

## 3 • Reactions in Aqueous Solution

### M O L A R I T Y

#### Notes:

Concentration can be measured in terms of molarity (M).

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{Liters of solution}} \quad \text{also}$$

$$\text{moles of solute} = (\text{Molarity}) \times (\text{Liters of solution})$$

Dilution problems can be solved with the formula:  $V \cdot M = V \cdot M$

Molarity can be used as a conversion factor to convert **moles** to **Liters** of solutions.

#### Solution Concentration

60. If 6.73 g of  $\text{Na}_2\text{CO}_3$  is dissolved in enough water to make 250. mL of solution, what is the molarity of the sodium carbonate?
62. What is the mass, in grams, of solute in 250. mL of a 0.0125 M solution of  $\text{KMnO}_4$ ?
64. What volume of 0.123 m NaOH, in milliliters, contains 25.0 g of NaOH?

#### Dilution Problems

66. If 4.00 mL of 0.0250 M  $\text{CuSO}_4$  is diluted to 10.0 mL with pure water, what is the molarity of copper(II) sulfate in the diluted solution?

#### Ion Concentrations

70. For each solution, identify the ions that exist in aqueous solution & specify the concentration of each.
- 0.25 M  $(\text{NH}_4)_2\text{SO}_4$
  - 0.056 M  $\text{HNO}_3$
  - 0.123 M  $\text{Na}_2\text{CO}_3$
  - 0.00124 M  $\text{KClO}_4$

#### Stoichiometry of Reactions in Solution

72. What volume of 0.125 M  $\text{HNO}_3$ , in milliliters, is required to react completely with 1.30 g of  $\text{Ba}(\text{OH})_2$ ?
- $$2 \text{HNO}_3(\text{aq}) + \text{Ba}(\text{OH})_2(\text{s}) \rightarrow \text{Ba}(\text{NO}_3)_2(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$$

76. In the photographic developing process, silver bromide is dissolved by adding sodium thiosulfate:
- $$\text{AgBr}(\text{s}) + 2 \text{Na}_2\text{S}_2\text{O}_3(\text{aq}) \rightarrow \text{Na}_3\text{Ag}(\text{S}_2\text{O}_3)_2(\text{aq}) + \text{NaBr}(\text{aq})$$

If you want to dissolve 0.250 g of AgBr, what volume of 0.0138 M  $\text{Na}_2\text{S}_2\text{O}_3$ , in milliliters, should be used?

#### Titration

82. What volume of 0.812 M HCl, in milliliters, is required to titrate 1.33 g of NaOH to the equivalence point?
- $$\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
84. What volume of 0.955 M HCl, in milliliters, is needed to titrate 2.152 g of  $\text{Na}_2\text{CO}_3$  to the equivalence point?
- $$\text{Na}_2\text{CO}_3(\text{aq}) + 2 \text{HCl}(\text{aq}) \rightarrow 2 \text{NaCl}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$



### 3• Reaction in Aqueous Solution

#### NAMING ACIDS

“ate” becomes “\_\_\_\_\_ic acid”  
“ite” becomes “\_\_\_\_\_ous acid”  
“ide” becomes “hydro\_\_\_\_\_ic acid”

in sulfur compounds, add “ur”  
in phosphorus compounds, add “or”

