Problem Set #15

CHEM101A: General College Chemistry

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23 Topic G Problem 23

The concentration of H^+ ions in a solution is 0.315 M.

a) Calculate the concentration of OH^- ions in this solution.

b) Where did these 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.

$$K_w = [\mathsf{H}^+][\mathsf{OH}^-] \tag{1}$$

$$[\mathsf{OH}^-] = \frac{K_w}{[\mathsf{H}^+]} = \frac{10^{-14}}{0.315} = 3.17 \times 10^{-14}\,\mathrm{M} = \boxed{3.2 \times 10^{-14}\,\mathrm{M}} \tag{2}$$

23.2 Solution (b)

The OH^- ions come from the surrounding water.

23.3 Solution (c)

Use the logarithm.

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

24 Topic G Problem 24

The pH of an HCl solution is 2.88.

a) What is the concentration of H^+ ions in this solution?

b) What is the concentration of OH^- ions in this solution?

c) What is the concentration of Cl^- ions in this solution?

24.1 Solution (a)

Use the exponential.

$$[\mathsf{H}^+] = 10^{-\mathrm{pH}} = 10^{-2.88} = \boxed{0.0013\,\mathrm{M}} \tag{4}$$

24.2 Solution (b)

The OH^- and H^+ concentrations are related.

$$K_w = [\mathsf{H}^+][\mathsf{OH}^-] \tag{5}$$

$$[\mathsf{OH}^-] = \frac{K_w}{[\mathsf{H}^+]} = \frac{10^{-14}}{0.0013} = 7.586 \times 10^{-12}\,\mathrm{M} = \boxed{7.6 \times 10^{-12}\,\mathrm{M}} \tag{6}$$

24.3 Solution (c)

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

25 Topic G Problem 25

Calculate the pH of a 7.4×10^{-4} M solution of $\mathsf{Ba(OH)_2}$.

25.1 Solution

Start by calculating the concentration of the $\mathsf{OH^-}$. It would be twice the concentration of the $\mathsf{Ba(OH)_2}$ because it is soluble in water.

$$[\mathsf{OH^-}] = 2 * 7.4 \times 10^{-4}\,\mathrm{M} = 1.48 \times 10^{-3}\,\mathrm{M} \tag{7}$$

This leads into a calculation of the concentration of the $\mathsf{H^+}$. We can use that to find the pH.

$$K_w = [\mathsf{H^+}][\mathsf{OH^-}] \tag{8}$$

$$[\mathsf{H^+}] = \frac{K_w}{[\mathsf{OH^-}]} = \frac{10^{-14}}{1.48 \times 10^{-3}\,\mathrm{M}} = 6.757 \times 10^{-12}\,\mathrm{M} \tag{9}$$

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

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) $\mathsf{H_2C_4H_4O_4}$

c) $\mathsf{NH_4^+}$

d) $\mathsf{H_2PO_4^-}$

26.1 Solution (a)

$$K_a = \frac{[\mathsf{H^+}][\mathsf{ClO^-}]}{[\mathsf{HClO}]} \tag{11}$$

$$\mathsf{HClO\,(aq)} \rightleftharpoons \mathsf{H^+(aq) + ClO^-(aq)} \tag{12}$$

26.2 Solution (b)

$$K_a = \frac{[\mathsf{H^+}][\mathsf{HC_4H_4O_4^-}]}{[\mathsf{H_2C_4H_4O_4}]} \tag{13}$$

$$\mathsf{H_2C_4H_4O_4\,(aq)} \rightleftharpoons \mathsf{H^+\,(aq) + HC_4H_4O_4^-\,(aq)} \tag{14}$$

26.3 Solution (c)

$$K_a = \frac{[\mathsf{H^+}][\mathsf{NH_3}]}{[\mathsf{NH_4^+}]} \tag{15}$$

$$\mathsf{NH_4^+\,(aq)} \rightleftharpoons \mathsf{H^+\,(aq) + NH_3\,(aq)} \tag{16}$$

26.4 Solution (d)

$$K_a = \frac{[\mathsf{H^+}][\mathsf{HPO_4^{2-}}]}{[\mathsf{H_2PO_4^-}]} \tag{17}$$

$$\mathsf{H_2PO_4^-\,(aq)} \rightleftharpoons \mathsf{H^+\,(aq) + HPO_4^{2-}\,(aq)} \tag{18}$$

27 Topic G Problem 27

The pH of a 0.464 M solution of phosphorous acid ($\mathsf{H_3PO_3}$) 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 $\mathsf{H^+}$ by using the pH.

