

Problem Set #15  
CHEM101A: General College Chemistry

Donald Aingworth

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## 23 Topic G Problem 23

The concentration of  $\text{H}^+$  ions in a solution is 0.315 M.

- a) Calculate the concentration of  $\text{OH}^-$  ions in this solution.
- b) Where did these  $\text{OH}^-$  ions come from?
- c) What is the pH of this solution?

### 23.1 Solution (a)

The concentration of hydrogen ions times the number of hydroxide ions is equal to a constant  $K_w = 10^{-14}$ . We can use that to find the concentration of hydroxide ions.

$$K_w = [\text{H}^+][\text{OH}^-] \quad (1)$$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{10^{-14}}{0.315} = 3.17 \times 10^{-14} \text{ M} = \boxed{3.2 \times 10^{-14} \text{ M}} \quad (2)$$

### 23.2 Solution (b)

The  $\text{OH}^-$  ions come from the surrounding water.

### 23.3 Solution (c)

Use the logarithm.

$$\text{pH} = -\log_{10}([\text{H}^+]) = -\log_{10}(0.315) = \boxed{0.50} \quad (3)$$

## 24 Topic G Problem 24

The pH of an HCl solution is 2.88.

- a) What is the concentration of  $\text{H}^+$  ions in this solution?
- b) What is the concentration of  $\text{OH}^-$  ions in this solution?
- c) What is the concentration of  $\text{Cl}^-$  ions in this solution?

### 24.1 Solution (a)

Use the exponential.

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-2.88} = \boxed{0.0013 \text{ M}} \quad (4)$$

### 24.2 Solution (b)

The  $\text{OH}^-$  and  $\text{H}^+$  concentrations are related.

$$K_w = [\text{H}^+][\text{OH}^-] \quad (5)$$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{10^{-14}}{0.0013} = 7.586 \times 10^{-12} \text{ M} = \boxed{7.6 \times 10^{-12} \text{ M}} \quad (6)$$

### 24.3 Solution (c)

There is much less  $\text{OH}^-$  than there is  $\text{H}^+$ . Even if some of the created  $\text{OH}^-$  balanced out the  $\text{H}^+$ , it would have been little. This means the  $\text{Cl}^-$  would be equivalent to the amount of  $\text{H}^+$ .  $\boxed{0.0013 \text{ M}}$

## 25 Topic G Problem 25

Calculate the pH of a  $7.4 \times 10^{-4}$  M solution of Ba(OH)<sub>2</sub>.

### 25.1 Solution

Start by calculating the concentration of the OH<sup>-</sup>. It would be twice the concentration of the Ba(OH)<sub>2</sub> because it is soluble in water.

$$[\text{OH}^-] = 2 * 7.4 \times 10^{-4} \text{ M} = 1.48 \times 10^{-3} \text{ M} \quad (7)$$

This leads into a calculation of the concentration of the H<sup>+</sup>. We can use that to find the pH.

$$K_w = [\text{H}^+][\text{OH}^-] \quad (8)$$

$$[\text{H}^+] = \frac{K_w}{[\text{OH}^-]} = \frac{10^{-14}}{1.48 \times 10^{-3} \text{ M}} = 6.757 \times 10^{-12} \text{ M} \quad (9)$$

$$\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(6.757 \times 10^{-12}) = \boxed{11.17} \quad (10)$$

## 26 Topic G Problem 26

Write the  $K_a$  expression and the corresponding chemical equation for each of the following weak acids.

