Chapter 4: Reactions in Aqueous Solutions

Molarity Calculations

Calculate the molarities of the following solutions:

1) 2.3 moles of sodium chloride in 0.45 liters of solution.

2) 1.2 moles of calcium carbonate in 1.22 liters of solution.

3) 0.09 moles of sodium sulfate in 12 mL of solution.

4) 0.75 moles of lithium fluoride in 65 mL of solution.

5) 0.8 moles of magnesium acetate in 5 liters of solution.

6) 120 grams of calcium nitrite in 240 mL of solution.

7) 98 grams of sodium hydroxide in 2.2 liters of solution.

8) 1.2 grams of hydrochloric acid in 25 mL of solution.

9) 45 grams of ammonia in 0.75 L of solution.

①

Explain how you would make the following solutions. You should tell how many grams of the substance you need to make the solution, not how many moles.

10)   2 L of 6 M HCl

11)   1.5 L of 2 M NaOH

12)   0.75 L of 0.25 M Na_2SO_4

13)   45 mL of 0.12 M sodium carbonate

14)   250 mL of 0.75 M lithium nitrite

15)   56 mL of 1.1 M iron (II) phosphate

16)   6.7 L of 4.5 M ammonium nitrate

17)   4.5 mL of 0.05 M magnesium sulfate

18)   90 mL of 1.2 M BF_3

Molarity Practice Problems

1) How many grams of potassium carbonate are needed to make 200 mL of a 2.5 M solution?

2) How many liters of 4 M solution can be made using 100 grams of lithium bromide?

3) What is the concentration of a 450 mL solution that contains 200 grams of iron (II) chloride?

4) How many grams of ammonium sulfate are needed to make a 0.25 M solution at a concentration of 6 M?

5) What is the concentration of a solution that has a volume of 2.5 L and contains 660 grams of calcium phosphate?

6) How many grams of copper (II) fluoride are needed to make 6.7 liters of a 1.2 M solution?

7) How many liters of 0.88 M solution can be made with 25.5 grams of lithium fluoride?

8) What is the concentration of a solution that with a volume of 660 that contains 33.4 grams of aluminum acetate?

9) How many liters of 0.75 M solution can be made using 75 grams of lead (II) oxide?

10) How many grams of manganese (IV) oxide are needed to make a 5.6 liters of a 2.1 M solution?

11) What is the concentration of a solution with a volume of 9 mL that contains 2 grams of iron (III) hydroxide?

12) How many liters of 3.4 M solution can be made using 78 grams of isopropanol (C_3H_8O)?

13) What is the concentration of a solution with a volume of 3.3 mL that contains 12 grams of ammonium sulfite?

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Dilutions Worksheet

1) If I have 340 mL of a 0.5 M NaBr solution, what will the concentration be if I add 560 mL more water to it?

2) If I dilute 250 mL of 0.10 M lithium acetate solution to a volume of 750 mL, what will the concentration of this solution be?

3) If I leave 750 mL of 0.50 M sodium chloride solution uncovered on a windowsill and 150 mL of the solvent evaporates, what will the new concentration of the sodium chloride solution be?

4) To what volume would I need to add water to the evaporated solution in problem 3 to get a solution with a concentration of 0.25 M?

Oxidation State Worksheet

*In each of the following chemicals, determine the oxidation states of each element:*

1) sodium nitrate _____

2) ammonia _____

3) zinc oxide _____

4) water _____

5) calcium hydride _____

6) carbon dioxide _____

7) nitrogen _____

8) sodium sulfate _____

9) aluminum hydroxide _____

10) magnesium phosphate _____

In each of the following reactions, determine what was oxidized and what was reduced.
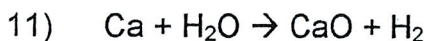
11) $Ca + H_2O \rightarrow CaO + H_2$

