1. Which laboratory test result can be used to determine if KCl(s) is an electrolyte?
   A) electrical conductivity of KCl(aq)
   B) pH of KCl(s)
   C) pH of KCl(aq)
   D) electrical conductivity of KCl(s)

2. Which substance is an electrolyte?
   A) CCl_4 B) HCl
   C) H_2O D) C_2H_6

3. Which sample of HCl(aq) contains the greatest number of moles of solute particles?
   A) 1.0 L of 2.0 M HCl(aq)
   B) 2.0 L of 2.0 M HCl(aq)
   C) 3.0 L of 0.50 M HCl(aq)
   D) 4.0 L of 0.50 M HCl(aq)

   $M = \frac{\#\ moles}{L}$ ex: $0.50 = \frac{\#\ moles}{4.0}$

4. A substance is classified as an electrolyte because
   A) its aqueous solution conducts an electric current
   B) it contains covalent bonds
   C) it has a high melting point
   D) its aqueous solution has a pH value of 7

5. Water containing dissolved electrolyte conducts electricity because the solution contains mobile
   A) ions B) atoms
   C) electrons D) molecules

6. Which sample of HCl most readily conducts electricity?
   A) HCl(s) B) HCl(g)
   C) HCl(aq) D) HCl(ℓ)

7. A hydrogen ion, H^+, in aqueous solution may also be written as
   A) H_2O B) H_2O_2
   C) OH^- D) H_3O^+

8. Which statement correctly describes a solution with a pH of 9? → Base
   A) It has a higher concentration of H_3O^+ than OH^- and causes methyl orange to turn yellow.
   B) It has a higher concentration of H_3O^+ than OH^- and causes litmus to turn blue.
   C) It has a higher concentration of OH^- than H_3O^+ and causes litmus to turn blue.
   D) It has a higher concentration of OH^- than H_3O^+ and causes methyl orange to turn red.

9. Which pH indicates a basic solution?
   A) 12 B) 1 C) 7 D) 5

10. Which of these pH numbers indicates the highest level of acidity? (lowest pH)
    A) 12 B) 5 C) 8 D) 10

11. Given the following solutions:

    Solution *A*: pH of 10
    Solution *B*: pH of 7
    Solution *C*: pH of 5
    Which list has the solutions placed in order of increasing H^+ concentration?

    A) *C, A, B* B) *B, A, C*
    C) *C, B, A* D) *A, B, C*

12. As an aqueous solution becomes more acidic, the OH^- hydroxide ion concentration
    A) decreases B) increases
    C) remains the same

13. Which of the following pH values indicates the highest concentration of hydronium ions in a solution?
    A) pH = 1 B) pH = 2
    C) pH = 3 D) pH = 4

14. As HCl(g) is added to water, the pH of the water solution → acid
    A) decreases B) increases
    C) remains the same

Acid/Base/Salt Characteristics:

On the line on the left, write **A** if the statement is a property of an **acidic** solution. Write **B** if it is a property of a **basic** solution. Write **X** if it is a property of **both** acidic and basic solutions.

B 1) Often feels smooth and slippery

A 2) Has a sour taste

X 3) Stings in open wounds

A 4) Typically reacts vigorously with metals

B 5) Has a bitter taste

A 6) Turns litmus paper from blue to red

X 7) Is an electrolyte

A 8) Often looks like pure water

B 9) Turns litmus paper from red to blue

B 10) Typically does not react with metals

11. Compare acids and bases in terms of H^+ and OH^- concentration.

Acids have a higher H^+ concentration and bases have a higher OH^- concentration.

12. Explain what it means to be an electrolyte and why acids, bases and salts are electrolytes.

Electrolytes conduct electricity when in solution. Acids and bases are electrolytes because they form ions when dissolved in water.

1. In the reaction

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

A conjugate acid-base pair is

(A) H_2O and OH^- B) H_2O and NH_4^+
C) NH_3 and H_2O D) NH_3 and OH^-

2. Which is the conjugate acid of HSO_4^-?

A) H_3O^+ B) HSO_3^- → add H^+
C) SO_4^{2-} (D) H_2SO_4

3. What are the bases that accept protons in the reaction?

acid base acid base
$H_2S + H_2O \leftrightarrow H_3O^+ + HS^-$

A) HS^- and H_3O^+ B) H_2S and H_3O^+
(C) HS^- and H_2O D) H_2S and H_2O

4. In the reaction:

$$HBr + H_2O \leftrightarrow H_3O^+ + Br^-$$

Which is a conjugate acid-base pair?

