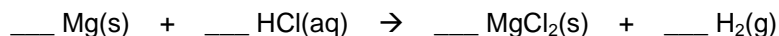# Chemistry: *Chemical Equations*

Write a balanced chemical equation for each word equation. Include the phase of each substance in the equation. Classify the reaction as synthesis, decomposition, single replacement, or double replacement.

1. Solid magnesium reacts with oxygen gas to yield solid magnesium oxide.

2. Solid aluminum reacts with a solution of lead (II) nitrate to yield solid lead and aqueous aluminum nitrate.

3. Solid diphosphorus pentoxide reacts with solid barium oxide to yield solid barium phosphate.

4. When heated, solid lead (IV) oxide breaks down into solid lead (II) oxide and oxygen gas.

5. A solution containing silver nitrate and potassium sulfate reacts to form a silver sulfate precipitate. The potassium nitrate that is formed remains in solution.
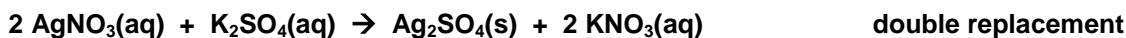
6. Solid sodium hydroxide decomposes into solid sodium oxide and liquid water.

7. Fluorine gas reacts with liquid water to form ozone gas and aqueous hydrofluoric acid.

8. Solid iron reacts with oxygen gas to yield solid iron (III) oxide.

9. Chlorine gas reacts with a solution of lithium iodide to form lithium chloride solution and iodine gas.

10. A solution of ammonium carbonate and lead (II) nitrate yields a solution of ammonium nitrate and a lead (II) carbonate precipitate.
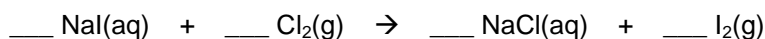
Chemistry: *Stoichiometry*

Balance the equations; then solve the following problems. Assume that excess amounts of other reactants are available, unless otherwise specified.

1. If 20.0 g of magnesium react with excess hydrochloric acid, what mass of magnesium chloride is produced?

$$\_\_\_ Mg(s) \ + \ \_\_\_ HCl(aq) \ \rightarrow \ \_\_\_ MgCl_2(s) \ + \ \_\_\_ H_2(g)$$

2. How many dm^3 of chlorine gas are needed (at STP) if 10.0 g of sodium chloride must be produced?

$$\_\_\_ NaI(aq) \ + \ \_\_\_ Cl_2(g) \ \rightarrow \ \_\_\_ NaCl(aq) \ + \ \_\_\_ I_2(g)$$

3. If 30.0 g of calcium hydroxide react with ammonium sulfate, how many molecules of ammonia are produced?

$$\_\_\_ (NH_4)_2SO_4(aq) \ + \ \_\_\_ Ca(OH)_2(s) \ \rightarrow \ \_\_\_ CaSO_4(s) \ + \ \_\_\_ NH_3(g) \ + \ \_\_\_ H_2O(l)$$

4. If 554 L of oxygen are consumed, how many kJ of energy are released?

$$\_\_\_ C_6H_{12}O_6(s) \ + \ \_\_\_ O_2(g) \ \rightarrow \ \_\_\_ CO_2(g) \ + \ \_\_\_ H_2O(l) \ + \ 2870 \ kJ$$

5. If 36.5 g of hydrochloric acid and 73.0 g of zinc are put together…

   A. …write a balanced chemical equation for this reaction.

   B. …determine the limiting reactant.

   C. …find the maximum volume of hydrogen gas formed at STP.

   D. …determine the mass of excess reactant that is left over, if the reaction is 100% efficient.

   E. …find actual volume of hydrogen produced at STP if the percent yield is 91.6%.

Chemistry: *Phase Changes and Calorimetry*

Solve each of the problems below. You may need to use some of the information given in the table.