Element oxidized: _____

Element reduced: _____

12) $2 H_2 + O_2 \rightarrow 2 H_2O$

Element oxidized: _____

Element reduced: _____

⑥
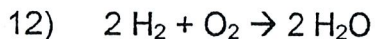
5 • Reactions in Aqueous Solution

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

    a) ~~BrO₃⁻~~

    b) $C_2O_4^{2-}$

    c) F_2

    d) CaH_2

    e) H_2SiO_4

    f) SO_4^{2-}

2. Determine the oxidation number of **each element** in the following ions or compounds:
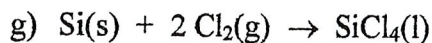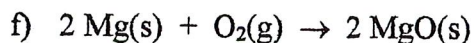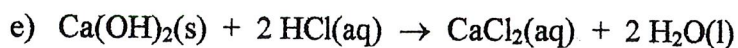
    a) SF_6

    b) $H_2AsO_4^-$

    c) UO_2^+

    d) N_2O_4

    e) PCl_4^+

    f) XeO_4^{2-}

3. Which of the following reactions is (are) oxidation-reduction reactions?

    a) $Zn(s) + 2 NO_3^-(aq) + 4 H^+(aq) \rightarrow Zn^{2+}(aq) + 2 NO_2(g) + 2 H_2O(l)$

    b) $Zn(OH)_2(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + 2 H_2O(l)$

    c) $Ca(s) + 2 H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$

    d) $2 Ca(s) + O_2(g) \rightarrow 2 CaO(s)$

    e) $Ca(OH)_2(s) + 2 HCl(aq) \rightarrow CaCl_2(aq) + 2 H_2O(l)$

    f) $2 Mg(s) + O_2(g) \rightarrow 2 MgO(s)$

    g) $Si(s) + 2 Cl_2(g) \rightarrow SiCl_4(l)$
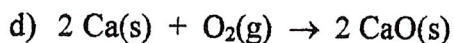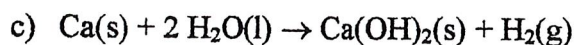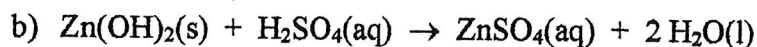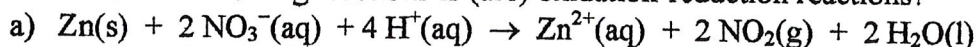
5 • Reaction in Aqueous Solution

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	BrO_3^-	$HBrO_3$	Bromic acid	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

5 • Reactions in Aqueous Solution

NAMING

Type of Compound	Ionic	Acids	Molecular
How To Recognize	Recognize + and - ion	H+ and - ion	Not Ionic
How To Name	names of + ion then - ion	"ides" → hydro---ic acid "ates" → ----ic acid "ites" → ---ous acid S (add "ur") P (add "or")	mono, di, tri, tetra, penta, hexa, hepta, octa, nona ,deca names ends with "ide" pentaoxide → pentoxide, etc.

Indicate the Type of Compound and then name the compound using the appropriate rules:

1. NaF   I Sodium Fluoride
2. $FeCl_3$ ___ _____
3. CO_2 ___ _____
4. $MgCl_2$ ___ _____
5. HF   ___ _____
6. SF_4 ___ _____
7. $HC_2H_3O_2$ ___ _____
8. H_2O ___ _____
9. NH_3 ___ _____
10. CaO   ___ _____
11. NH_4NO_3 ___ _____
12. NaI   ___ _____
13. $PbCO_3$ ___ _____
14. Na_2O ___ _____
15. $Ba(NO_3)_2$ ___ _____
16. K_2CrO_4 ___ _____
17. NO   ___ _____
18. HCl   ___ _____

20. H_2S ___ _____

21. $CuCl_2$ ___ _____
22. $AgNO_3$ ___ _____
23. CO   ___ _____
24. H_3PO_4 ___ _____
25. NaCl   ___ _____
26. N_2O_5 ___ _____
27. NO_2 ___ _____
28. HNO_3 ___ _____
29. NaOH   ___ _____
30. $SnCl_2$ ___ _____
31. $CaSO_4$ ___ _____
32. HBr   ___ _____
33. $Cu(OH)_2$ ___ _____
34. $Zn(OH)_2$ ___ _____
35. $BaCl_2$ ___ _____
36. PCl_5 ___ _____
37. PCl_3 ___ _____
38. AsF_5 ___ _____
39. H_2CO_3 ___ _____
40. OF_2 ___ _____

5 • Reactions in Aqueous Solution

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.