A) HBr and H_2O B) H_3O^+ and HBr
C) H_3O^+ and Br^- (D) HBr and Br^-

5. Given the reaction:

acid base
$CH_3COOH(aq) + H_2O(\ell) \leftrightarrow$
$CH_3COO^-(aq) + H_3O^+(aq)$
base acid

In this reaction, which substances are accepting protons? (bases)

A) $H_2O(\ell)$ and $H_3O^+(aq)$
(B) $H_2O(\ell)$ and $CH_3COO^-(aq)$
C) $CH_3COOH(aq)$ and $CH_3COO^-(aq)$
D) $CH_3COOH(aq)$ and $H_2O(\ell)$

6. In the reaction:

base acid acid base
$H_2PO_4 + H_2O \leftrightarrow H_3PO_4 + OH$

Which pair represents an acid and its conjugate base?

A) H_2O and H_2PO_4
B) H_3PO_4 and OH^-
C) H_2O and H_3PO_4
(D) H_3PO_4 and $H_2PO_4^-$

7. Given the reaction at equilibrium:

acid base base acid
$HSO_4^- + NH_3 \leftrightarrow SO_4^{2-} + NH_4^+$

What are the two species that are acids?

A) NH_3 and SO_4^{2-} B) NH_3 and NH_4^+
C) HSO_4^- and SO_4^{2-} (D) HSO_4^- and NH_4^+

8. In the reaction:

$$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$$

The water is

A) a proton donor, only
B) a proton acceptor, only
(C) both a proton donor and a proton acceptor
D) neither a proton donor nor a proton acceptor

9. The compound HNO_3 can be described as an

A) Arrhenius base and a nonelectrolyte
B) Arrhenius acid and a nonelectrolyte
(C) Arrhenius acid and an electrolyte
D) Arrhenius base and an electrolyte

10. Which compound releases hydroxide ions in an aqueous solution?

(A) KOH B) CH_3OH
C) HCl D) CH_3COOH

14) $H_2O + NH_3 \leftrightarrows NH_4^+ + OH^-$
acid base acid base

15) $H_2O + H_2O \leftrightarrows H_3O^+ \; OH^-$
acid base acid base

16) $NH_3 + NH_3 \leftrightarrows NH_4^+ + NH_2^-$
acid base acid base

17) $H_2SO_4 + Ca(OH)_2 \leftrightarrows CaSO_4 + 2H_2O$
acid base salt water

18) $O_3ClOH + H_2O \leftrightarrows H_3O^+ + O_3ClO^-$
acid base acid base

19) $H_2O + HI \rightarrow H_3O^+ + I^-$
base acid acid base

20) $CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$
acid base base acid

21) $NH_4^+ + OH^- \leftrightarrows NH_3 + H_2O$
acid base base acid

22) $H_2SO_4 + OH^- \rightarrow HSO_4^- + H_2O$
acid base base acid

23) $HSO_4^- + H_2O \rightarrow SO_4^{-2} + H_3O^+$
acid base base acid

* Each side of the equation contains an acid and base

ACID-BASE TITRATIONS: 5/20

To determine the concentration of an acid (or base), we can react it with a base (or acid) of known concentration until it is completely neutralized. This point of exact neutralization, know as the endpoint or equivalence point, is noted by the change in color of the indicator.

We use the following **Titration** formula from our Table T (Reference Tables):

M_A = molarity of acid
V_A = volume of acid

$$M_AV_A = M_BV_B$$

M_B = molarity of base
V_B = volume of base

Solve the following problems. SHOW ALL WORK!

