acidq2

Name

1. A solution containing HCl and the weak acid $HClO_2$ has a pH of 2.4. Enough KOH(*aq*) is added to the solution to increase the pH to 10.5. The amount of which of the following species increases as the KOH(*aq*) is added?

(A) $Cl^-(aq)$

(B) $H^+(aq)$

(C) $ClO_2^-(aq)$

(D) $HClO_2(aq)$

2. A solution is prepared by adding 100 mL of 1.0 *M* $HC_2H_3O_2(aq)$ to 100 mL of 1.0 *M* $NaC_2H_3O_2(aq)$. The solution is stirred and its pH is measured to be 4.73. After 3 drops of 1.0 *M* HCl are added to the solution, the pH of the solution is measured and is still 4.73. Which of the following equations represents the chemical reaction that accounts for the fact that acid was added but there was no detectable change in pH?

(A) $H_3O^+(aq) + OH^-(aq) \rightarrow 2\ H_2O(l)$

(B) $H_3O^+(aq) + Cl^-(aq) \rightarrow HCl(g) + H_2O(l)$

(C) $H_3O^+(aq) + C_2H_3O_2^-(aq) \rightarrow HC_2H_3O_2(aq) + H_2O(l)$

(D) $H_3O^+(aq) + HC_2H_3O_2(aq) \rightarrow H_2C_2H_3O_2^+(aq) + H_2O(l)$

acidq2

3.

$$H_3PO_4 \rightleftarrows H^+ + H_2PO_4^- \qquad K_{a_1} = 7.2 \times 10^{-3}$$

$$H_2PO_4^- \rightleftarrows H^+ + HPO_4^{2-} \qquad K_{a_2} = 6.3 \times 10^{-8}$$

$$HPO_4^{2-} \rightleftarrows H^+ + PO_4^{3-} \qquad K_{a_3} = 4.5 \times 10^{-13}$$

A solution is prepared by mixing 50 mL of 1 M NaH_2PO_4 with 50 mL of 1 M Na_2HPO_4. On the basis of the information above, which of the following species is present in the solution at the lowest concentration?

(A) Na^+

(B) HPO_4^{2-}

(C) $H_2PO_4^-$

(D) PO_4^{3-}

---

4. A student pours a $10.0\ \mathrm{mL}$ sample of a solution containing $HC_2H_3O_2$ ($\mathrm{p}K_a = 4.8$) and $NaC_2H_3O_2$ into a test tube. The student adds a few drops of bromocresol green to the test tube and observes a yellow color, which indicates that the pH of the solution is less than 3.8. Based on this result, which of the following is true about the relative concentrations of $HC_2H_3O_2$ and $NaC_2H_3O_2$ in the original solution?

(A) $[HC_2H_3O_2] > [NaC_2H_3O_2]$

(B) $[HC_2H_3O_2] = [NaC_2H_3O_2]$

(C) $[HC_2H_3O_2] < [NaC_2H_3O_2]$

(D) The relative concentrations cannot be determined without knowing the value of $\mathrm{p}K_b$ for $C_2H_3O_2^-$.

---

acidq2

5. $HCN(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + CN^-(aq) \qquad K_a = \frac{[H_3O^+][CN^-]}{[HCN]} = 6.2 \times 10^{-10}$

The equilibrium reaction shown above represents the partial ionization of the weak acid $HCN(aq)$. A $0.200\ M$ $HCN(aq)$ solution has a $pH \approx 4.95$. If 0.05 g (0.010 mol) of $NaCN(s)$ is added to 100 mL of $0.200\ M$ $HCN(aq)$, which of the following explains how and why the pH of the solution changes?

(A) The pH will be higher than 4.95 because adding CN^- will disrupt the equilibrium, resulting in an increased production of HCN that decreases the concentration of H_3O^+.

(B) The pH will be lower than 4.95 because adding CN^- will disrupt the equilibrium, resulting in an increased production of HCN that decreases the concentration of H_3O^+.

(C) The pH will be higher than 4.95 because CN^- is a strong base that can neutralize HCN.

