NOTES: Rainbow Demo, K_w , pH and pOH

Name ______________________________
Period ____ Date ______________

Part I: K_w and the relationship between H_3O^+ and OH^-

A) An introduction: Rainbow Demonstration

Solution 1: Start with 0.1 M HCl (aq) containing Universal Indicator. It is red. Why?______________

$HCl\ (aq) + H_2O\ (\ell) \longrightarrow$ _________ + _________

Solution 2: Saturated Na_2CO_3 (aq) with universal indicator. It is violet. Why? ___________________

$Na_2CO_3\ (aq) \xrightarrow{H_2O}$ _________ + _________

___________ + $H_2O \rightleftharpoons$ _________ + __________

Now, saturated Na_2CO_3 (aq) is added to HCl (aq). An acid-base reaction occurs.

____________ + ___________ $\rightleftharpoons$

acid *base*

RED ORANGE	Excess H_3O^+; Solution is Acidic (pH < 7): $[H_3O^+]$ is **(high, low)**; $[OH^-]$ is **(high, low)**
GREEN	Same moles of H_3O^+ and CO_3^{2-} ; Soln is Neutral (pH = 7) $[H_3O^+]$ and $[OH^-]$ are _________________
BLUE VIOLET	Excess CO_3^{2-}; Solution is Basic (pH > 7): $[H_3O^+]$ is **(high, low)**; $[OH^-]$ is **(high, low)**

Thus, the relationship between $[H_3O^+]$ and $[OH^-]$ is **(direct, inverse)**.

B) Concept of Self-Ionization of Water (Concept of K_w: The equilibrium constant for water)

$H_2O\ (\ell) + H_2O\ (\ell) \rightleftharpoons$ _________ + __________

Acid *Base*

$K_w = [H_3O^+][OH^-] = 1.0\times10^{-14}$

Now, use Le Châtelier's Principle:

- If $[H_3O^+]$, an acid, is added to water, the equilibrium shifts to the ___________ which causes the $[OH^-]$ to ______________________
- If $[OH^-]$, a base, is added to water, the equilibrium shifts to the ___________ which causes the $[H_3O^+]$ to _________________________

1) **Given either $[H_3O^+]$ or $[OH^-]$, calculate the value asked. Then, determine if the solution is acidic, neutral or basic and circle A, N or B.**

a) $[H_3O^+] = 0.1$ M $[OH^-] = ?$ A, N, B ?
(Acidic, neutral, basic?)

d) $[H_3O^+] = 8.9 \times 10^{-9}$ M $[OH^-] = ?$ A, N, B ?

b) $[OH^-] = 0.0001$ M $[H_3O^+] = ?$ A, N, B ?

e) 0.025 M KOH $[H_3O^+] = ?$ A, N, B ?

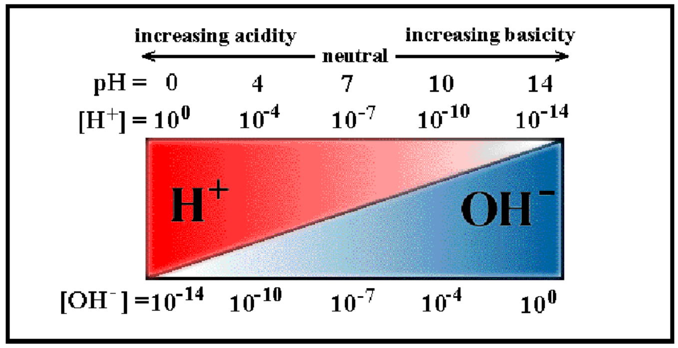
c) 0.001 M HCl $[OH^-] = ?$ A, N, B ?

f) 0.0075 M $Ca(OH)_2$ $[H_3O^+] = ?$ A, N, B ?

