Dougherty Valley • AP Chemistry Name_____

Acid Base Solutions

Period _____ Date _____

UNIT TEST – PRACTICE

Part 1 – Multiple Choice

You should allocate 30 minutes to finish this portion of the test. No calculator should be used. A periodic table and data table will be provided. Select the answer that best responds to each question.

1. Consider the equilibrium,
   $HF(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + F^-(aq)$.
   Which pair of substances makes up a conjugate acid-base pair?
   (A) H_2O and F^-
   (B) H_2O and H_3O^+
   (C) H_3O^+ and F^-
   (D) HF and H_2O

2. A solution of $NH_3(aq)$ and $H_2O(l)$ turns universal indicator blue (basic). In this situation, which of the following statements is true?
   (A) H_2O is a base because it accepts a proton from NH_3.
   (B) H_2O is amphoteric because it both accepts and donates a proton.
   (C) H_2O is an acid because it donates a proton to NH_3.
   (D) NH_3 is a base because it donates a proton to H_2O.

3. Methylamine, CH_3NH_2, is a weak base. When it reacts with water, the products include:
   (A) CH_3NH
   (B) $CH_3NH_3^+$
   (C) H_3O^+
   (D) NH_4^+

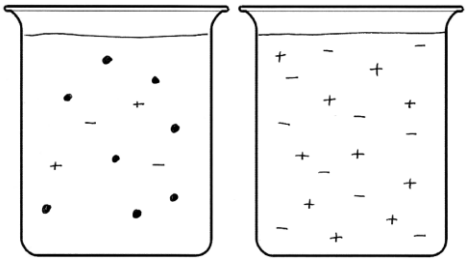
4. A 10.0 mL sample of a 0.010 M HCl solution was obtained. What is the pH of the solution if 90.0 mL of water was added to the solution?
   (A) 1.0
   (B) 2.0
   (C) 3.0
   (D) 4.0

5. At 0ºC, $K_w = 0.1 \times 10^{-14}$. What is the pH of a glass of pure ice water at 0ºC?
   (A) 8.0
   (B) 7.5
   (C) 7.0
   (D) 6.5

6. Milk of Magnesia, magnesium hydroxide, has low solubility in water and is used to neutralize excess stomach acid, hydrochloric acid. Which equation correctly represents the net reaction when milk of magnesia reaches the stomach?
   (A) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
   (B) $Mg(OH)_2(s) + 2HCl(aq) \rightarrow 2H_2O(l) + MgCl_2(s)$
   (C) $Mg^{2+}(aq) + 2Cl^-(aq) \rightarrow MgCl_2(s)$
   (D) **$Mg(OH)_2(s) + 2H^+(aq) \rightarrow 2H_2O(l) + Mg^{2+}(aq)$**

7. Which one of the following substances is ***not*** amphoteric/amphiprotic?
   (A) $H_2PO_3^-$
   (B) H_2O
   (C) HCO_3^-
   (D) **NH_4^+**

8. 0.200 M solutions with two different substances were prepared, and are represented by these particulate drawings:



The representation on the right best illustrates which of the following substances?
(A) HF(aq)
(B) NaOH(aq)
(C) H_2S(aq)
(D) NH_3(aq)

9. A 0.10 M sample of a weak base was placed in water. The pH of the solution was 11.0, when tested. What is the value of the K_b for the base?
(A) 1.0×10^{-1}
(B) 1.0×10^{-3}
(C) 1.0×10^{-5}
(D) 1.0×10^{-7}

10. How do the amounts of these species compare when solid $NaNO_2$ is added to water?
K_a of $HNO_2 = 4.0 \times 10^{-4}$.
(A) $H^+ < HNO_2 < OH^- < NO_2^- < Na^+$
(B) $H^+ < HNO_2 = OH^- < NO_2^- < Na^+$
(C) $HNO_2 < H^+ < OH^- < NO_2^- = Na^+$
(D) $HNO_2 < H^+ = OH^- < NO_2^- = Na^+$

11. Suppose we have a 0.10 M HF solution. Which of the following, when added, would result in the lowest $[F^-]$?
(A) Nothing else added
(B) 0.0010 mol HCl
(C) 0.0010 mol KF
(D) 0.0010 mol KOH

12. 0.100 M of which of the following would have the lowest pH?
(A) Chloroacetic acid, $K_a = 1.4 \times 10^{-3}$
(B) 3-chlorobenzoic acid, $K_a = 1.5 \times 10^{-4}$
(C) Benzoic acid, $K_a = 6.5 \times 10^{-5}$
(D) Ascorbic acid, $K_a = 8.0 \times 10^{-5}$

13. Of the following salts, which one forms a 0.1 M solution with the lowest pH?
(A) KBr
(B) $KC_2H_3O_2$
(C) $NaNO_2$
(D) NH_4Cl

14. Carbonic acid, H_2CO_3, is a diprotic acid. Which equation correctly shows the dissociation of carbonic acid's second proton?
(A) $H_2CO_3(aq) \leftrightarrows 2H^+(aq) + CO_3^{2-}(aq)$
(B) $H_2CO_3(aq) \leftrightarrows H_2O(g) + CO_2(g)$
(C) $HCO_3^- + H_2O(l) \leftrightarrows H_3O^+(aq) + CO_3^{2-}(aq)$
(D) $HCO_3^-(aq) + H_2O(l) \leftrightarrows H_2CO_3(aq) + OH^-(aq)$

15. Consider the following acids:
$HClO_3$, $HClO_4$, HIO_3, HIO_2
When listed from **weakest** to **strongest**, the order would be:
(A) $HClO_3 < HClO_4 < HIO_2 < HIO_3$
(B) $HClO_4 < HClO_3 < HIO_3 < HIO_2$
(C) $HIO_2 < HClO_3 < HIO_3 < HClO_4$
(D) $HIO_2 < HIO_3 < HClO_3 < HClO_4$

Part 2 – Free Response

You should allocate 30 minutes to finish this portion of the test. You may use a scientific calculator. A periodic table and data table will be provided. Respond to each part of the questions completely. Be sure to show your work clearly for questions that involve calculations.