# 5 • Reactions in Aqueous Solution

Precipitate Practice #1

A. Write balanced molecular reaction included phases
B. On another sheet of paper write a complete ionic equations
C. Strike out any spectator ions and write a net ionic equation

1. Solutions of lead (II) 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 (II) acetate are mixed.

7. Solutions of silver nitrate and ammonium sulfide are mixed.

⑪
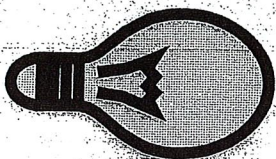
Electrolytes

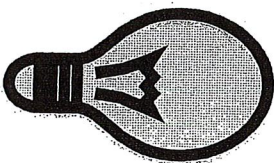## Strong Electrolytes

Ionize 100%

Strong Bases

Strong Acids

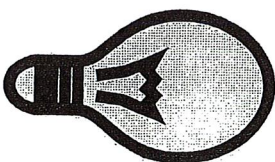Ionic compounds
Salt
Metal + nonmetal
NaCl

Weak Electrolytes
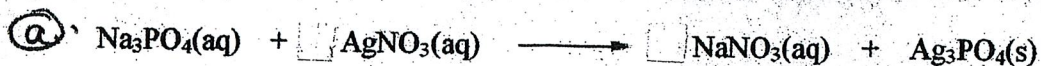
Partially Ionize

Weak Bases
NH_3

Weak Acids

Non-electrolytes

Molecule/don't ionize
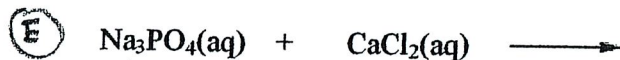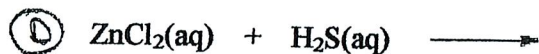
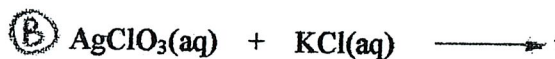Molecular compound
Nonmetal + nonmetal
CH_3CN
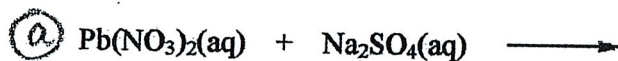$C_6H_6O_6$

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Chapter 4: Worksheet #3: Molecular, Net Ionic Equations, Solubility Rules, & Redox

1. Write the net ionic equations for each of the following **unbalanced** molecular equations.

   (a) $Na_3PO_4(aq) + AgNO_3(aq) \longrightarrow NaNO_3(aq) + Ag_3PO_4(s)$

   (b) $K_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + KCl(aq)$

   (c) $Hg_2(NO_3)_2(aq) + CaCl_2(aq) \longrightarrow Ca(NO_3)_2(aq) + Hg_2Cl_2(s)$

2. Using the solubility rules, predict the products, balance the equation, and write the complete ionic and net ionic equations for each of the following reactions.

   (a) $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \longrightarrow$

   (b) $AgClO_3(aq) + KCl(aq) \longrightarrow$

   (c) $KOH(aq) + Fe(NO_3)_3(aq) \longrightarrow$

   (d) $ZnCl_2(aq) + H_2S(aq) \longrightarrow$

   (e) $Na_3PO_4(aq) + CaCl_2(aq) \longrightarrow$

13

3. You have a sugar solution (solution *A*) with concentration *x*. You pour one-fourth of this solution into a beaker, and add an equivalent volume of water (solution *B*).
   a. What is the ratio of sugar in solutions *A* and *B*?
   b. Compare the volumes of solutions *A* and *B*.
   c. What is the ratio of the concentrations of sugar in solutions *A* and *B*?

4. You add an aqueous solution of lead nitrate to an aqueous solution of potassium iodide. Draw highly magnified views of each solution individually, and the mixed solution including any product that forms. Write the balanced equation for the reaction.

5. Order the following molecules from lowest to highest oxidation state of the nitrogen atom: HNO_3, NH_4Cl, N_2O, NO_2, $NaNO_2$.

6. Why is it that when something gains electrons, it is said to be *reduced*? What is being reduced?

7. Consider separate aqueous solutions of HCl and H_2SO_4 with the same molar concentrations. You wish to neutralize an aqueous solution of NaOH. For which acid solution would you need to add more volume (in milliliters) to neutralize the base?
   a. the HCl solution
   b. the H_2SO_4 solution
   c. You need to know the acid concentrations to answer this question.
   d. You need to know the volume and concentration of the NaOH solution to answer this question.
   e. c and d
   Explain.