(D) The pH will remain close to 4.95 because the K_a is so small that hardly any products form.

---

6. $CH_3COOH(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + CH_3COO^-(aq)$
$CH_3COO^-(aq) + H_2O(l) \rightleftarrows CH_3COOH(aq) + OH^-(aq)$
$2\ H_2O(l) \rightleftarrows H_3O^+(aq) + OH^-(aq)$

A buffer solution is made up of acetic acid (CH_3COOH) and sodium acetate ($NaCH_3COO$). The major equilibria in the buffer system are represented above. Which of the following equilibria could be used to support the claim that the addition of a small amount of $NaOH$ to the buffer will result in only a very small change in pH?

(A) $CH_3COOH(aq) + CH_3COO^-(aq) \rightleftarrows CH_3COO^-(aq) + CH_3COOH(aq)$

(B) $CH_3COOH(aq) + OH^-(aq) \rightleftarrows CH_3COO^-(aq) + H_2O(l)$

(C) $H_3O^+(aq) + OH^-(aq) \rightleftarrows 2\ H_2O(l)$

(D) $CH_3COOH(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + CH_3COO^-(aq)$

---

7. Caffeine ($C_8H_{10}N_4O_2$) is a weak base with a K_b value of 4 x 10^{-4}. The pH of a 0.01 *M* solution of caffeine is in the range of

acidq2

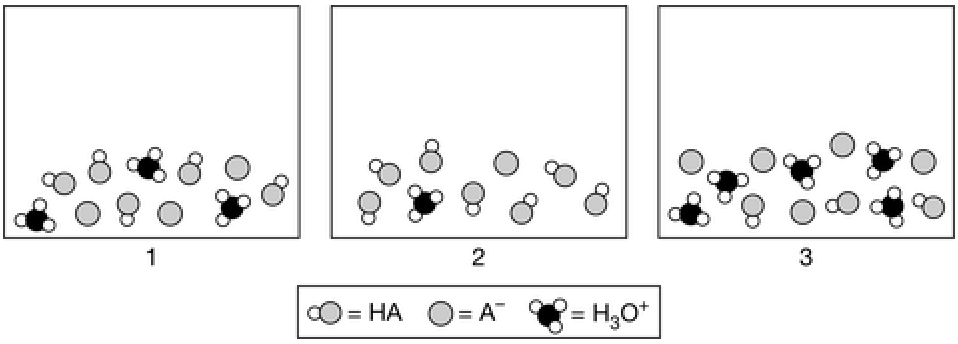
(A) 2–3

(B) 5–6

(C) 7–8

(D) 11–12

8.



Acid
HIO
HBrO
HClO

Each particle diagram shown is a representation of an aqueous solution of one of the acids listed in the table. The molarity of the acids in the solutions is the same. Based on the information, which particle diagram best corresponds to the indicated acid?

(A) Diagram 1 corresponds to HClO.

