Exercise 15.1a
*p*H & *p*OH - Answers

Name: ______________________

Date:_________________ Per:________

In any aqueous solution the water present will self-ionize to form hydronium (H_3O^+) and hydroxide (OH^-) ions according to the equation below. In pure water these concentrations must be equal due to the mole ratio in which they form during ionization. The amounts produced of each ion in pure water at 25°C are listed below the ionization equation. As the concentration of either ion changes, the concentration of the other changes to maintain equilibrium. *p*H and *p*OH are based on these concentrations. As *p*H increases, *p*OH decreases and vice versa.

$$H_2O(l) + H_2O(l) \rightleftarrows H_3O^+(aq) + OH^-(aq)$$

1.0 x 10⁻⁷ M *1.0 x 10⁻⁷ M* ☜ *Concentration in pure water*

In this chapter and those that follow, the symbols [ ] placed around a formula or number mean "the molar concentration of".

DIRECTIONS: Complete the following in the spaces provided:

1. $K_w = [H_3O^+][OH^-] =$ [1.0 x 10^{-7}] [1.0 x 10^{-7}] = 1.0 x 10^{-14}

2. Complete the formulas for calculating the following from $[OH^-]$ & $[H_3O^+]$ concentrations:

   $[H_3O^+] =$ 1.0 x 10^{-14} / $[OH^-]$ $[OH^-] =$ 1.0 x 10^{-14} / $[H_3O^+]$

3. What type of relationship exists between the $[H_3O^+]$ and $[OH^-]$ in an aqueous solution? ___inversely proportional____.

4. If the concentration of $[H_3O^+]$ in an aqueous solution doubles the $[OH^-]$ ___is halved__.

5. Complete the formulas for calculating the following from $[H_3O^+]$ & $[OH^-]$ concentrations:

   *p*H = −log $[H^+]$ *p*OH = −log $[OH^-]$

6. Without using a calculator, find the:

	$[H_3O^+]$ = 1.0 x 10^{-5} *M*	$[OH^-]$ = 1.0 x 10^{-3} *M*	$[OH^-]$ = 1.0 x 10^{-11} *M*	$[H_3O^+]$ = 1.0 x 10^{-8} *M*
*p*H of a solution with:	5	11	3	8
*p*OH of a solution with:	9	3	11	6
This solution is:	acid base	acid base	acid base	acid base

7. Without using a calculator, find the:

	*p*H = 4	*p*OH = 12	*p*H = 1	*p*OH = −1
$[H_3O^+]$ in a solution with:	1.0 x 10^{-4}	1.0 x 10^{-2}	1.0 x 10^{-1}	1.0 x 10^{-15}
$[OH^-]$ in a solution with:	1.0 x 10^{-10}	1.0 x 10^{-12}	1.0 x 10^{-13}	1.0 x 10^{1}
This solution is:	acid base	acid base	acid base	acid base

8. Complete the formulas for calculating the following from pH & pOH:

   $[H_3O^+] =$ antilog(−*p*H) $[OH^-] =$ antilog(−*p*OH)

9. Complete the formulas for calculating the following from pOH & pH:

   *p*H = 14.0 − *p*OH   *p*OH = 14.0 − *p*H

(OVER)

Revised: 2020-05-04

Answers: 18) 1.34 x 10^{-4} 19) 1.6 x 10^{-6}

Exercise 15.1a
*p*H & *p*OH - Answers

Name: ______________________

Date:________________ Per:________

DIRECTIONS: Using the logarithm/antilog functions of a calculator, complete the following:

	$[H^+]$	*p*H	$[OH^-]$	*p*OH	Acid/Base
10.	3.50×10^{-3} *M*	-log $(3.50 x 10^{-3})$ = 2.456	$1.0 x 10^{-14}/3.50 x 10^{-3} = 2.857 x 10^{-12}$	-log$(2.857 x 10^{-12})$ = 11.544	Acid
11.	antilog(–5.30) = $5.01 x 10^{-6}$	5.30	$1.0 x 10^{-14}/5.01 x 10^{-6} = 2.0 x 10^{-9}$	14.00 – 5.30 = 8.70	Acid
12.	$1.0 x 10^{-14}/6.70 x 10^{-3} = 1.492 x 10^{-12}$	-log$(1.492 x 10^{-12})$ = 11.826	6.70×10^{-3} *M*	-log$(6.70 x 10^{-3})$ = 2.174	Base
13.	$1.0 x 10^{-14}/2.0 x 10^{-10} = 5.0 x 10^{-5}$	14.00 – 9.70 = 4.30	antilog(–9.70) = $2.0 x 10^{-10}$	9.70	Acid
14.	4.50×10^{-9} *M*	-log$(4.50 x 10^{-9})$ = 8.346	$1.0 x 10^{-14}/4.50 x 10^{-9} = 2.222 x 10^{-6}$	-log$(2.222 x 10^{-6})$ = 5.653	Base
15.	antilog(–11.2) = $6 x 10^{-12}$ *	11.2	$1.0 x 10^{-14}/6.31 x 10^{-12} = 2 x 10^{-3}$ *	14.0 – 11.2 = 2.8	Base
16.	$1.0 x 10^{-14}/9.10 x 10^{-11} = 1.098 x 10^{-4}$	-log$(1.098 x 10^{-4})$ = 3.959	9.10×10^{-11} *M*	-log$(9.10 x 10^{-11})$ = 10.040	Acid
17.	antilog(–12.60) = $2.5 x 10^{-13}$	14.00 – 1.40 = 12.60	antilog(–1.40) = 0.0398	1.40	Base