8. Draw molecular-level pictures to differentiate between concentrated and dilute solutions.

A blue question or exercise number indicates that the answer to that question or exercise appears at the back of this book and a solution appears in the *Solutions Guide*.

Questions

9. Distinguish between the terms *slightly soluble* and *weak electrolyte*.

10. How would you determine experimentally whether a substance is a strong or weak electrolyte?

Exercises

In this section similar exercises are paired.

Aqueous Solutions: Strong and Weak Electrolytes

11. Show how each of the following strong electrolytes "breaks up" into its component ions upon dissolving in water.

a. NaBr   f. $FeSO_4$
b. $MgCl_2$ g. $KMnO_4$
c. $Al(NO_3)_3$ h. $HClO_4$
d. $(NH_4)_2SO_4$ i. $NH_4C_2H_3O_2$ (ammonium ac
e. HI

12. Show how each of the following strong acids or stro "breaks up" into its component ions upon dissolving
   a. HCl
   b. HNO_3
   c. $Ca(OH)_2$
   d. KOH

13. Calcium chloride is a strong electrolyte and is used t streets in the winter to melt ice and snow. Write a rea show how this substance breaks apart when it dissc water.

14. Commercial cold packs and hot packs are available fc ing athletic injuries. Both types contain a pouch of wa a dry chemical. When the pack is struck, the pouch o breaks, dissolving the chemical, and the solution beco ther hot or cold. Many hot packs use magnesium sulfa many cold packs use ammonium nitrate. Write react show how these strong electrolytes break apart whe dissolve in water.

Solution Concentration: Molarity

15. Calculate the molarity of each of these solutions.
   a. A 5.623-g sample of $NaHCO_3$ is dissolved in enoug ter to make 250.0 mL of solution.
   b. A 184.6-mg sample of $K_2Cr_2O_7$ is dissolved in ei water to make 500.0 mL of solution.
   c. A 0.1025-g sample of copper metal is dissolved in 3 of concentrated HNO_3 to form Cu^{2+} ions and then is added to make a total volume of 200.0 mL. (Calc the molarity of Cu^{2+}.)

16. Calculate the molarity of each of the following solut
   a. A 16.45-g sample of NaCl is dissolved in enough wal make 1.000 L of solution.
   b. An 853.5-mg sample of KIO_3 is dissolved in enough ter to make 250.0 mL of solution.
   c. A 0.4508-g sample of iron is dissolved in a small am of concentrated nitric acid forming Fe^{3+} ions in sol and is diluted to a total volume of 500.0 mL. (Calc the molarity of Fe^{3+}.)

17. Calculate the concentration of all ions present in each of following solutions of strong electrolytes.
   a. 0.15 M $CaCl_2$
   b. 0.26 M $Al(NO_3)_3$
   c. 0.25 M $K_2Cr_2O_7$
   d. 2.0×10^{-3} M $Al_2(SO_4)_3$

18. Calculate the concentration of all ions present in each of following solutions of strong electrolytes.
   a. 0.100 mol of $Ca(NO_3)_2$ in 100.0 mL of solution
   b. 2.5 mol of Na_2SO_4 in 1.25 L of solution

c. 5.00 g of NH_4Cl in 500.0 mL of solution

d. 1.00 g K_3PO_4 in 250.0 mL of solution

Which of the following solutions of strong electrolytes contains the largest number of moles of chloride ions: 100.0 mL of 0.30 M $AlCl_3$, 50.0 mL of 0.60 M $MgCl_2$, or 200.0 mL of 0.40 M NaCl?

Which of the following solutions of strong electrolytes contains the largest number of ions: 100.0 mL of 0.100 M NaOH, 50.0 mL of 0.200 M $BaCl_2$, or 75.0 mL of 0.150 M Na_3PO_4?

What volume of a 0.100 M solution of $NaHCO_3$ contains 0.350 g of $NaHCO_3$?

How many grams of NaOH are contained in 250.0 mL of a 0.400 M sodium hydroxide solution?