Part II: pH and pOH

A) pH: Power of hydronium ion concentration

$pH = -\log [H_3O^+]$; $[H_3O^+] = 10^{-pH}$



2) **Given the following $[H_3O^+]$ values, determine the pH of each solution. Circle either A, N, B.**
Note: Determining sig figs is tricky when dealing with logs. The rule is that the number of sig figs of the $[H_3O^+]$ value is equal to the number of decimal places in the pH value.

a) $[H_3O^+] = 1.0 \times 10^{-3}$ M
pH = ________ A, N, B?

b) $[H_3O^+] = 1.0 \times 10^{-7}$ M
pH = ________ A, N, B?

c) $[H_3O^+] = 1.0 \times 10^{-12}$ M
pH = _________ A, N, B?

d) $[H_3O^+] = 6.5 \times 10^{-11}$ M
pH = _________ A, N, B?

e) $[H_3O^+] = 11.5 \times 10^{-6}$ M
pH = ________ A, N, B?

f) 12 M HBr
pH = _________ A, N, B?

3) **Given the following pH values, determine the $[H_3O^+]$ for the solutions. Circle either A, N, B.**

a) pH = 11.00 A, N, B?
$[H_3O^+]$ = _______________

b) pH = 3.87 A, N, B?
$[H_3O^+]$ = _______________

c) pH = 8.40 A, N, B?
$[H_3O^+]$ = _______________

4) **Solution A has a pH of 2 and solution B has a pH of 5.** Which solution has a higher concentration of $[H_3O^+]$?_______ How much stronger is that solution than the other solution? Explain your reasoning.

B) Relationships between pH, pOH, $[H_3O^+]$ and $[OH^-]$

Similarly to pH, pOH is the power of hydroxide ion. Thus, $pOH = -\log [OH^-]$ & $[OH^-] = 10^{-pOH}$.
Similarly, $pK_w = -\log K_w$. We already know that $K_w = [H_3O^+][OH^-] = 1.0\times10^{-14}$. Thus, if you take the − log of both sides, one gets…

$$-\log K_w = -\log [H_3O^+] + (-\log [OH^-]) = -\log (1.0\times10^{-14})$$
$$pK_w = pH + pOH = 14.00$$

Thus, we now have 6 equations we can use to convert between pH, pOH, $[H_3O^+]$ and $[OH^-]$. To review, those equations are as follows: **$K_w = [H_3O^+][OH^-] = 1.0\times10^{-14}$ $pH + pOH = 14.00$**

$pH = -\log [H_3O^+]$ $[H_3O^+] = 10^{-pH}$ $pOH = -\log [OH^-]$ $[OH^-] = 10^{-pOH}$

5) Calculate the pH and pOH of the following solutions of strong acids and bases.

a) 1.0×10^{-4} M HI

b) 0.050 M HNO_3

c) 1.0×10^{-3} M KOH

d) 2.4×10^{-5} M $Mg(OH)_2$

6) Use what is given to determine any missing values.

a) **$[H_3O^+]$= 1.0 × 10^{-9} M**	$[OH^-]$=	pH=	pOH=	A, N, B
b) $[H_3O^+]$=	$[OH^-]$=	pH=	**pOH= 2.0**	A, N, B
c) $[H_3O^+]$=	**$[OH^-]$= 4.5×10^{-8} M**	pH=	pOH=	A, N, B
d) $[H_3O^+]$=	$[OH^-]$=	**pH= 10.76**	pOH=	A, N, B

Answers: 1a) 1 × 10^{-13} M; 1b) 1 × 10^{-10} M; 1c) 1 × 10^{-11} M; 1d) 1.1 × 10^{-6} M; 1e) 4.0 × 10^{-13} M; 1f) 6.7 × 10^{-13} M; 2a) 3.00; 2b) 7.00; 2c) 12.00; 2d) 10.19; 2e) 4.939; 2f) –1.08; 3a) 1.0 × 10^{-11}; 3b) 1.3 × 10^{-4} M; 3c) 4.0 × 10^{-9} M; 5a) pH = 4.00, pOH = 10.00; 5b) pH = 1.30, pOH = 12.70; 5c) pOH = 3.00, pH = 11.00; 5d) pOH = 4.32, pH = 9.68; 6a) 1.0 × 10^{-5} M, 9, 5; 6b) 1.0 × 10^{-12} M, 1.0 × 10^{-2} M, 12; 6c) 2.2 × 10^{-7} M, 6.65, 7.35; 6d) 1.7 × 10^{-11} M; 5.8 × 10^{-4} M, 3.24