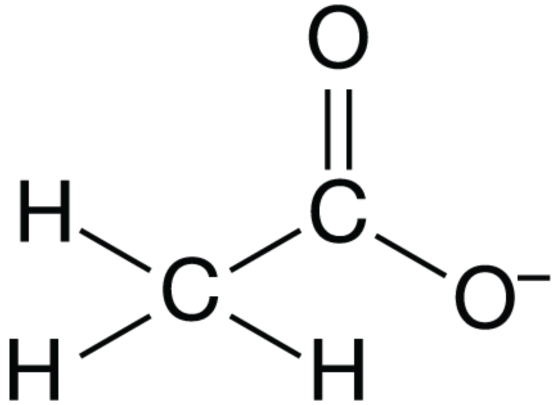
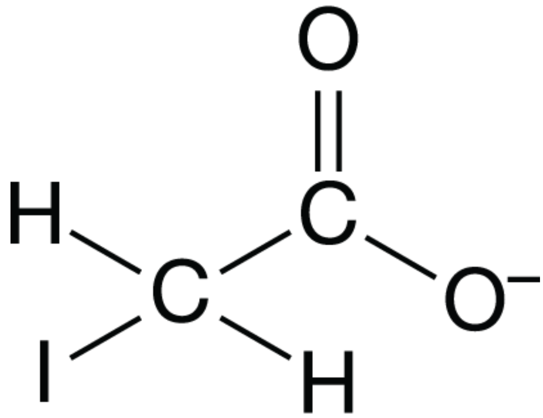
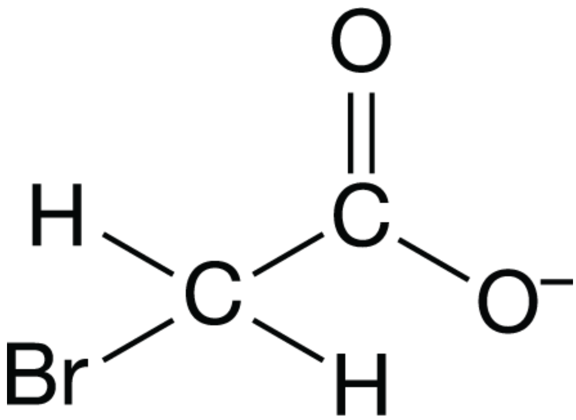
(B) Diagram 2 corresponds to HClO.

(C) Diagram 2 corresponds to HIO.

(D) Diagram 3 corresponds to HBrO.

acidq2

9.

Structure	K_b
	5.7×10^{-10}
	1.5×10^{-11}
	7.9×10^{-12}

$B(aq) + H_2O(l) \rightleftarrows HB^{+}(aq) + OH^{-}(aq) \qquad K_b = \frac{[HB^{+}][OH^{-}]}{[B]}$ The table above provides the chemical structures for weak bases and their ionization constants, K_b. Based on the data, which of the following provides the best reason for the trend in base strengths?

(A) The number of hydrogen atoms

(B) The number of resonance structures

(C) The different electronegativities of H, I, and Br

(D) The different molar masses

---

10. Mixtures that would be considered buffers include which of the following?
I. 0.10 *M* HCl + 0.10 *M* NaCl
II. 0.10 *M* HF + 0.10 *M* NaF
III. 0.10 *M* HBr + 0.10 *M* NaBr

(A) I only

(B) II only

(C) III only

(D) I and II

(E) II and III

---

11. $\mathrm{HNO_2}(aq) + \mathrm{NH_3}(aq) \rightleftarrows \mathrm{NH_4}^+(aq) + \mathrm{NO_2}^-(aq)\ K_c = 1 \times 10^6$

Nitrous acid reacts with ammonia according to the balanced chemical equation shown above. If $50.\ \mathrm{mL}$ of $0.20\ M\ \mathrm{HNO_2}(aq)$ and $50.\ \mathrm{mL}$ of $0.20\ M\ \mathrm{NH_3}(aq)$ are mixed and allowed to reach equilibrium at $25^\circ\mathrm{C}$, what is the approximate $[\mathrm{NH_3}]$ at equilibrium?

(A) $0.00010\ M$

(B) $0.0010\ M$

(C) $0.010\ M$

(D) $0.10\ M$

---

12. $HF(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + F^-(aq) \qquad K_a = 6.3 \times 10^{-4}$ at $25^\circ C$

The acid ionization equilibrium for HF is represented by the chemical equation above. A student claims that the pH of a solution that contains $0.100\ M\ HF(aq)$ and $0.100\ M\ NaF(aq)$ will change only slightly when small amounts of acids or bases are added. Which of the following pairs of equations can the student use to justify the claim?