Describe how you would prepare 2.00 L of each of the following solutions.

a. 0.250 M NaOH from solid NaOH

b. 0.250 M NaOH from 1.00 M NaOH stock solution

c. 0.100 M K_2CrO_4 from solid K_2CrO_4

d. 0.100 M K_2CrO_4 from 1.75 M K_2CrO_4 stock solution

How would you prepare 1.00 L of a 0.50 M solution of each of the following?

a. H_2SO_4 from "concentrated" (18 M) sulfuric acid

b. HCl from "concentrated" (12 M) reagent

c. $NiCl_2$ from the salt $NiCl_2 \cdot 6H_2O$

d. HNO_3 from "concentrated" (16 M) reagent

e. Sodium carbonate from the pure solid

A solution is prepared by dissolving 10.8 g ammonium sulfate in enough water to make 100.0 mL of stock solution. A 10.00-mL sample of this stock solution is added to 50.00 mL of water. Calculate the concentration of ammonium ions and sulfate ions in the final solution.

Calculate the sodium ion concentration when 70.0 mL of 3.0 M sodium carbonate is added to 30.0 mL of 1.0 M sodium bicarbonate.

A standard solution is prepared for the analysis of fluoxymesterone ($C_{20}H_{29}FO_3$), an anabolic steroid. A stock solution is first prepared by dissolving 10.0 mg of fluoxymesterone in enough water to give a total volume of 500.0 mL. A 100.0-μL aliquot (portion) of this solution is diluted to a final volume of 100.0 mL. Calculate the concentration of the final solution in terms of molarity.

A stock solution containing Mn^{2+} ions was prepared by dissolving 1.584 g pure manganese metal in nitric acid and diluting to a final volume of 1.000 L. The following solutions were then prepared by dilution:

For solution A, 50.00 mL of stock solution was diluted to 1000.0 mL.

For solution B, 10.00 mL of solution A was diluted to 250.0 mL.

For solution C, 10.00 mL of solution B was diluted to 500.0 mL.

Calculate the concentrations of the stock solution and solutions A, B, and C.

Precipitation Reactions

29. When the following solutions are mixed together, what precipitate (if any) will form?

a. $BaCl_2(aq) + Na_2SO_4(aq)$

b. $Pb(NO_3)_2(aq) + KCl(aq)$

c. $AgNO_3(aq) + Na_3PO_4(aq)$

d. $NaOH(aq) + Fe(NO_3)_3(aq)$

30. When the following solutions are mixed together, what precipitate (if any) will form?

a. $FeSO_4(aq) + KCl(aq)$

b. $Al(NO_3)_3(aq) + Ba(OH)_2(aq)$

c. $CaCl_2(aq) + Na_2SO_4(aq)$

d. $K_2S(aq) + Ni(NO_3)_2(aq)$

31. For the reactions in Exercise 29, write the balanced molecular equation, complete ionic equation, and net ionic equation. If no precipitate forms, write "No reaction."

32. For the reactions in Exercise 30, write the balanced molecular equation, complete ionic equation, and net ionic equation. If no precipitate forms, write "No reaction."

33. Write net ionic equations for each of the following.

a. $AgNO_3(aq) + KI(aq) \rightarrow$

b. $CuSO_4(aq) + Na_2S(aq) \rightarrow$

c. $CoCl_2(aq) + NaOH(aq) \rightarrow$

d. $NiCl_2(aq) + KNO_3(aq) \rightarrow$

34. Write net ionic equations for each of the following.

a. $AgNO_3(aq) + BaCl_2(aq) \rightarrow$

b. $FeSO_4(aq) + K_2S(aq) \rightarrow$

c. $NaOH(aq) + K_2SO_4(aq) \rightarrow$

d. $Hg_2(NO_3)_2(aq) + CaCl_2(aq) \rightarrow$

35. Write net ionic equations for the reaction, if any, that occurs when aqueous solutions of the following are mixed.

a. Ammonium sulfate and barium nitrate

b. Lead(II) nitrate and sodium chloride

c. Sodium phosphate and potassium nitrate

d. Sodium bromide and rubidium chloride

e. Copper(II) chloride and sodium hydroxide

36. Write net ionic equations for the reaction, if any, that occurs when aqueous solutions of the following are mixed.

a. cobalt(III) chloride and sodium hydroxide

b. silver nitrate and ammonium carbonate

c. copper(II) sulfate and mercury(II) chloride

d. strontium nitrate and potassium iodide

37. A lake may be polluted with Pb^{2+} ions. What precipitation reaction might you use to test for the presence of Pb^{2+}?