bromate \_\_\_\_\_

perchlorate \_\_\_\_\_

periodate \_\_\_\_\_

bisulfate\* \_\_\_\_\_

carbonate \_\_\_\_\_

hypoiodite \_\_\_\_\_

peroxide\* \_\_\_\_\_

bicarbonate\* \_\_\_\_\_

chloride \_\_\_\_\_

sulfate \_\_\_\_\_

chlorite \_\_\_\_\_

iodite \_\_\_\_\_

thiosulfate \_\_\_\_\_

acetate \_\_\_\_\_

sulfide \_\_\_\_\_

iodide \_\_\_\_\_

dichromate \_\_\_\_\_

bromide \_\_\_\_\_

hypobromite \_\_\_\_\_

hydroxide\* \_\_\_\_\_

sulfite \_\_\_\_\_

phosphate \_\_\_\_\_

chromate \_\_\_\_\_

hypochlorite \_\_\_\_\_

permanganate \_\_\_\_\_

phosphite \_\_\_\_\_

iodate \_\_\_\_\_

oxide\* \_\_\_\_\_

perbromate \_\_\_\_\_

fluoride \_\_\_\_\_

cyanide \_\_\_\_\_

thiocyanate \_\_\_\_\_

chlorate \_\_\_\_\_

bromite \_\_\_\_\_

nitrate \_\_\_\_\_

nitrite \_\_\_\_\_

\* = be careful

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#### Precipitate Practice #1

Write balanced molecular and detailed ionic equations. Strike out any spectator ions.

1. Solutions of lead nitrate and potassium chloride are mixed.
2. Solutions of sodium sulfate and calcium bromide are mixed.
3. Solutions of aluminum acetate and lithium hydroxide are mixed.
4. Solutions of iron(III) sulfate and sodium sulfide are mixed.
5. Solutions of aluminum sulfate and calcium hydroxide are mixed.
6. Solutions of potassium chromate and lead acetate are mixed.
7. Solutions of silver nitrate and ammonium sulfide are mixed.

# 3• Reactions in Aqueous Solution

## Oxidation Numbers & RedOx

### Overview:

There are two kinds of reactions in the world, Oxidation-Reduction Reactions and Acid-Base Reactions. In a redox reaction, electrons are gained and electrons are lost.

Double Replacement Reactions are \_\_\_\_\_ (redox/non-redox/either)  
Single Replacement Reactions are \_\_\_\_\_ (redox/non-redox/either)  
Synthesis Reactions are \_\_\_\_\_ (redox/non-redox/either)  
Decomposition Reactions are \_\_\_\_\_ (redox/non-redox/either)  
Combustion Reactions are \_\_\_\_\_ (redox/non-redox/either)

An important idea to help recognize oxidation-reduction reactions is to identify the oxidation number (or oxidation state) of an atom. The oxidation number is also called the “apparent charge.” Atoms in ionic compounds have charges and these are also the oxidation numbers. Atoms in molecular compounds can also have oxidation numbers, although they do not have charges.

### Rules:

The oxidation number of:

Example:

- an element in the uncombined state is 0.
- a monatomic ion equals the charge on the ion.
- hydrogen is generally +1; in hydrides, -1.
- oxygen is generally -2; in peroxides, -1.
- elements other than oxygen and hydrogen in a neutral compound is such that the sum of the oxidation numbers for all atoms in the compound is 0.
- elements other than oxygen and hydrogen in a polyatomic ion is such that the sum of the oxidation numbers for all atoms in the ion equals the charge on the ion.

### Practice:

Determine the oxidation number of the underlined element. Answers are given below:

1. <u>Ba</u> <sup>2+</sup>	2. <u>N</u> <sub>2</sub>	3. <u>H</u> I	4. <u>O</u> <sub>2</sub> <sup>2-</sup>
5. Ag <u>Br</u>	6. <u>Cu</u> Cl <sub>2</sub>	7. H <u>N</u> O <sub>3</sub>	8. <u>Cl</u> O <sub>3</sub> <sup>-</sup>
9. <u>S</u> O <sub>3</sub>	10. Na <sub>2</sub> <u>S</u> O <sub>3</sub>	11. Ba <u>Cr</u> O <sub>4</sub>	12. Ca <u>S</u> O <sub>4</sub>
1. +2	2. 0	3. +1	4. -1
5. -1	6. +2	7. +5	8. +5
9. +6	10. +4	11. +6	12. +6

## Practice Problems from the Textbook

54. Determine the oxidation number of each element in the following ions or compounds:

- |                                |                             |
|--------------------------------|-----------------------------|
| a) $\text{BrO}_3^-$            | d) $\text{CaH}_2$           |
| b) $\text{C}_2\text{O}_4^{2-}$ | e) $\text{H}_4\text{SiO}_4$ |
| c) $\text{F}_2$                | f) $\text{SO}_4^{2-}$       |

55. Determine the oxidation number of each element in the following ions or compounds:

- |                               |                           |
|-------------------------------|---------------------------|
| a) $\text{SF}_6$              | d) $\text{N}_2\text{O}_4$ |
| b) $\text{H}_2\text{AsO}_4^-$ | e) $\text{PCl}_4^+$       |
| c) $\text{UO}_2^+$            | f) $\text{XeO}_4^{2-}$    |

56. Which of the following reactions is (are) oxidation-reduction reactions? Explain your answer briefly. classify the remaining reactions.