Acetic acid (CH_3COOH)	$c_p = 2.05$ J/g°C		
Aluminum	$c_p = 0.89$ J/g°C	$c_f = 389$ J/g	$c_v = 10778$ J/g
Chalk ($CaCO_3$)	$c_p = 0.920$ J/g°C		
Glass	$c_p = 0.753$ J/g°C		
Gold	$c_p = 0.128$ J/g°C	$c_f = 65$ J/g	$c_v = 1742$ J/g
Kerosene	$c_p = 2.09$ J/g°C		
Toluene ($C_6H_5CH_3$)	$c_p = 1.80$ J/g°C		

Find the change in energy when…

1. …14.2 g of water condense at 100°C.

2. …27.3 g of aluminum freeze at 660°C.

3. …76.4 g of gold melt at 1064°C.

4. …49.2 g of acetic acid are heated from 24.1°C to 67.3°C.

5. …9.61 g of toluene are heated from 19.6°C to 75.0°C.

6. …2.47 g of kerosene are heated from 17.1°C to 46.7°C.

7. …31.9 g of chalk are cooled from 83.2°C to 55.5°C.

8. …63.6 g of glass are cooled from 95.5°C to 42.3°C.

9. …175 g of water are heated from – 11.0°C to 140.0°C.

10. If 100.0 g of 27°C water are placed in an insulated flask, how many g of ice at 0°C must be added so that the final temperature is 5.0°C?

Chemistry: *The Gas Laws*

Solve each of the problems below, showing your work and using proper units.

1. A sample of hydrogen has an initial volume of 75.0 cm^3 and an initial temperature of 20.0°C. If the temperature drops to –10.0°C and the pressure remains constant, find the new volume.

2. A gas occupies 560.0 dm^3 of space at 120.0°C. To what temperature (in °C) must the gas be cooled for it to occupy 400.0 dm^3?

3. At 25.0°C and 121 kPa, find the volume occupied by a 183 g sample of chlorine.

4. At 58°C and an unknown pressure, a sample of oxygen has a volume of 433 mL. If the gas takes up 868 mL at STP, find the initial pressure, in atm.

5. At a certain temperature and pressure, chlorine molecules have an average velocity of 412 m/s. Find the average velocity of sulfur dioxide molecules under the same conditions.

6. Find the pressure of the confined gas, in mm Hg.

7. One sample of Xe in a 3.55 L container exerts a pressure of 6.2 atm. A second sample of Xe is confined into a 1.85 L container and exerts 2.4 atm of pressure. If these samples are placed together into a 9.75 L container, find the resulting pressure.

8. Propane burns according to the equation: $C_3H_8(g)$ + $5 O_2(g)$ → $3 CO_2(g)$ + $4 H_2O(g)$

   If the sample of propane occupies 22 L at 30°C and under 12 atm of pressure, how many grams of oxygen are needed to react with all of the propane?

Chemistry: *Solutions*

Solve each of the problems below, showing your work and using correct units.

1. Calculate the molarity of the following solutions.

   A. 30.0 g of acetic acid (CH_3COOH) in 825 mL of solution

   B. 49.0 g of phosphoric acid (H_3PO_4) in 2.05 L of solution

   C. 0.375 kg of potassium hydroxide (KOH) in 4750 mL of solution

2. Calculate the number of liters of solution needed to make each of the following.

   A. a 2.00 M solution using 80.0 g of sodium hydroxide (NaOH)

   B. a 0.500 M solution using 56 g of ammonium hydroxide (NH_4OH)

   C. a 6.00 M solution using 126 g of nitric acid (HNO_3)

3. Calculate the mass of solute in the following solutions.

   A. 250.0 mL of 2.00 M $Na_2SO_4 \cdot 7H_2O$ solution

   B. 1.500 L of 0.240 M KH_2PO_4 solution

   C. 25,000 mL of 4.00 M HCl solution

4. What volume of 2.50 M H_2SO_4 can be made from 4.00 L of 12.3 M H_2SO_4?

5. Given the balanced chemical equation: $2 Al(s)$ + $3 CuSO_4(aq)$ → $3 Cu(s)$ + $Al_2(SO_4)_3(aq)$

   What volume of 0.25 M $CuSO_4$ is required to completely react with 125 g of aluminum?