$$[\mathsf{H^+}] = 10^{-\mathrm{pH}} = 10^{-1.11} = 0.0776247 \tag{19}$$

That would in turn be the molarity of the $\mathsf{H_2PO_3^-}$. Without having to use an ICE table, we can figure out that the equilibrium molarity of the $\mathsf{H_3PO_3}$ will be the nitial molarity minus the molarity of the $\mathsf{H^+}$.

$$[\mathsf{H_3PO_3}]_f = [\mathsf{H_3PO_3}]_i - [\mathsf{H^+}] = 0.464 - 0.078 = 0.386 \tag{20}$$

Use these and the molarity of the $\mathsf{H_3PO_3}$ to fnd the K_a.

$$K_a = \frac{[\mathsf{H^+}][\mathsf{H_2PO_3^-}]}{[\mathsf{H_3PO_3}]} = \frac{0.0776247^2}{0.386} = \boxed{0.016} \tag{21}$$

28 Topic G Problem 28

Calculate the pH of a 0.27 M solution of $\mathsf{HCO_2H}$ (formic acid, $K_a = 1.8 \times 10^{-4}$).

28.1 Solution

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

M	$\mathsf{HCO_2H}$ $\rightleftharpoons$	$\mathsf{H^+}$	+	$\mathsf{CO_2H^-}$
I	0.27	0		0
C	$-x$	$+x$		$+x$
E	$0.27 - x$	x		x

Use this with the K_a. Solve for x.

$$K_a = \frac{[\mathsf{H^+}][\mathsf{CO_2H^-}]}{[\mathsf{HCO_2H}]} = \frac{x^2}{0.27 - x} = 1.8 \times 10^{-4} \tag{22}$$

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

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

$$x = 0.00688195 \text{ or } \cancel{-0.00706195} \tag{25}$$

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

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

29 Topic G Problem 29

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

a) 0.1 M HCl or 0.1 M $\mathsf{HNO_2}$

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 $\boxed{\mathsf{HNO_2}}$.

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 $\boxed{\mathsf{HClO}}$.

29.3 Solution (c)

HCN has $K_a = 6.2 \times 10^{-10}$. The HCN will increase the concentration of the $\mathsf{H^+}$. NaCN has no K_a because it has no Hydrogen. However, the entirety of the NaCN will dissociate because of the $\mathsf{Na^+}$ present. The $\mathsf{CN^-}$ will then bond with the $\mathsf{H^+}$ and lower the molarity of the $\mathsf{H^+}$. The HCN will result in a higher concentration of $\mathsf{H^+}$, while the NaCN will lower the concentration of the $\mathsf{H^+}$. Since pH is inversely (logarithmically) proportional to concentration, this means the $\boxed{\mathsf{NaCN}}$ 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) $HC_3H_5O_3$
b) $N_2H_5^+$
c) H_2O
d) HCO_3^-
e) H_2SO_4

30.1 Solution

a/ $C_3H_5O_3^-$
b/ N_2H_4
c/ OH^-
d/ CO_3^{2-}
e/ HSO_4^-

31 Topic G Problem 31

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

a) NH_3
b) HSO_3^-
c) H_2O
d) PO_4^{3-}

31.1 Solution

a) NH_4^+
b) H_2SO_3
c) H_3O^+
d) HPO_4^{2-}

32 Topic G Problem 32

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

1. $HNO_2(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + NO_2^-(aq)$
2. $H_2PO_4^-(aq) + HSO_4^-(aq) \longrightarrow H_3PO_4(aq) + SO_4^{2-}(aq)$

32.1 Solution (a)

Acid: HNO_2
Base: H_2O

32.2 Solution (b)

Acid: HSO_4^-
Base: $H_2PO_4^-$

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.

a) $\mathsf{HC_3H_5O_3(aq) + CN^-(aq) \rightleftharpoons C_3H_5O_3{}^-(aq) + HCN(aq)}$

b) $\mathsf{HOCl(aq) + OH^-(aq) \rightleftharpoons OCl^-(aq) + H_2O(l)}$

33.1 Solution (a)

K_a for $\mathsf{HC_3H_5O_3}$ is 1.4×10^{-4}. K_a for HCN is 6.2×10^{-10}. The K_a for $\mathsf{HC_3H_5O_3}$ is greater, so the equilibrium will favor the products.

33.2 Solution (b)

K_a for HOCl is 3.5×10^{-8}. K_a for $\mathsf{H_2O}$ is 1.0×10^{-14}. The K_a for HOCl is greater, so the equilibrium will favor the products.

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