Key

ChemQuest 48

Intro to Acids and Bases

Name: _____

Date: _____

Hour: _____

Information: Definitions of Acids and Bases

Arrhenius definitions

1) acid: substance that when dissolved in water increases $[H^+]$; (note: H^+ exists bonded to water as the hydronium ion, H_3O^+, so $[H^+]$ and $[H_3O^+]$ are equivalent expressions)
2) base: substance that when dissolved in water increases $[OH^-]$

Bronsted-Lowry definitions

1) acid: substance that donates a proton, H^+, in a reaction
2) base: substance that accepts a proton, H^+, in a reaction

Table 1: Equilibrium constants (at 25°C) for some acid-base equilibrium reactions.

Reaction	K_c
1. $C_2H_3O_2^- + H_2O \leftrightarrow HC_2H_3O_2 + OH^-$	1.07×10^{-11}
2. $HCN + SO_4^{2-} + H_2O \leftrightarrow HSO_4^- + CN^- + H_2O$	4.9×10^{-11}
3. $HC_2H_3O_2 + H_2O \leftrightarrow H_3O^+ + C_2H_3O_2^-$	3.09×10^{-7}
4. $H_2CO_3 + H_2O \leftrightarrow H_3O^+ + HCO_3^-$	7.82×10^{-9}
5. $HCl + H_2O \leftrightarrow H_3O^+ + Cl^-$	2.0×10^{4}

Critical Thinking Questions

1. List all of the reactants in Table 1 that are Arrhenius acids.
   $HC_2H_3O_2$, H_2CO_3, and HCl

2. List all of the reactants in Table 1 that are Arrhenius bases.
   $C_2H_3O_2^-$

3. List all of the reactants in Table 1 that are Bronsted-Lowry acids.
   H_2O, HCN, $HC_2H_3O_2$, H_2CO_3, and HCl

4. List all of the reactants in Table 1 that are Bronsted-Lowry bases.
   $C_2H_3O_2^-$, SO_4^{2-}, H_2O

5. Is it possible for an ion to act as a base? Explain.
   Yes, $C_2H_3O_2^-$ and SO_4^{2-} act like bases in the above reactions.
6. Can a substance act as both an acid and a base under different conditions? Explain.
   Yes, for example in the above table H_2O acts like a base and an acid in different reactions.
7. Is this statement true: "All substances that are Arrhenius acids are also Bronsted-Lowry acids"? Explain.
   Yes, all of the substances in our answer to question 1 also are found in our answer to question 3.

8. If a substance is a Bronsted-Lowry acid, can we conclude that the substance is also an Arrhenius acid? Explain.
   No because not all of the substances from question 3 are listed in question 1.

9. a) What is the strongest acid among the reactants in reactions 3-5 inTable 1? Explain.
   HCl because the large K_c indicates that it forms H_3O^+ in large concentrations.
   b) What is the weakest acid among the reactants in reactions 3-5 inTable 1? Explain.
   HCN, because of its very small K_c.
10. Consider Reaction 3.
   a) What substance is formed (by the acid) after the acid loses a proton?
   $C_2H_3O_2^-$
   b) Is this substance an acid or a base? (Hint: look at reaction 1.)
   It is a base since it produces OH^- in reaction 1.
11. Drawing a conclusion from question 10, what can be said about a substance after it loses a proton? Is the substance formed acidic or basic?
   After an acid loses an H^+, the substance formed is a base.

Information: Conjugate Acid-Base Pairs

After an acid loses a proton in a reaction, the substance formed behaves like a base. Verify this by examining Reactions 3 and 1 in Table 1. Notice from reaction 3 that $HC_2H_3O_2$ is an acid. After it loses a proton it becomes the acetate ion, $C_2H_3O_2^-$. The acetate ion is a base, as seen in reaction 1; there is a special name for this base: it is a conjugate base. So, $C_2H_3O_2^-$ is the conjugate base of $HC_2H_3O_2$. Similarly, HSO_4^- is the conjugate acid of SO_4^{2-}. Verify this by examining Reaction 2.