Chemistry: *Equilibrium*

Answer each question below by writing SHIFT LEFT (or ←), SHIFT RIGHT (or →), or NO SHIFT to indicate what happens to the equilibrium position when the indicated stress or condition change occurs.

1. For the balanced chemical equation: $N_2(g) + 3 H_2(g) \leftrightarrow 2 NH_3(g) + energy$

   remove $NH_3(g)$ _____

   decrease pressure _____

2. For the balanced chemical equation: $CO_2(g) + H_2(g) + energy \leftrightarrow CO(g) + H_2O(l)$

   decrease temperature _____

   add a catalyst _____

3. For the balanced chemical equation: $2 SO_2(g) + O_2(g) \leftrightarrow 2 SO_3(g) + energy$

   increase $SO_2(g)$ concentration _____

   increase temperature _____

4. For the balanced chemical equation: $CO_2(g) + C(s) + energy \leftrightarrow 2 CO(g)$

   increase temperature _____

   increase CO concentration _____

5. For the balanced chemical equation: $N_2O_4(g) + energy \leftrightarrow 2 NO_2(g)$

   decrease pressure _____

   remove $N_2O_4(g)$ _____

6. For the balanced chemical equation: $H_2(g) + Cl_2(g) \leftrightarrow 2 HCl(g) + energy$

   increase $H_2(g)$ concentration _____

   increase pressure _____

7. For the balanced chemical equation: $N_2(g) + O_2(g) + energy \leftrightarrow 2 NO(g)$

   decrease $O_2(g)$ concentration _____

   add a catalyst _____

8. For the balanced equation: $CO_2(aq) + 2 NH_3(aq) \leftrightarrow NH_2CONH_2(aq) + H_2O(l) + energy$

   remove $NH_2CONH_2(aq)$ _____

   increase CO_2 concentration _____

   increase temperature _____

   add a catalyst _____

Chemistry: *Acids and Bases*

Solve each of the problems below, showing your work and using correct units.

1. Calculate the concentration of hydroxide ion in an aqueous solution in which the hydrogen ion concentration is 2.42 x 10^{-12} M. Then calculate the pH and pOH, and tell whether the solution is an acid or a base.

2. Find the hydronium ion concentration in a water solution in the hydroxide ion concentration is 5.11 x 10^{-8} M. Then calculate the pH and pOH, and tell whether the solution is an acid or a base.

3. Calculate the hydronium and hydroxide ion concentrations in a solution having a pH of 5.46. Also find the pOH, and tell whether the solution is an acid or a base.

4. Calculate the concentration of a magnesium hydroxide solution, given that 99.3 mL of the basic solution is neutralized by 383.0 mL of a 0.325 M solution of nitric acid. Assume 100% dissociation.

5. Calculate the number of milliliters of 0.540 M sulfuric acid required to neutralize 0.750 L of 0.283 M potassium hydroxide. Assume 100% dissociation.

6. Find the pH of a solution consisting of 0.0023 g of H_2SO_4 that is dissolved in 7.38 L of solution.

7. If 956 mL of 5.8 x 10^{-5} M lithium hydroxide solution are added to the solution of Question 6, find the new pH of the resulting mixture.

Chemistry: *Final Exam Review Problems, Selected Answers*

Stoichiometry
1. 78.4 g $MgCl_2$
2. 1.91 dm^3 Cl_2
3. 4.87 x 10^{23} m'cules NH_3
4. 1.18 x 10^4 kJ
5. B. HCl is LR
    C. 11.2 L H_2
    D. 40.3 g Zn
    E. 10.3 L H_2

The Gas Laws
1. 67.3 cm^3
2. $7.7^{\circ}C$
3. 52.8 L Cl_2
4. 2.43 atm
5. 434 m/s
6.
7. 2.71 atm
8. 1.7 x 10^3 g O_2