1. A 25.0 mL sample of HCl was titrated to the endpoint with 15.0 mL of 2.0 M NaOH. What is the molarity of the HCl?

$V_A = 25.0mL$
$V_B = 15.0mL$
$M_B = 2.0M$

$M_AV_A = M_BV_B$
$M_A \cdot 25.0 = 2.0 \times 15.0$

$\frac{M_A \cdot 25.0}{25.0} = \frac{30.0}{25.0}$

$M_A = 1.2M$

2. A 10.0 mL sample of H_2SO_4 was exactly neutralized by 13.5 mL of 1.0 M KOH. What is the molarity of the H_2SO_4?

$V_A = 10.0mL$
$V_B = 13.5mL$
$M_B = 1.0M$

$M_AV_A = M_BV_B$
$M_A \times 10.0 = 1.0 \times 13.5$
$\frac{M_A \times 10.0}{10.0} = \frac{13.5}{10.0}$

$M_A = 1.35M$

3. How much 1.5 M NaOH is necessary to exactly neutralize 20.0 mL of 2.5 M H_3PO_4?

$M_B = 1.5M$
$V_A = 20.0mL$
$M_A = 2.5M$

$M_AV_A = M_BV_B$
$2.5 \cdot 20.0 = 1.5 \cdot V_B$

$\frac{50}{1.5} = \frac{1.5V_B}{1.5}$

$33.3mL = V_B$

4. How much of 0.5 M HNO_3 is necessary to titrate 25.0 mL of 0.05 M $Ca(OH)_2$ solution to the endpoint?

$M_A = 0.5M$
$M_B = 0.05M$
$V_B = 25.0mL$

$M_AV_A = M_BV_B$
$0.5 \times V_A = 0.05 \times 25.0$
$V_A = \frac{1.25}{0.5}$

$V_A = 2.5mL$

5. What is the molarity of a NaOH solution if 15.0 mL is exactly neutralized by 7.5 mL of a 0.02 M $HC_2H_3O_2$ solution?

$V_B = 15.0mL$
$V_A = 7.5mL$
$M_A = 0.02M$

$M_AV_A = M_BV_B$
$0.02 \times 7.5 = M_B \times 15.0$
$\frac{0.15}{15.0} = \frac{M_B \times 15.0}{15.0}$

$M_B = 0.01M$

Titration Practice:

A titration was set up and used to determine the unknown molar concentration of a solution of NaOH. A 1.2 M HCl solution was used as the titration standard. The following data were collected.

	Trial 1	Trial 2	Trial 3	Trial 4
Volume of 1.2 M HCl	10.0 mL	10.0 mL	10.0 mL	10.0 mL
Initial Reading of NaOH	0.0 mL	12.2 mL	23.2 mL	35.2 mL
Final Reading of NaOH	12.2 mL	23.2 mL	35.2 mL	47.7 mL
Volume of NaOH used (mL)	12.2mL	11.0mL	12.0mL	12.5mL
Molarity of NaOH (M)	0.984M	1.09M	1.00M	0.960M

1) Calculate the volume of NaOH used to neutralize the acid for each trial. Record in data table above. Show one sample calculation below.

Trial 4: $M_AV_A = M_BV_B$

$1.2 \times 10.0 = M_B \times 12.5$

$\frac{12.0}{12.5} = \frac{M_B \times 12.5}{12.5}$

$0.96\,M = M_B$

Sorry!

2) Using the $M_AV_A = M_BV_B$ formula calculate the molarity of the base for each trial. Record in data table above. Show one sample calculation below.

Final Reading − Initial Reading

Trial 4: $47.7 - 35.2 = 12.5\,mL$

3) Calculate the average molarity of the NaOH using your results from question 2. Your answer must include the correct number of significant figures and the correct units.

$$\frac{0.984 + 1.09 + 1.00 + 0.960}{4} = 1.0085$$

$\boxed{1.01M}$

3 sig figs

5/21 - 5/22

Lesson 41 Redox Reactions

Key Words

oxidation number: number given to each atom in a chemical formula to show the number of electrons that might be gained, lost, or shared during bond formation.

redox reaction: short term for an oxidation-reduction reaction

KEY IDEAS

In a redox reaction, oxidation numbers change. These numbers are used to show the direction of electron movement in the reactions. When an atom loses electrons, its oxidation number increases. When an atom gains electrons, its oxidation number decreases.

Redox reactions that take place in the body can lead to disease and aging. Antioxidants can stop or slow down harmful redox reactions. For this reason, nurses and other health care workers need to know about antioxidants present in foods and medicines.