Critical Thinking Questions

12. Describe how a conjugate base is formed.
   It is formed by an acid losing a H^+.
13. How is a conjugate acid formed?
   It is formed by a base gaining a H^+.
14. For each of the acids below, write the reaction of the acid with water and circle the formula of the conjugate base in your reaction.
   a) H_2SO_4 $\quad H_2SO_4 + H_2O \leftrightarrow H_3O^+ + (HSO_4^-)$
   b) HCO_3^- $\quad HCO_3^- + H_2O \leftrightarrow H_3O^+ + (CO_3^{2-})$
   c) HF $\quad HF + H_2O \leftrightarrow H_3O^+ + (F^-)$

15. For each of the bases below, write the reaction of the base with water and circle the formula of the conjugate acid in your reaction.
   a) NH_3 $\quad NH_3 + H_2O \leftrightarrow (NH_4^+) + OH^-$
   b) OH^- $\quad OH^- + H_2O \leftrightarrow (H_2O) + OH^-$
   c) NO_3^- $\quad NO_3^- + H_2O \leftrightarrow (HNO_3) + OH^-$

ChemQuest 49

pH and pOH

Name: _____

Date: _____

Hour: _____

Information: Measuring Acidity

Many people have heard of "pH", and many people know that it probably refers to acidity, but not very many understand what exactly it measures. The pH is a measure of the concentration of hydrogen ions (H^+) in a solution. Recall that in water H^+ ions bond to water to form H_3O^+ (hydronium ions). Keep this in mind because hydrogen (H^+) and hydronium (H_3O^+) are often used interchangeably.

The pH of a solution can range from 0-14. The equation for calculating pH is:

$$pH = -\log[H^+]$$

Critical Thinking Questions

1. A certain solution has a concentration of hydrogen ions of 2.5×10^{-3} M. What is the pH?
   $pH = -\log[H^+] = -\log(2.5 \times 10^{-3}) = 2.60$

2. The same solution as question 1 has a concentration of hydroxide ions of 4.0×10^{-12}. What is the pOH?
   $pOH = -\log[OH^-] = -\log(4.0 \times 10^{-12}) = 11.40$

3. A certain solution has a pH of 5.2. What is the concentration of hydrogen ions?
   $[H^+] = 10^{(-pH)} = 10^{(-5.2)} = 6.3 \times 10^{-6}$ M

4. The same solution as question 3 has a pOH of 8.8. What is the concentration of hydroxide ions?
   $[OH^-] = 10^{(-pOH)} = 10^{(-8.8)} = 1.6 \times 10^{-9}$ M

5. Use the information given and your answers to questions 1 and 2 to find the following:
   a) Divide the pH by the pOH of the solution.
      $2.60 \div 11.40 = 0.228$

   b) Multiply the pH by the pOH of the solution.
      $2.60 \times 11.40 = 29.64$

   c) Add the pH and the pOH together.
      $2.60 + 11.40 = 14.00$

   d) Multiply $[H^+]$ and $[OH^-]$ together.
      $2.5 \times 10^{-3} \times 4.0 \times 10^{-12} = 1.0 \times 10^{-14}$

   e) Divide $[H^+]$ by $[OH^-]$.
      $2.5 \times 10^{-3} \div 4.0 \times 10^{-12} = 6.25 \times 10^{8}$

6. Use the information given and your answers to questions 3 and 4 to find the following:
   a) Divide the pH by the pOH of the solution.
   $5.2 \div 8.8 = 0.591$

   b) Multiply the pH by the pOH of the solution.
   $5.2 \times 8.8 = 45.76$

   c) Add the pH and the pOH together.
   $5.2 + 8.8 = 14.0$

   d) Multiply $[H^+]$ and $[OH^-]$ together.
   $6.3\times10^{-6} \times 1.6\times10^{-9} = 1.0\times10^{-14}$

   e) Divide $[H^+]$ by $[OH^-]$.
   $6.3\times10^{-6} \div 1.6\times10^{-9} = 3937.5$

7. Consider your answers to questions 5 and 6. Were there any that gave the same answer (or just about the same answer)? If so, which ones?
   5c and 6c: $pH + pOH = 14$
   5d and 6d: $[H^+]\times[OH^-] = 1.0\times10^{-14}$

8. Given your answer to number 7, you should be able to answer the following questions.
   a) Find the pH of a solution that has a pOH of 4.6.
   9.4; $pH + pOH = 14 \rightarrow pH = 14 - pOH = 9.4$

   b) The $[H_3O^+]$ of a solution is 2.55×10^{-3} M. What is the $[OH^-]$?
   3.92×10^{-12} M; $[H^+] \times [OH^-] = 1.00\times10^{-14} \rightarrow [H^+] = 1.00\times10^{-14} \div 2.55\times10^{-3} = 3.92\times10^{-12}$ M

9. What is the pOH of a solution that has a $[H^+] = 4.22 \times 10^{-3}$ M.
   11.625; $pH = -\log(4.22\times10^{-3}) = 2.375 \rightarrow pOH = 14 - pH = 14 - 2.375 = 11.625$