Solutions
1. A. 0.606 M
    B. 0.244 M
    C. 1.41 M
2. A. 1.00 L
    B. 3.2 L
    C. 0.333 L
3. A. 134 g
    B. 49 g
    C. 3650 g
4. 19.7 L
5. 27.8 L

Acids and Bases
1. $[OH^{1-}] = 4.13$ x 10^{-3} M
    pH = 11.62
    pOH = 2.38
    base
2. $[H_3O^{1+}] = 1.96$ x 10^{-7} M
    pH = 6.71
    pOH = 7.29
    acid
3. $[H_3O^{1+}] = 3.48$ x 10^{-6} M
    $[OH^{1-}] = 2.88$ x 10^{-9} M
    pOH = 8.54
    acid
4. 0.627 M
5. 196.5 mL
6. 5.20
7. 8.01

Chemistry: *Chemical Equations*

Write a balanced chemical equation for each word equation. Include the phase of each substance in the equation. Classify the reaction as synthesis, decomposition, single replacement, or double replacement.

1. Solid magnesium reacts with oxygen gas to yield solid magnesium oxide.

   2 Mg(s) + O$_2$(g) → 2 MgO(s)   **synthesis**

2. Solid aluminum reacts with a solution of lead (II) nitrate to yield solid lead and aqueous aluminum nitrate.

   2 Al(s) + 3 Pb(NO$_3$)$_2$(aq) → 3 Pb(s) + 2 Al(NO$_3$)$_3$(aq)   **single replacement**

3. Solid diphosphorus pentoxide reacts with solid barium oxide to yield solid barium phosphate.

   P$_2$O$_5$(s) + 3 BaO(s) → Ba$_3$(PO$_4$)$_2$(s)   **synthesis**

4. When heated, solid lead (IV) oxide breaks down into solid lead (II) oxide and oxygen gas.

   2 PbO$_2$(s) → 2 PbO(s) + O$_2$(g)   **decomposition**

5. A solution containing silver nitrate and potassium sulfate reacts to form a silver sulfate precipitate. The potassium nitrate that is formed remains in solution.

   2 AgNO$_3$(aq) + K$_2$SO$_4$(aq) → Ag$_2$SO$_4$(s) + 2 KNO$_3$(aq)   **double replacement**

6. Solid sodium hydroxide decomposes into solid sodium oxide and liquid water.

   2 NaOH(s) → Na$_2$O(s) + H$_2$O(l)   **decomposition**

7. Fluorine gas reacts with liquid water to form ozone gas and aqueous hydrofluoric acid.

   3 F$_2$(g) + 3 H$_2$O(l) → O$_3$(g) + 6 HF(aq)   **single replacement**

8. Solid iron reacts with oxygen gas to yield solid iron (III) oxide.

   4 Fe(s) + 3 O$_2$(g) → 2 Fe$_2$O$_3$(s)   **synthesis**

9. Chlorine gas reacts with a solution of lithium iodide to form lithium chloride solution and iodine gas.

   Cl$_2$(g) + 2 LiI(aq) → 2 LiCl(aq) + I$_2$(g)   **single replacement**
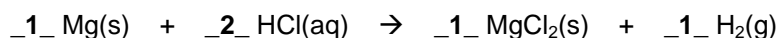
10. A solution of ammonium carbonate and lead (II) nitrate yields a solution of ammonium nitrate and a lead (II) carbonate precipitate.

   (NH$_4$)$_2$CO$_3$(aq) + Pb(NO$_3$)$_2$(aq) → 2 NH$_4$NO$_3$(aq) + PbCO$_3$(s)   **double replacement**

Chemistry: *Stoichiometry*

Balance the equations; then solve the following problems. Assume that excess amounts of other reactants are available, unless otherwise specified.