(A) $HF(aq) + OH^-(aq) \rightarrow H_2O(l) + F^-(aq)$ and $OH^-(aq) + H_3O^+(aq) \rightarrow 2\,H_2O(l)$

(B) $H_3O^+(aq) + OH^-(aq) \rightarrow 2\,H_2O(l)$ and $F^-(aq) + H_3O^+(aq) \rightarrow HF(aq) + H_2O(l)$

(C) $HF(aq) + OH^-(aq) \rightarrow H_2O(l) + F^-(aq)$ and $F^-(aq) + H_2O(l) \rightarrow HF(aq) + OH^-(aq)$

(D) $HF(aq) + OH^-(aq) \rightarrow H_2O(l) + F^-(aq)$ and $F^-(aq) + H_3O^+(aq) \rightarrow HF(aq) + H_2O(l)$

---

13. Which of the following statements about the pH of $0.010\ M\ HClO_4$ is correct?

(A) $\mathrm{pH} = 2.00$, because $[\mathrm{H}^+] = 1.0 \times 10^{-2}\ M$.

(B) $\mathrm{pH} = 2.00$, because $[\mathrm{H}^+] = 2.0 \times 10^{-2}\ M$.

(C) $\mathrm{pH} > 2.00$, because $\mathrm{HClO_4}$ is a strong acid.

(D) $\mathrm{pH} < 2.00$, because $\mathrm{HClO_4}$ is a weak acid.

---

14. A student prepares a lactic acid-sodium lactate buffer solution by mixing $40.\ \mathrm{mL}$ of $0.50\ M\ \mathrm{HC_3H_5O_3}(aq)$ with $200.\ \mathrm{mL}$ of $1.0\ M\ \mathrm{NaC_3H_5O_3}(aq)$. The $\mathrm{p}K_a$ of $\mathrm{HC_3H_5O_3}$ is 3.08. What is the pH of the resulting solution?

(A) 2.08

(B) 3.08

(C) 3.38

(D) 4.08

---

15. $\mathrm{HC_4H_7O_2}(aq) + \mathrm{H_2O}(l) \rightleftarrows \mathrm{H_3O^+}(aq) + \mathrm{C_4H_7O_2}^-(aq)$

The chemical equation above represents the acid ionization equilibrium for $\mathrm{HC_4H_7O_2}$ for which $\mathrm{p}K_a = 4.8$. Which of the following is the best estimate for the pH of a buffer prepared by mixing $100.\ \mathrm{mL}$ of $0.20\ M\ \mathrm{HC_4H_7O_2}$ with $100.\ \mathrm{mL}$ of $0.10\ M\ \mathrm{NaC_4H_7O_2}$?

acidq2

(A) 1.0

(B) 4.5

(C) 4.8

(D) 7.0

The equilibrium for the reaction between $(CH_3)_2NH$, a weak base, and water is represented by the equation below. The table shows the pH of three solutions of $(CH_3)_2NH(aq)$ at $25^\circ C$.

$(CH_3)_2NH(aq) + H_2O(l) \rightleftarrows (CH_3)_2NH_2{}^+(aq) + OH^-(aq) \qquad K_b = 5.4 \times 10^{-4}$ at $25^\circ C$

$[(CH_3)_2NH]$	pH at $25^\circ C$
0.050	11.69
0.10	11.85
0.20	12.01

16. Which of the following equations can be used to correctly calculate the pH of a solution at $25^\circ C$ that is $0.100\ M$ $(CH_3)_2NH(aq)$ and $0.100\ M$ $(CH_3)_2NH_2Cl(aq)$?

(A) $pH = -\log\left(\frac{1.0\times10^{-14}}{5.4\times10^{-4}}\right)$

(B) $pH = -\log\left(\frac{5.4\times10^{-4}}{1.0\times10^{-14}}\right)$

(C) $pH = 14.00 + (-\log 5.4 \times 10^{-4})$

(D) $pH = (-\log 5.4 \times 10^{-4}) + \log(\frac{0.100}{0.100})$

acidq2

17. A student mixes 100. mL of $0.200\ M\ (CH_3)_2NH(aq)$ with 100. mL of $0.200\ M\ (CH_3)_2NH_2Cl(aq)$ and claims that if a small amount of strong base is added to the mixture, then the resulting change in pH of the mixture will be smaller than the change in pH that would result from adding the same amount of strong base to 200. mL of $0.200\ M\ (CH_3)_2NH(aq)$. Which of the following best explains whether or not the student's claim is correct?