- $\text{Zn(s)} + 2 \text{NO}_3^-(\text{aq}) + 4 \text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2 \text{NO}_2(\text{g}) + 2 \text{H}_2\text{O(l)}$
- $\text{Zn(OH)}_2(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{ZnSO}_4(\text{aq}) + 2 \text{H}_2\text{O(l)}$
- $\text{Ca(s)} + 2 \text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2(\text{s}) + \text{H}_2(\text{g})$

57. Which of the following reactions is (are) oxidation-reduction reactions? Explain your answer briefly. classify the remaining reactions.

- $\text{CdCl}_2(\text{aq}) + \text{Na}_2\text{S}(\text{aq}) \rightarrow \text{CdS(s)} + 2 \text{NaCl(aq)}$
- $2 \text{Ca(s)} + \text{O}_2(\text{g}) \rightarrow 2 \text{CaO(s)}$
- $\text{Ca(OH)}_2(\text{s}) + 2 \text{HCl(aq)} \rightarrow \text{CaCl}_2(\text{aq}) + 2 \text{H}_2\text{O(l)}$

58. In each of the following reactions, decide which reactant is oxidized and which is reduced. Designate the oxidizing agent and reducing agent.

- $2 \text{Mg(s)} + \text{O}_2(\text{g}) \rightarrow 2 \text{MgO(s)}$
- $\text{C}_2\text{H}_4(\text{g}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O(g)}$
- $\text{Si(s)} + 2 \text{Cl}_2(\text{g}) \rightarrow \text{SiCl}_4(\text{l})$

59. In each of the following reactions, decide which reactant is oxidized and which is reduced. Designate the oxidizing agent and reducing agent.

- $\text{Ca(s)} + 2 \text{HCl(aq)} \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2(\text{g})$
- $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 3 \text{Sn}^{2+}(\text{aq}) + 14 \text{H}^+(\text{aq}) \rightarrow 2 \text{Cr}^{3+}(\text{aq}) + 3 \text{Sn}^{4+}(\text{aq}) + 7 \text{H}_2\text{O(l)}$
- $\text{FeS(s)} + 3 \text{NO}_3^-(\text{aq}) + 4 \text{H}^+(\text{aq}) \rightarrow 3 \text{NO(g)} + \text{SO}_4^{2-}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) + 2 \text{H}_2\text{O(l)}$