1. If 20.0 g of magnesium react with excess hydrochloric acid, what mass of magnesium chloride is produced?

$$\_1\_ \ Mg(s) \ + \ \_2\_ \ HCl(aq) \ \rightarrow \ \_1\_ \ MgCl_2(s) \ + \ \_1\_ \ H_2(g)$$

$$X \ g \ MgCl_2 = 20 \ g \ Mg\left(\frac{1\,mol\,Mg}{24.3\,g\,Mg}\right)\left(\frac{1\,mol\,MgCl_2}{1\,mol\,Mg}\right)\left(\frac{95.3\,g\,MgCl_2}{1\,mol\,MgCl_2}\right) = 78.4 \ g \ MgCl_2$$

2. How many dm^3 of chlorine gas are needed (at STP) if 10.0 g of sodium chloride must be produced?

$$\_2\_ \ NaI(aq) \ + \ \_1\_ \ Cl_2(g) \ \rightarrow \ \_2\_ \ NaCl(aq) \ + \ \_1\_ \ I_2(g)$$
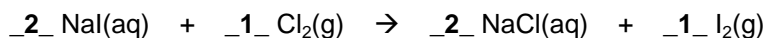
$$X \ dm^3 \ Cl_2 = 10 \ g \ NaCl\left(\frac{1\,mol\,NaCl}{58.5\,g\,NaCl}\right)\left(\frac{1\,mol\,Cl_2}{2\,mol\,NaCl}\right)\left(\frac{22.4\,dm^3\,Cl_2}{1\,mol\,Cl_2}\right) = 1.91\,dm^3 \ Cl_2$$

3. If 30.0 g of calcium hydroxide react with ammonium sulfate, how many molecules of ammonia are produced?

$$\_1\_ \ (NH_4)_2SO_4(aq) \ + \ \_1\_ \ Ca(OH)_2(s) \ \rightarrow \ \_1\_ \ CaSO_4(s) \ + \ \_2\_ \ NH_3(g) \ + \ \_2\_ \ H_2O(l)$$

$$X \ m'c \ NH_3 = 30 \ g \ Ca(OH)_2\left(\frac{1\,mol\,Ca(OH)_2}{74.1\,g\,Ca(OH)_2}\right)\left(\frac{2\,mol\,NH_3}{1\,mol\,Ca(OH)_2}\right)\left(\frac{6.02x10^{23}\,m'c\,NH_3}{1\,mol\,NH_3}\right) = 4.87x10^{23} \ m'c \ NH_3$$

4. If 554 L of oxygen are consumed, how many kJ of energy are released?

$$\_1\_ \ C_6H_{12}O_6(s) \ + \ \_6\_ \ O_2(g) \ \rightarrow \ \_6\_ \ CO_2(g) \ + \ \_6\_ \ H_2O(l) \ + \ 2870 \ kJ$$
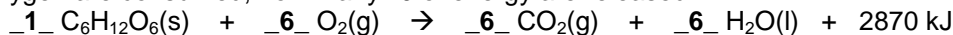
$$X \ kJ = 554 \ L\,O_2\left(\frac{1\,mol\,O_2}{22.4\,L\,O_2}\right)\left(\frac{2870\,kJ}{6\,mol\,O_2}\right) = 1.18x10^4 \ kJ$$

5. If 36.5 g of hydrochloric acid and 73.0 g of zinc are put together…

   A. …write a balanced chemical equation for this reaction.

   2 HCl(aq) + Zn(s) → ZnCl₂(aq) + H₂(g)

   B. …determine the limiting reactant.

   $$X \ mol \ HCl = 36.5 \ g \ HCl\left(\frac{1\,mol\,HCl}{36.5\,g\,HCl}\right) = 1.0\,mol\,HCl \quad \textbf{would only need 0.5 mol Zn}$$

   $$X \ mol \ Zn = 73.0 \ g \ Zn\left(\frac{1\,mol\,Zn}{65.4\,g\,Zn}\right) = 1.116\,mol\,Zn \qquad \textbf{HCl is LR}$$