* Nasty rounding issues due to sig figs.

DIRECTIONS: Using the logarithm/antilog functions of a calculator, complete the following:

18. Uric acid is a chemical created when the body breaks down substances called purines. A 0.128 *M* solution of uric acid ($HC_5H_3N_4O_3$) has a *p*H of 2.39. Calculate the K_a of uric acid.

$HC_5H_3N_4O_3(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_5H_3N_4O_3^-(aq)$

$[H_3O^+]_{equil}$ = antilog(−2.39) = $4.07 x 10^{-3}$ *M*

Reaction:	$HC_5H_3N_4O_3(aq)$	+	$H_2O(l)$	$\rightleftarrows$	$H_3O^+(aq)$	+	$C_5H_3N_4O_3^-(aq)$	
Initial:	[0.128]		na		0		0	Picture the reaction completely shifted to the left - there would only be $HC_5H_3N_4O_3(aq)$ and no products.
Change:	− x		na		+ x		+ x	As the reaction proceeds $HC_5H_3N_4O_3(aq)$ is consumed and produces equal amounts of each product. (1:1 mole ratio)
Equilibrium:	$[0.128 - 4.07 x 10^{-3}]$		na		$[4.07 x 10^{-3}]$		$[4.07 x 10^{-3}]$	The amount of H_3O^+ (x) can be found based on the *p*H and substituted for the changes that occurred.

$$K_a = \frac{[H_3O^+][C_5H_3N_4O_3^-]}{[HC_5H_3N_4O_3]} = \frac{[4.07 x 10^{-3}]\,[4.07 x 10^{-3}]}{[0.01239]} = 1.336 \text{ x } 10^{-3}$$

$\boxed{1.34 \text{ x } 10^{-3}}$

19. Codeine ($C_{18}H_{21}NO_3$) is a weak organic base. A $5.0 \text{ x } 10^{-3}$ M solution of codeine has a *p*H of 9.95. Calculate the value of K_b for this substance.

$C_{18}H_{21}NO_3(aq) + H_2O(l) \rightleftarrows OH^-(aq) + HC_{18}H_{21}NO_3^+(aq)$

If pH = 9.95, then *(14.00-9.95 = 4.05)* pOH = 4.05

$[OH^-]_{equil}$ = antilog(−4.05) = $8.91 x 10^{-5}$ *M*

Reaction:	$C_{18}H_{21}NO_3$	+	$H_2O(l)$	$\rightleftarrows$	$OH^-(aq)$	+	$HC_{18}H_{21}NO_3^+$ (aq)	
Initial:	$[5.0 \text{ x } 10^{-3}]$		na		0		0	Picture the reaction completely shifted to the left - there would only be $C_{18}H_{21}NO_3$ (aq) and no products.
Change:	− x		na		+ x		+ x	As the reaction proceeds $C_{18}H_{21}NO_3$ (aq) is consumed and produces equal amounts of each product. (1:1 mole ratio)
Equilibrium:	$[5.0 \text{ x } 10^{-3} - 8.91 x 10^{-5}]$		na		$[8.91 x 10^{-5}]$		$[8.91 x 10^{-5}]$	The amount of OH^- (x) can be found based on the *p*H (really *p*OH) and substituted for the changes that occurred.

$$K_b = \frac{[OH^-][HC_{18}H_{21}NO_3^+]}{[C_{18}H_{21}NO_3]} = \frac{[8.91 x 10^{-5}]\,[8.91 x 10^{-5}]}{[4.91 \text{ x } 10^{-3}]} = 1.61 \text{ x } 10^{-6}$$

$\boxed{1.6 \text{ x } 10^{-6}}$

Answers: 18) $1.34 \text{ x } 10^{-4}$ 19) $1.6 \text{ x } 10^{-6}$