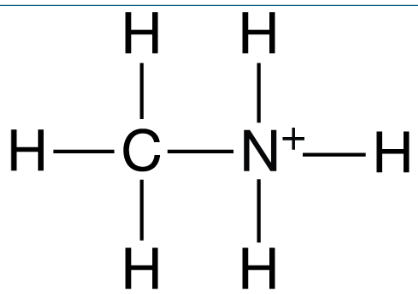
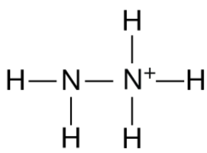
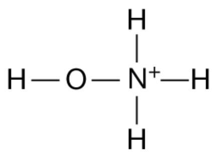
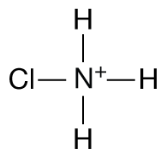
(A) The claim is correct because the mixture contains only half of the $(CH_3)_2NH(aq)$ that the $0.200\ M\ (CH_3)_2NH(aq)$ contains. The lesser amount of base in the mixture makes the pH of the mixture lower than the pH of the $0.200\ M\ (CH_3)_2NH(aq)$; therefore, when a small amount of strong base is added, the change in the pH of the mixture will be smaller than the change in the pH of the $0.200\ M\ (CH_3)_2NH(aq)$.

(B) The claim is correct because the mixture contains a significant amount of the acid $(CH_3)_2NH_2{}^+(aq)$, which can react with and partially neutralize the added strong base, thereby reducing the change in pH. In $0.200\ M\ (CH_3)_2NH(aq)$, the concentration of the acid $(CH_3)_2NH_2{}^+(aq)$ is very small; therefore, the added strong base is not neutralized and the change in pH will be larger.

(C) The claim is incorrect because the mixture contains only half of the $(CH_3)_2NH(aq)$ that the $0.200\ M\ (CH_3)_2NH(aq)$ contains. The lesser amount of base in the mixture makes the pH of the mixture lower than the pH of the $0.200\ M\ (CH_3)_2NH(aq)$; therefore, when a small amount of strong base is added, the change in the pH of the mixture will be larger than the change in the pH of the $0.200\ M\ (CH_3)_2NH(aq)$.

(D) The claim is incorrect because the change in pH resulting from the addition of a small amount of strong base to the mixture and to the $0.200\ M\ (CH_3)_2NH(aq)$ will be the same given that the same amount of strong base is being added to the same volume of solution.

18.

Base	CH_3NH_2	NH_2NH_2	$HONH_2$	$ClNH_2$
Conjugate Acid				

The table above includes the Lewis diagrams of the conjugate acids of some weak nitrogenous bases. Based on the relative stability of the conjugate acids, which of the following bases has the largest value for K_b ?

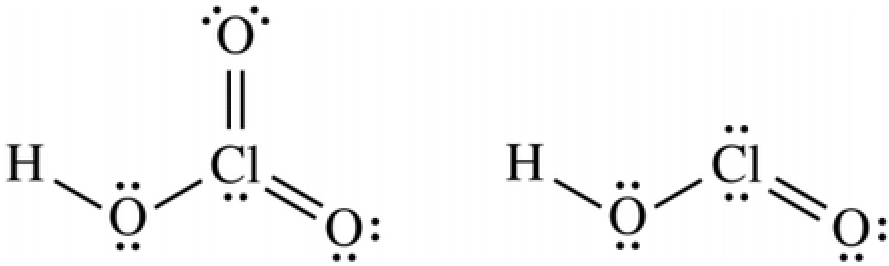
(A) CH_3NH_2

(B) NH_2NH_2

(C) $HONH_2$

(D) $ClNH_2$

19.



The Lewis electron-dot diagrams of the $HClO_3$ molecule and the $HClO_2$ molecule are shown above at the left and right, respectively. Which of the following statements identifies the stronger acid and correctly identifies a factor that contributes to its being the stronger acid?

(A) $HClO_3$(*aq*) is the stronger acid because its molecules experience stronger London dispersion forces.

(B) $HClO_3$(*aq*) is the stronger acid because the additional electronegative oxygen atom on the chlorine atom stabilizes the conjugate base.