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#### PRACTICE TEST

- On the basis of the solubility rules, which of the following is insoluble?
  - K<sub>2</sub>O
  - Na<sub>2</sub>CO<sub>3</sub>
  - PbS
  - (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>
  - Ba(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>
- In a double replacement reaction, formation of which of the following does not necessarily lead to a chemical change?
  - HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>
  - AgCl
  - CO<sub>2</sub>
  - H<sub>2</sub>S
  - NaCl
- Reaction of an acid with a carbonate (such as CaCO<sub>3</sub>) always results in the formation of
  - O<sub>2</sub>
  - C<sub>(diamond)</sub>
  - CH<sub>4</sub>
  - O<sub>3</sub>
  - CO<sub>2</sub>
- Which of the following is incorrect?
  - all salts containing NH<sub>4</sub><sup>+</sup> are soluble.
  - all salts containing NO<sub>3</sub><sup>-</sup> are soluble.
  - all fluorides are soluble.
  - all sulfates (except those of Ca<sup>2+</sup>, Sr<sup>2+</sup>, Ba<sup>2+</sup>, and Pb<sup>2+</sup>) are soluble.
  - most hydroxides are insoluble, except those of Ca<sup>2+</sup>, Sr<sup>2+</sup>, Ba<sup>2+</sup>, the alkali metals and NH<sub>4</sub><sup>+</sup>.
- One of the gases shown below is NOT usually formed in a double replacement reaction. Which one?
  - N<sub>2</sub>
  - CO<sub>2</sub>
  - SO<sub>2</sub>
  - NH<sub>3</sub>
  - H<sub>2</sub>S
- Write the balanced molecular equation for the reaction of washing soda, Na<sub>2</sub>CO<sub>3</sub> and vinegar, HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>.
- The net ionic equation for the above reaction is:
- How many moles of H<sup>+</sup> are associated with the acid, H<sub>2</sub>SO<sub>3</sub>, during neutralization?
  - 0
  - 1
  - 2
  - 3
- How many moles Al<sub>2</sub>O<sub>3</sub> are needed to neutralize 1 mole of HCl?
  - 1/3
  - 2/3
  - 2
  - 6
  - 12
  - 1/6
- Write the net reaction that will occur when solid ammonium carbonate is added to a solution of hydrosulfuric acid.

11. When  $\text{H}_2\text{SO}_4$  and  $\text{Ba}(\text{OH})_2$  are reacted in a double replacement reaction, one of the products of the reaction is...
- $\text{H}_2$
  - $\text{H}_2\text{O}$
  - $\text{BaS}$
  - $\text{BaH}_2$
  - $\text{SO}_2$
12. In the double replacement reaction between the weak acid,  $\text{HC}_2\text{H}_3\text{O}_2$  and strong base,  $\text{NaOH}$ , which ion(s) are spectator ions?
- $\text{Na}^+$ ,  $\text{C}_2\text{H}_3\text{O}_2^-$
  - $\text{Na}^+$ ,  $\text{OH}^-$
  - $\text{OH}^-$  only
  - $\text{H}^+$ ,  $\text{C}_2\text{H}_3\text{O}_2^-$
  - $\text{Na}^+$  only
13. Which of the following is a base?
- $\text{KOH}$
  - $\text{C}_2\text{H}_5\text{OH}$
  - $\text{Br}^-$
  - $\text{CH}_3\text{OH}$
  - $\text{CO}_2$
14. Which of the following is a strong acid?
- $\text{H}_2\text{CO}_3$
  - $\text{HF}$
  - $\text{H}_3\text{PO}_4$
  - $\text{HClO}_3$
  - $\text{HNO}_3$
15. Which of the following is an acid in aqueous solutions?
- $\text{H}_2\text{CO}_3$
  - $\text{Al}_2\text{O}_3$
  - $\text{CH}_4$
  - $\text{H}_2\text{O}$
  - $\text{BaO}$
16.  $\text{SO}_2$  turns into which acid in solution?
- $\text{HNO}_3$
  - $\text{H}_2\text{SO}_3$
  - $\text{H}_2\text{SO}_4$
  - $\text{H}_2\text{S}$
  - $\text{HNO}_2$
17. What is the oxidation number of C in  $\text{CO}_3^{2-}$ ?
- +6
  - +4
  - +2
  - +1
  - 1
18. What is the oxidation number of Br in  $\text{KBrO}_4$ ?
- +1
  - 1
  - +5
  - +7
  - +8
19. For each change below, label the change of the underlined element as **Oxidation**, **Reduction**, or **Neither**
- \_\_\_  $\underline{\text{Cu}}^{2+} \rightarrow \underline{\text{Cu}}^0$
- \_\_\_  $\underline{\text{C}}\text{H}_4 \rightarrow \underline{\text{C}}\text{O}_2$
- \_\_\_  $\text{H}_2\underline{\text{O}}_2 \rightarrow \text{H}_2\underline{\text{O}}$
- \_\_\_  $\underline{\text{C}}\text{O}_2 \rightarrow \text{H}_2\underline{\text{C}}\text{O}_3$
20. How many milliliters of 0.123 M  $\text{NaOH}$  solution contain 25.0 g of  $\text{NaOH}$  (molar mass = 40.00 g/mol)?
- 5.08 mL
  - 50.8 mL
  - 508 mL
  - 625 mL
  - 5080 mL
21. If you need 1.00 L of 0.125 M  $\text{H}_2\text{SO}_4$ , how would you prepare this solution?
- Add 950. mL of water to 50.0 mL of 3.00 M  $\text{H}_2\text{SO}_4$ .
  - Add 500. mL of water to 500. mL of 0.500 M  $\text{H}_2\text{SO}_4$ .
  - Add 750 mL of water to 250 mL of 0.375 M  $\text{H}_2\text{SO}_4$ .
  - Dilute 36.0 mL of 1.25 M  $\text{H}_2\text{SO}_4$  to a volume of 1.00 L.
  - Dilute 20.8 mL of 6.00 M  $\text{H}_2\text{SO}_4$  to a volume of 1.00 L.
22. What is the ion concentration in a 0.12 M solution of  $\text{BaCl}_2$ ?
- $[\text{Ba}^{2+}] = 0.12 \text{ M}$  and  $[\text{Cl}^-] = 0.12 \text{ M}$ .
  - $[\text{Ba}^{2+}] = 0.12 \text{ M}$  and  $[\text{Cl}^-] = 0.060 \text{ M}$ .
  - $[\text{Ba}^{2+}] = 0.12 \text{ M}$  and  $[\text{Cl}^-] = 0.24 \text{ M}$ .
  - $[\text{Ba}^{2+}] = 0.060 \text{ M}$  and  $[\text{Cl}^-] = 0.060 \text{ M}$ .
  - $[\text{Ba}^+] = 0.12 \text{ M}$  and  $[\text{Cl}_2^-] = 0.12 \text{ M}$ .