- a) HClO
- b)  $\text{H}_2\text{C}_4\text{H}_4\text{O}_4$

- c)  $\text{NH}_4^+$
- d)  $\text{H}_2\text{PO}_4^-$

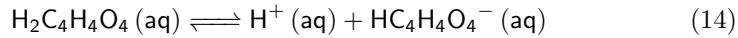
### 26.1 Solution (a)

$$K_a = \frac{[\text{H}^+][\text{ClO}^-]}{[\text{HClO}]} \quad (11)$$



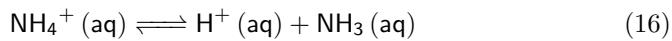
### 26.2 Solution (b)

$$K_a = \frac{[\text{H}^+][\text{HC}_4\text{H}_4\text{O}_4^-]}{[\text{H}_2\text{C}_4\text{H}_4\text{O}_4]} \quad (13)$$



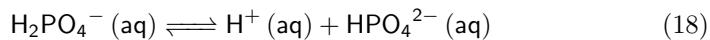
### 26.3 Solution (c)

$$K_a = \frac{[\text{H}^+][\text{NH}_3]}{[\text{NH}_4^+]} \quad (15)$$



### 26.4 Solution (d)

$$K_a = \frac{[\text{H}^+][\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} \quad (17)$$



## 27 Topic G Problem 27

The pH of a 0.464 M solution of phosphorous acid ( $\text{H}_3\text{PO}_3$ ) is 1.11. Using this information, calculate the  $K_a$  of phosphorous acid. (You may assume that only one hydrogen ion dissociates from phosphorous acid.)

### 27.1 Solution

First find the molarity of the  $\text{H}^+$  by using the pH.

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-1.11} = 0.0776247 \quad (19)$$

That would in turn be the molarity of the  $\text{H}_2\text{PO}_3^-$ . Without having to use an ICE table, we can figure out that the equilibrium molarity of the  $\text{H}_3\text{PO}_3$  will be the initial molarity minus the molarity of the  $\text{H}^+$ .

$$[\text{H}_3\text{PO}_3]_f = [\text{H}_3\text{PO}_3]_i - [\text{H}^+] = 0.464 - 0.078 = 0.386 \quad (20)$$

Use these and the molarity of the  $\text{H}_3\text{PO}_3$  to find the  $K_a$ .

$$K_a = \frac{[\text{H}^+][\text{H}_2\text{PO}_3^-]}{[\text{H}_3\text{PO}_3]} = \frac{0.0776247^2}{0.386} = \boxed{0.016} \quad (21)$$

## 28 Topic G Problem 28

Calculate the pH of a 0.27 M solution of  $\text{HCO}_2\text{H}$  (formic acid,  $K_a = 1.8 \times 10^{-4}$ ).

### 28.1 Solution

Use an ICE table to find the molarity of the  $\text{H}^+$ .

M	$\text{HCO}_2\text{H}$	$\rightleftharpoons$	$\text{H}^+$	+	$\text{CO}_2\text{H}^-$
I	0.27		0		0
C	$-x$		$+x$		$+x$
E	$0.27 - x$		$x$		$x$

Use this with the  $K_a$ . Solve for  $x$ .

$$K_a = \frac{[\text{H}^+][\text{CO}_2\text{H}^-]}{[\text{HCO}_2\text{H}]} = \frac{x^2}{0.27 - x} = 1.8 \times 10^{-4} \quad (22)$$

$$x^2 = 4.86 \times 10^{-5} - 1.8 \times 10^{-4}x \quad (23)$$

$$0 = x^2 + 1.8 \times 10^{-4}x - 4.86 \times 10^{-5} \quad (24)$$

$$x = 0.00688195 \text{ or } \underline{-0.00706195} \quad (25)$$

This value of  $x$  is the concentration of the  $\text{H}^+$ . Use this to find the pH.

$$\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10} x = -\log_{10} 0.00688195 = \boxed{2.16} \quad (26)$$

## 29 Topic G Problem 29

Determine which solution from each of the following pairs has the higher pH. You may need to refer to the  $K_a$  values in Table 12.4.2 of your textbook.

- a) 0.1 M HCl or 0.1 M HNO<sub>2</sub>
- b) 0.1 M HF or 0.1 M HClO
- c) 0.1 M HCN or 0.1 M NaCN

### 29.1 Solution (a)

The HCl is a strong acid, so practically all the HCl will dissociate. We will resultantly have a low pH. That means that the higher pH goes to the HNO<sub>2</sub>.