   C. …find the maximum volume of hydrogen gas formed at STP.

   $$X \ L\,H_2 = 1\,mol\,HCl\left(\frac{1\,mol\,H_2}{2\,mol\,HCl}\right)\left(\frac{22.4\,L\,H_2}{1\,mol\,H_2}\right) = 11.2\,L\,H_2$$

   D. …determine the mass of excess reactant that is left over, if the reaction is 100% efficient.

   Have 1.116 mol Zn, use up 0.5 mol Zn $\qquad X \ g \ Zn = 0.616\,mol\,Zn\left(\frac{65.4\,g\,Zn}{1\,mol\,Zn}\right) = 40.3\,g \ Zn$

   0.616 mol Zn is left over; convert to grams

   E. …find actual volume of hydrogen produced at STP if the percent yield is 91.6%.

   $$X \ L\,H_2 = 0.916\,(1.2\,L\,H_2) = 10.3\,L\,H_2$$

Chemistry: *Phase Changes and Calorimetry*

Solve each of the problems below. You may need to use some of the information given in the table.

Acetic acid (CH_3COOH)	$c_p = 2.05$ J/g°C		
Aluminum	$c_p = 0.89$ J/g°C	$c_f = 389$ J/g	$c_v = 10778$ J/g
Chalk ($CaCO_3$)	$c_p = 0.920$ J/g°C		
Glass	$c_p = 0.753$ J/g°C		
Gold	$c_p = 0.128$ J/g°C	$c_f = 65$ J/g	$c_v = 1742$ J/g
Kerosene	$c_p = 2.09$ J/g°C		
Toluene ($C_6H_5CH_3$)	$c_p = 1.80$ J/g°C		

Find the change in energy when…

1. …14.2 g of water condense at 100°C.

2. …27.3 g of aluminum freeze at 660°C.

3. …76.4 g of gold melt at 1064°C.

4. …49.2 g of acetic acid are heated from 24.1°C to 67.3°C.

5. …9.61 g of toluene are heated from 19.6°C to 75.0°C.

6. …2.47 g of kerosene are heated from 17.1°C to 46.7°C.

7. …31.9 g of chalk are cooled from 83.2°C to 55.5°C.

8. …63.6 g of glass are cooled from 95.5°C to 42.3°C.

9. …175 g of water are heated from – 11.0°C to 140.0°C.

10. If 100.0 g of 27°C water are placed in an insulated flask, how many g of ice at 0°C must be added so that the final temperature is 5.0°C?

Chemistry: *The Gas Laws*

Solve each of the problems below, showing your work and using proper units.

1. A sample of hydrogen has an initial volume of 75.0 cm^3 and an initial temperature of 20.0°C. If the temperature drops to –10.0°C and the pressure remains constant, find the new volume.

$$\frac{75\,cm^3}{293\,K} = \frac{V_2}{263\,K} \quad \rightarrow \quad V_2 = 67.3\,cm^3$$

2. A gas occupies 560.0 dm^3 of space at 120.0°C. To what temperature (in °C) must the gas be cooled for it to occupy 400.0 dm^3?

$$\frac{560\,dm^3}{393\,K} = \frac{400\,dm^3}{T_2} \quad \rightarrow \quad T_2 = 280.7\,K = 7.7°C$$

3. At 25.0°C and 121 kPa, find the volume occupied by a 183 g sample of chlorine.

$$121kPa\left(V\right) = \left[183\,g\left(\frac{1\,mol\,Cl_2}{71.0\,g\,Cl_2}\right)\right]\left(8.314\frac{L-kPa}{mol-K}\right)\left(298\,K\right) \rightarrow 52.8\,L\,Cl_2$$

4. At 58°C and an unknown pressure, a sample of oxygen has a volume of 433 mL. If the gas takes up 868 mL at STP, find the initial pressure, in atm.

$$\frac{P_1\left(433\,mL\right)}{331\,K} = \frac{1\,atm\left(868\,mL\right)}{273\,K} \quad \rightarrow \quad P_1 = 2.43\,atm$$