23. What is the molarity of the solution that results when 60.0 g NaOH is added to enough water to make 500. mL solution?
- a) 1.33 M                      d) 8.0 M  
b) 12.0 M                      e) 1.50 M  
c) 3.00 M
24. What is the molarity of the solution that results when 45.0 g HCl is dissolved in enough water to make 250. mL solution?
- a) 4.94 M                      d) 1.80 M  
b) 4.50 M                      e) 1.46 M  
c) 3.24 M
25. What is the concentration of Cl<sup>-</sup> ion in 0.60 M AlCl<sub>3</sub> solution?
- a) 1.8 M                      d) 0.30 M  
b) 0.60 M                      e) 0.10 M  
c) 0.20 M
26. How many grams of Na<sub>2</sub>CO<sub>3</sub> (molar mass = 106.0 g/mol) are required for complete reaction with 25.0 mL of 0.155 M HNO<sub>3</sub>?
- $$\text{Na}_2\text{CO}_3 + 2\text{HNO}_3 \rightarrow 2\text{NaNO}_3 + \text{CO}_2 + \text{H}_2\text{O}$$
- a) 0.122 g                      d) 20.5 g  
b) 0.205 g                      e) 205 g  
c) 0.410 g
27. What volume of 0.150 M NaOH is needed to react completely with 3.45 g iodine according to the equation:
- $$3 \text{I}_2 + 6 \text{NaOH} \rightarrow 5 \text{NaI} + \text{NaIO}_3 + 3 \text{H}_2\text{O}$$
- a) 181 mL                      d) 2.04 mL  
b) 45.3 mL                      e) 1.02 mL  
c) 4.08 mL
28. What is the concentration of an NaOH solution if it takes 16.25 mL of a 0.100 M HCl solution to titrate 25.00 mL of the NaOH solution?
- a) 0.0165 M                      d) 0.100 M  
b) 0.151 M                      e) 0.413 M  
c) 0.0650 M
29. A 4.00 M solution of H<sub>3</sub>PO<sub>4</sub> will contain \_\_\_\_g of H<sub>3</sub>PO<sub>4</sub> in 0.250 L of solution.
- a) 196 g                      d) 24.0 g  
b) 98.0 g                      e) 12.0 g  
c) 49.0 g