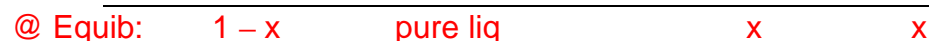
For this problem we are looking for the strongest acid. Strong acids react with strong bases (like NaOH) to produce neutral salts (do-nothing cations and do-nothing anions). The strongest acid is HPF<sub>6</sub>, with a pK<sub>a</sub> = -10.

3. (5 pts) Order the acids in Table 1 from strongest to weakest. Circle the correct choice.

- a) CH<sub>4</sub> > H<sub>2</sub>S > benzoic > H<sub>3</sub>PO<sub>4</sub> > CF<sub>3</sub>COOH > HPF<sub>6</sub>  
**b) HPF<sub>6</sub> > CF<sub>3</sub>COOH > H<sub>3</sub>PO<sub>4</sub> > benzoic > H<sub>2</sub>S > CH<sub>4</sub>**  
 c) benzoic > H<sub>2</sub>S > H<sub>3</sub>PO<sub>4</sub> > HPF<sub>6</sub> > CF<sub>3</sub>COOH > CH<sub>4</sub>  
 d) H<sub>2</sub>S > benzoic > H<sub>3</sub>PO<sub>4</sub> > CF<sub>3</sub>COOH > HPF<sub>6</sub> > CH<sub>4</sub>  
 e) H<sub>3</sub>PO<sub>4</sub> > H<sub>2</sub>S > HPF<sub>6</sub> > benzoic > CF<sub>3</sub>COOH > CH<sub>4</sub>

The strongest acid is the one with the most negative pK<sub>a</sub> value, which in this case is HPF<sub>6</sub>, with a pK<sub>a</sub> = -10. One then sorts the list from smallest pK<sub>a</sub> to the largest (weakest acid).

4. (5 pts) What is the pH of a 1 M solution of the base methylamine (CH<sub>3</sub>NH<sub>2</sub>)? pK<sub>a</sub> = 10. Please show all your work.



You first need to convert the pK<sub>a</sub> into a K<sub>a</sub>, then into a K<sub>b</sub> for this basic equilibrium:

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{1 \times 10^{-10}} = 1 \times 10^{-4} \quad \text{now you can setup your equilb: } K_b = \frac{(x)(x)}{(1-x)} = 1 \times 10^{-4}$$

assume that  $x \ll 1$ ,  $\frac{(x)(x)}{(1)} = 1 \times 10^{-4}$  or  $x^2 = 1 \times 10^{-4}$ , or  $x = [\text{OH}^-] = 1 \times 10^{-2}$  pOH = 2. **BUT**

**THIS IS NOT YOUR ANSWER**, since I asked for the pH!! **pH = 14 - 2 = 12**

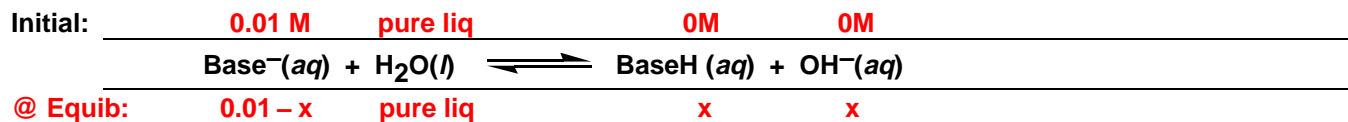
- a) 4      b) 5      c) 8      **d) 12**      e) 22

5. (5 pts) Circle the following pK<sub>a</sub> value that best fits the extremely strong base KH (potassium hydride)?

- a) -20      b) 0      c) 7      d) 14      **e) 30**

6. (10 pts) What is the pH of a 0.01 M solution of KCN?  $pK_a = 4$ . Clearly show all your work.

The first thing to realize is that this is a **basic salt** that will generate a **basic** solution!  $K^+$  is a do-nothing cation, while  $CN^-$  is a **basic** anion that acts as a weak base in solution.