38. A sample may contain any or all of the following ions: Hg_2^{2+}, Ba^{2+}, and Mn^{2+}. No precipitate formed when an aqueous solution of NaCl or Na_2SO_4 was added to the sample solution. A precipitate formed when the sample solution was made basic with NaOH. Which ion or ions are present in the sample solution?

Chemistry Chapter 4 Review

This is a general review for some of the topics that we covered in chapter 4. This is intended as a supplementary study tool, all material in notes and in the text may be tested on.

1. What is the difference between a nonelectrolyte and an electrolyte?

2. What property of water enables its molecules to interact with ions in solution?

3. Classify the following, X each box that applies to the compound.

Compound	Strong electrolyte	Weak Electrolyte	Nonelectrolyte
HCl			
$C_{12}H_{22}O_{11}$			
LiOH			
NaF			
NaCl			
NaOH			
$Mg(OH)_2$			
H_2SO_4			
CH_3COOH			

4. What is the difference between an ionic compound and a molecular compound?

5. Which of the following compounds are not soluble in water?

	Soluble	Insoluble
$ZnSO_4$		
$Hg(NO_3)_2$		
$Ca(OH)_2$		
$AgClO_3$		
$Mn(OH)_2$		

6. Complete the reaction and show the molecular, complete ionic, net ionic equations.
Mixing a $NaNO_3$ solution with a $CuSO_4$ solution.

Molecular:

Complete Ionic:

Net ionic:

7.
Which of the following is not a salt?
     A) NaF
     B) CaO
     C) CH_4
     D) KBr

8.
Which of the following is a weak acid?
     A) HBr
     B) HCl
     C) HI
     D) None

9.
Which of the following is a weak base?
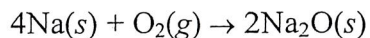   A) LiOH
     B) NaOH
     C) AlOH
     D) HBr

10. Arrange the following species in order of increasing oxidation number of the sulfur atom:
H_2S, S_8, H_2SO_4, S^{3-}.

_____ < _____ < _____ < _____

10. For the following reaction which species is:

    Oxidized_____   Reduced:_____

    Oxidizing Agent :_____   Reducing Agent:_____

$$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$$

11. Give the oxidation number of the underlined atoms in:

    $\underline{Mg}F_2$ _____ $\underline{Fe}F_7$ _____ $\underline{C}_2H_2$ _____   K$\underline{Mn}O_4$ _____

12. Calculate the mass of KI in grams required to prepare 5.00×10^2 mL of a 2.80 M solution.

13. How many moles of $MgCl_2$ are present in 60.0 mL of 0.100 M $MgCl_2$ solution?

14. How many grams of KOH are present in 35.0 mL of a 5.50 M solution?

15. Calculate the molarity of a solution of 15.4 g of sucrose ($C_{12}H_{22}O_{11}$) in 74.0 mL of solution.

16. Calculate the molarity of a solution of 10.4 g of calcium chloride ($CaCl_2$) in 2.20×10^2 mL of solution.

17. Calculate the volume in **mL** required to provide 2.14 g of sodium chloride from a 0.270 M solution.

18. Water is added to 25.0 mL of a 0.866 M KNO_3 solution until the volume of the solution is exactly 500 mL. What is the concentration of the final solution?

19. You have 505 mL of a 0.125 M HCl solution and you want to dilute it to exactly 0.100 M. **How much water should you add?** (Think about the formula you are using and what it tells you)

20. Calculate the volume in mL of a 1.420 M NaOH solution required to titrate 25.00 mL of a 2.430 M HCl solution.

21. When aqueous solutions of Na_2SO_4 and $Pb(NO_3)_2$ are mixed, $PbSO_4$ precipitates. Calculate the mass of $PbSO_4$ formed when 1.25 L of 0.0500 M $Pb(NO_3)_2$ and 2.00L of 0.0250 M Na2SO4 are mixed?