Finding Oxidation Numbers. Electrons are gained, lost, or shared when atoms bond together. Oxidation numbers are used to keep track of electrons during bonding. It is easy to find the **oxidation number** of an atom by using the following set of rules:

The oxidation number of a one-atom ion is equal to its charge. For example, the oxidation number of calcium in Ca^{2+} is +2. The oxidation number of sulfur in S^{2-} is –2.

The oxidation number of an element is zero. An uncombined atom such as K or P has an oxidation number of zero. When atoms of the same element bond together, each atom also has an oxidation number of zero. Thus the oxygen atoms in O_2 and the oxygen atoms in ozone O_3 both have oxidation numbers of zero.

In compounds made up of only two elements, the more electronegative element has a negative oxidation number. The less electronegative element has a positive oxidation number. In PCl_3, chlorine is more electronegative than phosphorus. Chlorine therefore has an oxidation number of –1. Phosphorus in PCl_3 is less electronegative than chlorine. Thus, phosphorus has a charge of +3.

In compounds, hydrogen usually has an oxidation number of +1. Oxygen usually has an oxidation number of –2. In HCl, the oxidation number of hydrogen is +1. In CaO, the oxidation number of oxygen is –2.

The sum of the oxidation numbers in an ion made up of many elements is equal to its charge. One example is the nitrate ion NO_3^-, shown in Fig. 41-1. In this ion, each oxygen atom has an oxidation number of –2. Three oxygen atoms have an oxidation number of –6, since 3(–2) = –6. The sum of the oxidation numbers is the charge on the ion, which is –1. That is, the oxidation number of nitrogen added to –6 should equal –1. So the oxidation number of the nitrogen must be +5.

Fig. 41-1

$(N^{?}O_3^{2-})^{1-}$

$(N^{5+}O_3^{2-})^{1-}$

In the sulfate ion SO_4^{2-}, the oxidation numbers add up to –2. Look at Fig. 41-2. Each oxygen atom has an oxidation number of –2. The oxidation number of sulfur is +6 because (+6) + (4)(–2) = –2.

Fig. 41-2

$(S^{6+}O_4^{2-})^{2-}$

Sulfate ion

The sum of the oxidation numbers in a compound is zero. In water, the oxidation number of the oxygen is –2. The oxidation number of each hydrogen is +1. The oxidation number of both hydrogens is 2(+1) = +2. The sum of –2 for the oxygen and +2 for the hydrogens is zero. In nitric acid HNO_3, the oxidation number of the hydrogen is +1, and the charge on the nitrate ion is -1.

☑ 1. **What is the oxidation number of a free element?** 0

☑ 2. **What is the usual oxidation number of oxygen?** –2

☑ 3. **What is the sum of the oxidation numbers in a compound?** 0

Oxidation Numbers in Reactions. A **redox reaction** is an oxidation-reduction reaction. Look at the equation shown in Fig. 41-3.

Fig. 41-3

$$\overset{2+\ 2(1-)\quad 0}{Ba\ Br_2} + \overset{}{Cl_2} \longrightarrow \overset{2+\ 2(1-)}{BaCl_2} + \overset{0}{Br_2}$$

oxidation number decreases (reduction)

oxidation number increases

In this reaction, the oxidation number of the bromine changes from –1 to 0. The oxidation number of the chlorine changes from 0 to –1. Each bromine atom loses an electron, which is oxidation. Each chlorine atom gains an electron, which is reduction. Thus, the reaction shown is a redox reaction.

Now look at the equation in Fig. 41-4. In this reaction, no change of oxidation numbers occurs. If none of the oxidation numbers change, no redox reaction takes place.

Fig. 41-4

$$\overset{1+\ 1-}{HCl} + \overset{1+\ 2-1+}{Na\ OH} \longrightarrow \overset{1+\ 1-}{NaCl} + \overset{1+\ 2-1+}{HOH}$$

TAKE ANOTHER LOOK

Look at the redox reaction between sodium (Na) and sulfur (S) shown in Figs. 41-5 and 41-6. The diagrams show the movement of electrons during the same reaction in different ways. Notice that sodium loses electrons, which is oxidation. Sulfur gains electrons, which is reduction. The oxidation number of each sodium atom increases from 0 to +1. The oxidation number of the sulfur atom decreases from 0 to –2.