10. A certain solution has a pH of 3.25.
   a) Find the pOH of the solution.
   $pOH = 14 - 3.25 = 10.75$

   b) Find the $[H^+]$ of the solution.
   $[H^+] = 10^{(-pH)} = 10^{(-3.25)} = 5.623\times10^{-4}$ M

   c) Find the $[OH^-]$ of the solution.
   $[OH^-] = 1\times10^{-14} \div [H^+] = 1\times10^{-14} \div 5.623 \times 10^{-4} = 1.778\times10^{-11}$ M

11. Find the pH of a 0.035 M solution of HNO_3. (Hint: First find the $[H^+]$ by realizing that nitric acid dissociates according to this balanced equation: $HNO_3 \rightarrow H^+ + NO_3^-$. If the concentration of HNO_3 is 0.035, then $[H^+]$ is also 0.035.)
    pH = -log(0.035) = 1.46

12. Find the pH of a 0.16 M solution of HCl.
    pH = -log(0.16) = 0.80

13. Find the pH of a 0.045 M solution of NaOH. ($NaOH \rightarrow Na^+ + OH^-$)
    12.65; pOH = -log[OH^-] = -log(0.045) = 1.35; pH = 14 – pOH = 14-1.35 = 12.65

14. Find the pH of a 0.0045 M solution of LiOH.
    11.65; pOH = -log[OH^-] = -log(0.0045) = 2.35; pH = 14 – pOH = 14-2.35 = 11.65

15. If 14.5 g of NaOH is dissolved in 720 mL of water, what is the pH?
    13.702
    14.5g ÷ 40 g/mol = 0.363 mol; 0.363 mol ÷ 0.720 L = 0.503 M = [NaOH] = [OH^-]
    pOH = -log[OH^-] = -log(0.503) = 0.298
    pH = 14 – pH = 14 – 0.298 = 13.702

16. A certain solution contains 0.35 mol of HCl in 1200 mL of water.
    a) Find the pH and pOH of the solution.
    pH = 0.535 pOH = 13.465
    [HCl] = $[H^+]$ = 0.35mol ÷ 1.200L = 0.292 M
    pH = -log(0.292) = 0.535; pOH = 14 – pH = 14 – 0.535 = 13.465

    b) Find the $[H^+]$ and the [OH^-] in the solution.

    $[H^+] = 10^{(-pH)} = 10^{(-0.535)} = 0.292$ M
    [OH^-] = $10^{(-pOH)} = 10^{(-13.465)} = 3.428 \times 10^{-14}$ M

Skill Practice 49

pH Practice

Name: _____

Date: _____

Hour: _____

1. What is the pH of a 0.034 M solution of HNO_3?

   1.47

3. Calculate the pH of a 0.0105 M solution of NaOH?

   12.0212

4. a) Calculate the pH of a 0.025 M solution of HNO_3.

   1.60

   b) What is the pOH of this solution?

   12.40

5. Calculate $[H^+]$, $[OH^-]$, pOH and the pH for a 0.0015 M solution of HCl.

   $[H^+] = 0.0015$ M
   $[OH^-] = 6.67 \times 10^{-12}$ M
   pOH = 11.18
   pH = 2.82

6. Calculate $[H^+]$, $[OH^-]$, pOH and the pH for a 0.00024 M solution of sodium hydroxide, NaOH.

   $[H^+] = 4.17 \times 10^{-11}$ M
   $[OH^-] = 0.00024$ M
   pOH = 3.62
   pH = 10.38

Skill Practice 48

Acids Practice

Name: _____

Date: _____

Hour: _____

1. A certain substance in solution is known to increase the concentration of H_3O^+. Is this substance an acid or a base?

   Acid

2. Given the following reaction, identify the Arrhenius acid and describe why the substance you chose is an Arrhenius acid.

   $H_2SO_4 \rightarrow HSO_4^- + H^+$

   It is an acid because it increases the concentration of H^+ in solution.

3. How do the Bronsted-Lowry definitions and the Arrhenius definitions differ?

   Bronsted-Lowry: an acid donates a proton (H^+)
   Arrhenius: an acid increases the concentration of H^+ in solution.

4. Describe the difference between a weak and a strong acid.

   Strong acids dissociate completely, but weak acids only dissociate partially.

5. In each of the following reactions identify an acid (if there is one) and then specify whether it is an acid according to the Arrhenius definitions or the Bronsted-Lowry definitions or both.

   a) $H_2CO_3 + CN^- \rightarrow HCN + HCO_3^-$ Bronsted-Lowry

   b) $F^- + HSO_4^- \rightarrow HF + SO_4^{2-}$ Bronsted-Lowry

   c) $HSO_4^- + H_2O \rightarrow H_3O^+ + SO_4^{2-}$ Both

6. What is the conjugate base of HCN?

   CN^-