16. Methylamine, CH_3NH_2, is a weak base, and has a base ionization constant, K_b, of 4.17×10^{-4} at 25°C

a. Consider the ionization of methylamine when dissolved in water.

i. Write the chemical equation for this process.

$CH_3NH_2 + H_2O \leftrightarrows CH_3NH_3^+ + OH^-$

ii. Identify a Brønsted-Lowry conjugate acid-base pair in this reaction.

Acid: H_2O, Base: OH^- OR Acid: $CH_3NH_3^+$, Base: CH_3NH_2

iii. A sample of methylamine has a pH of 12.26. What is the molar concentration of methylamine in this sample?

pOH = 14.00 – 12.26 = 1.74

$[OH^-] = 10^{-1.74} = 1.8 \times 10^{-2}$ M = $[CH_3NH_3^+]$

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = \frac{(1.8 \times 10^{-2})(1.8 \times 10^{-2})}{[CH_3NH_2]} = 4.17 \times 10^{-4}$$

$[CH_3NH_2] = 0.79$ M (This is a reverse ICE Box question.)

b. 0.100 mol KOH was added to 1.00 L of a 0.200 M CH_3NH_2 solution. What is the pH of this solution?

$CH_3NH_2 + H_2O \leftrightarrows CH_3NH_3^+ + OH^-$ (WB + SB)

	CH_3NH_2	$CH_3NH_3^+$	OH^-
I	0.200	0	0.100
C	−x	+x	+x
E	0.200−x	x	0.10+x

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = \frac{(x)(0.10 + x)}{(0.200 - x)} = 4.17 \times 10^{-4}$$

x = 0.000834 M

$[OH^-]$ = 0. 100 + 0.000834 = 0.101 M pOH = 0.996 pH = 13.004

c. 50.00 g of methylammonium chloride, CH_3NH_3Cl, was dissolved in water to prepare a 150.0 mL solution.

i. Write the net ionic equation for this process.

$CH_3NH_3^+ + H_2O \leftrightarrows CH_3NH_2 + H_3O^+$

ii. Find the value of the acid ionization constant, K_a, of the methylammonium ion, $CH_3NH_3^+$.

$$K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{4.17 \times 10^{-4}} = 2.4 \times 10^{-11}$$

iii. Calculate the pH of this solution.

Molar Mass of CH_3NH_3Cl = 67.52 g/mol

$$[CH_3NH_3^+] = \frac{50.00\text{ g}}{0.1500\text{ L}}\left(\frac{1\text{ mol}}{67.52\text{ g}}\right) = 4.93\text{ M}$$

$CH_3NH_3^+ + H_2O \leftrightarrows CH_3NH_2 + H_3O^+$

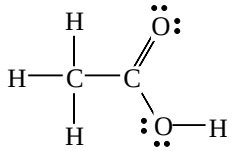
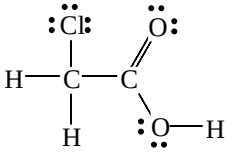
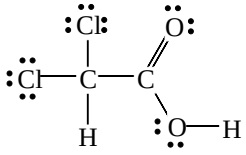
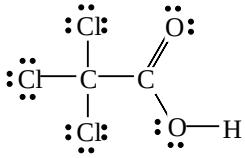
	$CH_3NH_3^+$	CH_3NH_2	H_3O^+
I	4.93	0	0
C	−x	+x	+x
E	4.93−x	x	x

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} = \frac{(x)(x)}{(4.93 - x)} = 2.4 \times 10^{-11}$$

$x = 1.1 \times 10^{-5}$ M

$pH = -\log(1.1 \times 10^{-5}) = 4.96$

17. Consider the following acids:

Acetic acid CH_3COOH	Chloroacetic acid $CH_2ClCOOH$	Dichloroacetic acid $CHCl_2COOH$	Trichloroacetic acid CCl_3COOH
			
$pK_a = 4.76$	$pK_a = 2.86$	$pK_a = 1.35$	$pK_a = 0.66$

a. Which is the strongest among the four acids? Justify your answer quantitatively.

Trichloroacetic acid (CCl_3COOH) is the strongest acid because it has the most negative pK_a (which is the largest K_a).

b. Provide a reason using the molecular structure to explain why the acid in part a. is the strongest.

The increased Cl polarizes the electrons away from and weakens the O−H bond, so H^+ is more easily removed resulting in a stronger acid.

c. Consider the salts $NaCH_3COO$ and $NaCCl_3COO$. If 0.100 mol of each were used to make a 1.00 L solution, which would have the lower pH? Explain.

$NaCCl_3COO$ has a lower pH.

The Na^+ ions are neutral. Since CCl_3COOH is a stronger acid than CH_3COOH, its conjugate base CCl_3COO^- is a weaker base than CH_3COO^-, resulting in lower pH.