### 29.2 Solution (b)

HF has  $K_a = 3.5 \times 10^{-4}$ . HClO has  $K_a = 3.5 \times 10^{-8}$ . HClO has the lower  $K_a$ , which means it will have a higher pH. The answer is HClO.

### 29.3 Solution (c)

HCN has  $K_a = 6.2 \times 10^{-10}$ . The HCN will increase the concentration of the H<sup>+</sup>. NaCN has no  $K_a$  because it has no Hydrogen. However, the entirety of the NaCN will dissociate because of the Na<sup>+</sup> present. The CN<sup>-</sup> will then bond with the H<sup>+</sup> and lower the molarity of the H<sup>+</sup>. The HCN will result in a higher concentration of H<sup>+</sup>, while the NaCN will lower the concentration of the H<sup>+</sup>. Since pH is inversely (logarithmically) proportional to concentration, this means the NaCN will have the higher pH.

## 30 Topic G Problem 30

Each of the following species can function as an acid. Write the formula of its conjugate base.

- |                                      |                         |                            |
|--------------------------------------|-------------------------|----------------------------|
| a) $\text{HC}_3\text{H}_5\text{O}_3$ | c) $\text{H}_2\text{O}$ | e) $\text{H}_2\text{SO}_4$ |
| b) $\text{N}_2\text{H}_5^+$          | d) $\text{HCO}_3^-$     |                            |

### 30.1 Solution

- |                                       |                       |                     |
|---------------------------------------|-----------------------|---------------------|
| a/ $\text{C}_3\text{H}_5\text{O}_3^-$ | c/ $\text{OH}^-$      | e/ $\text{HSO}_4^-$ |
| b/ $\text{N}_2\text{H}_4$             | d/ $\text{CO}_3^{2-}$ |                     |

## 31 Topic G Problem 31

Each of the following species can function as a base. Write the formula of its conjugate acid.

- |                     |                         |
|---------------------|-------------------------|
| a) $\text{NH}_3$    | c) $\text{H}_2\text{O}$ |
| b) $\text{HSO}_3^-$ | d) $\text{PO}_4^{3-}$   |

### 31.1 Solution

- |                            |                           |
|----------------------------|---------------------------|
| a) $\text{NH}_4^+$         | c) $\text{H}_3\text{O}^+$ |
| b) $\text{H}_2\text{SO}_3$ | d) $\text{HPO}_4^{2-}$    |

## 32 Topic G Problem 32

Identify the acid and the base in each of the following reactions.

1.  $\text{HNO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \longrightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$
2.  $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{HSO}_4^-(\text{aq}) \longrightarrow \text{H}_3\text{PO}_4(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$

### 32.1 Solution (a)

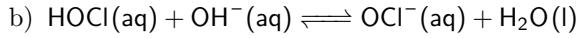
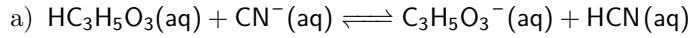
Acid:  $\text{HNO}_2$   
Base:  $\text{H}_2\text{O}$

### 32.2 Solution (b)

Acid:  $\text{HSO}_4^-$   
Base:  $\text{H}_2\text{PO}_4^-$

## 33 Topic G Problem 33

For each of the following reactions, tell whether the equilibrium will favor the reactants or the products. Use the  $K_a$  values in Table 12.4.2 of your textbook.



### 33.1 Solution (a)

$K_a$  for  $\text{HC}_3\text{H}_5\text{O}_3$  is  $1.4 \times 10^{-4}$ .  $K_a$  for  $\text{HCN}$  is  $6.2 \times 10^{-10}$ . The  $K_a$  for  $\text{HC}_3\text{H}_5\text{O}_3$  is greater, so the equilibrium will favor the products.

### 33.2 Solution (b)

$K_a$  for  $\text{HOCl}$  is  $3.5 \times 10^{-8}$ .  $K_a$  for  $\text{H}_2\text{O}$  is  $1.0 \times 10^{-14}$ . The  $K_a$  for  $\text{HOCl}$  is greater, so the equilibrium will favor the products.

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