(C) $HClO_2$(*aq*) is the stronger acid because its molecules experience weaker London dispersion forces.

(D) $HClO_2$(*aq*) is the stronger acid because the lone pairs of electrons on the chlorine atom stabilize the conjugate base.

---

20. The pH of a 0.01 *M* HNO_2 (*aq*) solution is in which of the following ranges? (For HNO_2 (*aq*), $K_a = 4.0 \times 10^{-4}$)

acidq2

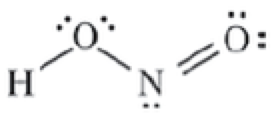
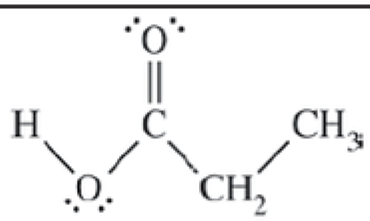
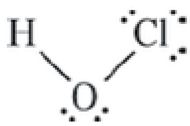
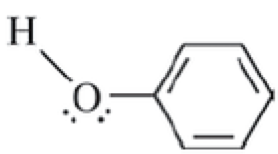
(A) Between 1 and 2

(B) Between 2 and 3

(C) Between 4 and 5

(D) Between 6 and 7

21.

Acid	Structure	K_a
HNO_2		4.0×10^{-4}
$HC_3H_5O_2$		1.3×10^{-5}
$HClO$		3.0×10^{-8}
HOC_6H_5		1.6×10^{-10}

The table above shows the values of K_a for four weak acids. Which of the following pairs of chemical species, when combined in equimolar amounts, results in a buffer with a pH closest to 7.5 ?

(A) HNO_2 and OH^-

(B) $HC_3H_5O_2$ and $C_3H_5O_2-$

(C) HClO and ClO^-

(D) C_6H_5OH and $C_6H_5O^-$

---

22. $HC_2H_3O_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2{}^-(aq) \qquad pK_a = 4.76$

The equilibrium for the acid ionization of $HC_2H_3O_2$ is represented by the equation above. A student wants to prepare a buffer with a pH of 4.76 by combining $25.00\ \mathrm{mL}$ of $0.30\ M\ HC_2H_3O_2$ with $75.00\ \mathrm{mL}$ of $0.10\ M\ NaC_2H_3O_2$. While preparing the buffer, the student incorrectly measures the volume of $NaC_2H_3O_2$ so that the actual volume used is $76.00\ \mathrm{mL}$ instead of $75.00\ \mathrm{mL}$. Based on the error, which of the following is true about the buffer prepared by the student?

(A) The pH of the buffer will be slightly lower than 4.76 because the total volume of the buffer is $101.00\ \mathrm{mL}$ instead of $100.00\ \mathrm{mL}$, and the $HC_2H_3O_2$ was diluted.

(B) The pH of the buffer will be slightly lower than 4.76 because the amount of $C_2H_3O_2{}^-$ added was higher than the amount of $HC_2H_3O_2$ added.

(C) The buffer solution will have a slightly higher capacity for the addition of bases than for the addition of acids because the total volume of the buffer is $101.00\ \mathrm{mL}$ instead of $100.00\ \mathrm{mL}$, and the $HC_2H_3O_2$ was diluted.

(D) The buffer solution will have a slightly higher capacity for the addition of acids than for the addition of bases because the amount of $C_2H_3O_2{}^-$ added was higher than the amount of $HC_2H_3O_2$ added.

---

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

At $5.0^\circ\mathrm{C}$, the value of K_w for the equilibrium shown above is 1.9×10^{-15} and the value of pK_w is 14.73. Based on this information, which of the following is correct for pure water at this temperature?

acidq2

(A) $[H_3O^+] = \sqrt{1.9 \times 10^{-15}}$

(B) $pH = -\log(1.9 \times 10^{-15})$

(C) $14.73 = [H_3O^+]_{eq}[OH^-]_{eq}$

(D) $pOH = pH + 14.73$