Chapter 16 Worksheet

1. What are some physical properties that historically led chemists to classify various substances as acids and bases?

2. In the Arrhenius definition, what characterizes an acid? What characterizes a base? Why are the Arrhenius definitions too restrictive?

3. What is an acid in the Bronsted-Lowry model? What is a base?

4. In each of the following chemical equations, identify the conjugate acid-base pairs.
   A. $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
   B. $PO_4^{3-} + H_2O \rightarrow HPO_4^{2-} + OH^-$
   C. $C_2H_3O_2 + H_20 \rightarrow HC_2H_3O_2 + OH^-$

5. Write the conjugate acid for each of the following:
   A. HSO_4
   B. SO_3
   C. CIO
   D. H_2PO_4

6. Write the conjugate base for each of the following
   A. HCO_3
   B. H_2PO_4
   C. HCI
   D. HSO_4

7. What does it mean to say that an acid is strong in aqueous solution? What does this reveal about the ability of the acid's anion to attract protons?

8. What does it mean to say that an acid is weak in aqueous solution? What does this reveal about the ability of the acids anion to attract protons?

9. Why do scientists tend to express the acidity of a solution in terms of its pH, rather than in terms of the molarity of hydrogen ion present? How is pH defined mathematically?

10. As the hydrogen ion concentration of a solution increases, does the pH of the solution increase or decrease. Explain

11. Calculate the pH corresponding to each of the hydrogen ion concentrations given below. Tell whether each solution is acidic, basic, or neutral.
    A. [H+]=0.00100M
    B. [H+]=$2.19x10^{-4}$M
    C. [H+]=$9.18x10^{-11}$M
    D. [H+]=$4.71x10^{-7}$M

12. Calculate the pH corresponding to each of the hydroxide ion concentrations given below. Tell whether each solution is acidic, basic, or neutral.
    A. [OH-]=$1.00x10^{-7}$M
    B. [OH-]=$4.59x10^{-13}$M
    C. [OH-]=$1.04x10^{-4}$M
    D. [OH-]=$7.00x10^{-1}$M

13. Calculate the pH corresponding to each of the pOH values listed. Tell whether each solution is acidic, basic, or neutral.
    A. pOH=4.32
    B. pOH=8.90
    C. pOH=1.81
    D. pOH=13.1

Answers

1) Acids were recognized primarily from their sour taste. Bases were recognized from their bitter taste and slippery feel on skin.
2) In the Arrhenius definition, an acid is a substance which produces hydrogen ions (H^+) when dissolved in water, whereas a base is a substance which produces hydroxide ions (OH^-) in aqueous solution. These definitions proved to be too restrictive since the only base permitted was hydroxide ion, and the only solvent permitted was water.
3) A Brønsted-Lowry acid is a molecule or ion capable of providing a proton to some other species; acids are *proton donors*. A Brønsted-Lowry base is a molecule or ion capable of receiving a proton from some other species; bases are *proton acceptors*. It is the *transfer of protons* that characterizes the Brønsted-Lowry model for acids and bases.
4) a. NH_3 (base), NH_4^+ (acid); H_2O (acid), OH^- (base)
   b. PO_4^{3-} (base), HPO_4^{2-} (acid); H_2O (acid), OH^- (base)
   c. $C_2H_3O_2^-$ (base), $HC_2H_3O_2$ (acid); H_2O (acid), OH^- (base)
5) The conjugate *acid* of the species indicated would have *one additional proton*:
   a. H_2SO_4
   b. HSO_3^-
   c. $HClO_4$
   d. H_3PO_4
6) The conjugate *bases* of the species indicated would have *one less proton*:
   a. CO_3^{2-}
   b. HPO_4^{2-}
   c. Cl^-
   d. SO_4^{2-}
7) A strong acid is one for which the equilibrium in water lies far to the right. A strong acid is almost completely converted to its conjugate base when dissolved in water. A strong acid's anion (its conjugate base) must be very poor at attracting, or holding onto, protons. A regular arrow ($\rightarrow$) rather than a double arrow ($\rightleftharpoons$) is used when writing an equation for the dissociation of a strong acid to indicate this.
8) To say that an acid is *weak* in aqueous solution means that the acid does not easily transfer protons to water (and does not fully ionize). If an acid does not lose protons easily, then the acid's anion must be a strong attractor of protons (good at holding on to protons).
9) Because the concentrations of $[H^+]$ and $[OH^-]$ in aqueous solutions tend to be expressed in scientific notation, and since these numbers have negative exponents for their powers of ten, it tends to be clumsy to make comparisons between different concentrations of these ions (see questions 24 and 25 above). The pH scale converts such numbers into "ordinary" numbers between 0 and 14 which can be more easily compared. The pH of a solution is defined as the *negative* of the base 10 logarithm of the hydrogen ion concentration, $pH = -\log[H^+]$.
10) The pH of a solution is defined as the *negative* of the logarithm of the hydrogen ion concentration, $pH = -\log[H^+]$. Mathematically, the *negative sign* in the definition causes the pH to *decrease* as the hydrogen ion concentration *increases*.
11) $pH = -\log[H^+]$
    a. $pH = -\log[0.00100\ M] = 3.000$; solution is acidic
    b. $pH = -\log[2.19 \times 10^{-4}\ M] = 3.660$; solution is acidic
    c. $pH = -\log[9.18 \times 10^{-11}\ M] = 10.037$; solution is basic

d. $pH = -\log[4.71 \times 10^{-7}\ M] = 6.327$; solution is acidic

12) $pOH = -\log[OH^-]$ $pH = 14.00 - pOH$

a. $pOH = -\log[1.00 \times 10^{-7}\ M] = 7.000$

$pH = 14.00 - 7.000 = 7.00$; solution is neutral

b. $pOH = -\log[4.59 \times 10^{-13}\ M] = 12.338$

$pH = 14.00 - 12.338 = 1.66$; solution is acidic

c. $pOH = -\log[1.04 \times 10^{-4}\ M] = 3.983$

$pH = 14.00 - 3.983 = 10.02$; solution is basic

d. $pOH = -\log[7.00 \times 10^{-1}\ M] = 0.155$

$pH = 14.00 - 0.155 = 13.85$; solution is basic

13) $pH = 14 - pOH$

a. $pH = 14.00 - 4.32 = 9.68$; solution is basic

b. $pH = 14.00 - 8.90 = 5.10$; solution is acidic

c. $pH = 14.00 - 1.81 = 12.19$; solution is basic

d. $pH = 14.00 - 13.1 = 0.9$; solution is acidic