Fig. 41-5

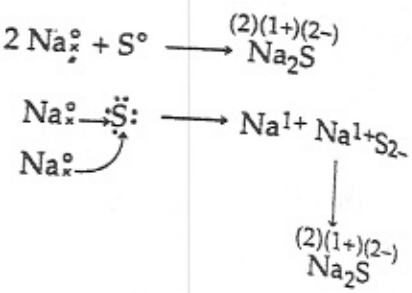
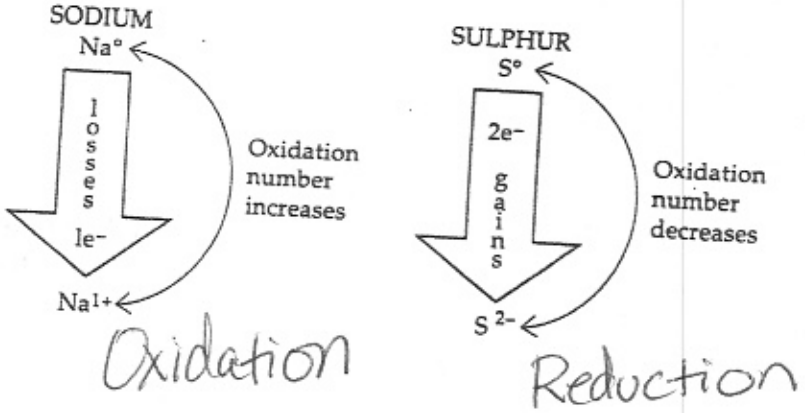


Fig. 41-6



Check Your Understanding

Fill in the blanks with the correct terms.

The rules for finding oxidation numbers are the following: The oxidation number of an ion equals (4) its charge. The oxidation number of an element equals (5) 0. In two-element compounds, the more electronegative element has a (6) negative charge, and the less electronegative element has a (7) positive charge. Hydrogen usually has an oxidation number of (8) +1, and the oxidation number of oxygen is usually (9) –2. The sum of the oxidation numbers of an ion equals (10) its charge. The sum of the oxidation numbers of a compound equals (11) 0.

Assign oxidation numbers to each element in the following unbalanced equation.

$$\overset{-3\,+1}{NH_3} + \overset{0}{O_2} \longrightarrow \overset{+2\,-2}{NO} + \overset{+1\,-2}{H_2O}$$

12. The oxidation number of the nitrogen changes from –3 to +2.

13. The oxidation number of the oxygen changes from 0 to –2.

14. What is the oxidation number of each element in the following compounds?

(a) HCl H = +1 Cl = −1

(b) H_2SO_4 H = +1 S = +6 O = −2 [2(+1) + 1(+6) + 4(−2)]

(c) $KMnO_4$ K = +1 Mn = +7 O = −2 [+2 + 6 − 8 = 0]

(d) NO N = +2 O = −2

15. Which of the following reactions are redox reactions? a, c, d

(a) $\overset{0}{H_2} + \overset{0}{Cl_2} \longrightarrow 2\overset{+1\ -1}{HCl}$ (oxidation #s change)

(b) $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$ no changes

(c) $\overset{0}{Zn} + \overset{+2+6-2}{CuSO_4} \longrightarrow \overset{0}{Cu} + \overset{+2+6-2}{ZnSO_4}$

(d) $\overset{+2-2}{2HgO} \longrightarrow 2\overset{0}{Hg} + \overset{0}{O_2}$

Dinitrogen tetroxide (N_2O_4) and hydrazine (N_2H_2) are used as rocket fuels. The reaction between these two compounds produces nitrogen and water, as shown below.

$$\overset{+4\ -2}{N_2O_4} + 2\overset{+2\ +1}{N_2H_4} \longrightarrow \overset{0}{3N_2} + \overset{+1\ -2}{4H_2O}$$

16. What two changes of oxidation number does the nitrogen undergo?

+4 → 0

+2 → 0

17. Does the oxidation number of the oxygen change? No, it is −2 on both sides