Next you need to convert the  $pK_a$  value I've given you into a  $K_a$ , then  $K_b$  for the conjugate base in this basic equilibrium:

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{1 \times 10^{-4}} = 1 \times 10^{-10} \quad \text{now you can setup your equilib: } K_b = \frac{(x)(x)}{(0.01 - x)} = 1 \times 10^{-10}$$

assume that  $x \ll 0.01$ ,  $\frac{(x)(x)}{(0.01)} = 1 \times 10^{-10}$  or  $x^2 = 1 \times 10^{-12}$ , or  $x = [OH^-] = 1 \times 10^{-6}$

pOH = 6. **BUT THIS IS NOT YOUR ANSWER**, since I asked for the pH!!  $pH = 14 - pOH = 8$  so the **pH = 8**

7. (10 pts) Consider the following list of salts (use information from your notes & Table 1 to help):

- |               |                   |                      |             |
|---------------|-------------------|----------------------|-------------|
| A) $Li_2CO_3$ | B) $Al_2(SO_4)_3$ | C) $Na_2S$           | D) $NH_4Cl$ |
| E) $Ca(OH)_2$ | F) $BeI_2$        | G) potassium acetate | H) $LiNO_3$ |
| I) $CsBr$     | J) $Co(PF_6)_3$   |                      |             |

Which salts will generate an **acidic** solution? **B, D, F, J**

Which salts will generate a **basic** solution? **A, C, E, G**

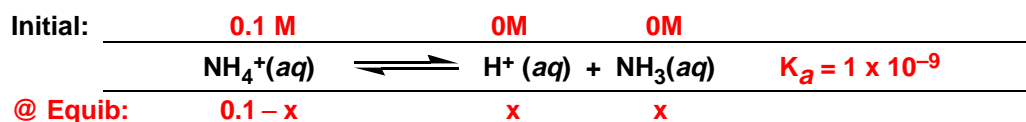
Which salts will generate a **neutral** solution? **H, I**

8. (10 pts) What is the pH if 500 mL of 0.2 M HCl is added to 500 mL of 0.2 M ammonia ( $NH_3$ )  $pK_a = 9$

The first thing to realize is that ammonia is a weak base and that we are titrating it with a strong acid. If there are equal amounts of each, we will be making the salt of a weak base, which is a weak acid! Calculate the # of moles of each:

# moles strong acid = (500 mL HCl)(0.2 M HCl) = 100 mmoles  $H^+$   
 # moles weak base = (500 mL ammonia)(0.2 M ammonia) = 100 mmoles ammonia

Write out an acid equilibria, convert the  $pK_a$  into  $K_a$  and calculate  $[H^+]$ :

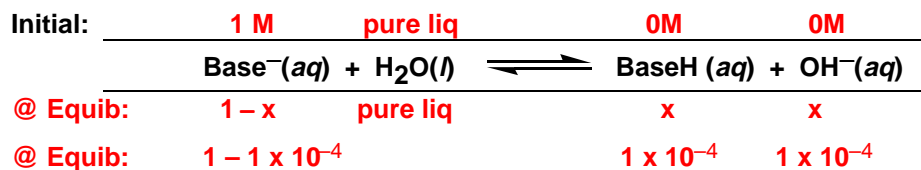


Don't forget that we will make 1000 mL total solution volume. This will generate a 100 mmoles/1000 mL = 0.1 M solution of  $NH_4Cl$ , which is a **weak acid**.

now you can setup your equilib:  $K_a = \frac{(x)(x)}{(0.1 - x)} = 1 \times 10^{-9}$  assume that  $x \ll 0.1$ :  $\frac{(x)(x)}{(0.1)} = 1 \times 10^{-9}$

or  $x^2 = 1 \times 10^{-10}$ , or  $x = [H^+] = 1 \times 10^{-5}$  so the **pH = 5**

9. (5 pts) Calculate the  $pK_b$  of the weak base phenylamine if a 1 M solution has a pH = 10.



A pH of 10 means that the pOH is 4. We do NOT use the pH directly in this problem because we are dealing with a basic equilibrium!! Thus, we know that the  $[OH^-] = 1 \times 10^{-4}$  M.

Plug into the  $K_b$  expression and solve:  $K_b = \frac{(1 \times 10^{-4})^2}{1 - 1 \times 10^{-4}} = 1 \times 10^{-8}$  **pK<sub>b</sub> = 8**