5. At a certain temperature and pressure, chlorine molecules have an average velocity of 412 m/s. Find the average velocity of sulfur dioxide molecules under the same conditions.

$$\frac{v_{SO2}}{412\,m/s} = \sqrt{\frac{71\,g}{64.1\,g}} \quad \rightarrow \quad v_{SO2} = 434\,m/s$$

6. Find the pressure of the confined gas, in mm Hg.

$$98.6\,kPa\left(\frac{760\,mm\,Hg}{101.3\,kPa}\right)+182\,mm\,Hg = 922\,mm\,Hg$$

7. One sample of Xe in a 3.55 L container exerts a pressure of 6.2 atm. A second sample of Xe is confined into a 1.85 L container and exerts 2.4 atm of pressure. If these samples are placed together into a 9.75 L container, find the resulting pressure.

$$\frac{6.2\,atm\left(3.55\,L\right)}{9.75\,L} + \frac{2.4\,atm\left(1.85\,L\right)}{9.75\,L} = P_z \quad \rightarrow \quad P_z = 2.71\,atm$$

8. Propane burns according to the equation: $C_3H_8(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$

   If the sample of propane occupies 22 L at 30°C and under 12 atm of pressure, how many grams of oxygen are needed to react with all of the propane?

$$12\,atm\left(22\,L\right) = n\left(0.0821\frac{L \bullet atm}{mol \bullet K}\right)\left(303\,K\right) \rightarrow n = 10.6\,mol\,C_3H_8$$

$$X\,g\,O_2 = 10.6\,mol\,C_3H_8\left(\frac{5\,mol\,O_2}{1\,mol\,C_3H_8}\right)\left(\frac{32\,g\,O_2}{1\,mol\,O_2}\right) = 1.7x10^3\,g\,O_2$$

Chemistry: *Solutions*

Solve each of the problems below, showing your work and using correct units.

1. Calculate the molarity of the following solutions.

    A. 30.0 g of acetic acid (CH_3COOH) in 825 mL of solution

    $$X\,mol = 30\,g\left(\frac{1\,mol}{60\,g}\right) = 0.5\,mol\,CH_3COOH \quad \rightarrow \quad M = \frac{0.5\,mol}{0.825\,L} = 0.606\,M\,CH_3COOH$$

    B. 49.0 g of phosphoric acid (H_3PO_4) in 2.05 L of solution

    $$X\,mol = 49\,g\left(\frac{1\,mol}{98\,g}\right) = 0.5\,mol\,H_3PO_4 \quad \rightarrow \quad M = \frac{0.5\,mol}{2.05\,L} = 0.244\,M\,H_3PO_4$$

    C. 0.375 kg of potassium hydroxide (KOH) in 4750 mL of solution

    $$X\,mol = 375\,g\left(\frac{1\,mol}{56.1\,g}\right) = 6.6845\,mol\,KOH \quad \rightarrow \quad M = \frac{6.6845\,mol}{4.750\,L} = 1.41\,M\,KOH$$

2. Calculate the number of liters of solution needed to make each of the following.

    A. a 2.00 M solution using 80.0 g of sodium hydroxide (NaOH)

    $$X\,mol = 80\,g\left(\frac{1\,mol}{40\,g}\right) = 2.0\,mol\,NaOH \quad \rightarrow \quad 2.00\,M = \frac{2.0\,mol}{X\,L} \quad \rightarrow \quad X\,L = 1.00\,L$$

    B. a 0.500 M solution using 56 g of ammonium hydroxide (NH_4OH)

    $$X\,mol = 56\,g\left(\frac{1\,mol}{35\,g}\right) = 1.6\,mol\,NH_4OH \quad \rightarrow \quad 0.500\,M = \frac{1.6\,mol}{X\,L} \quad \rightarrow \quad X\,L = 3.2\,L$$

    C. a 6.00 M solution using 126 g of nitric acid (HNO_3)

    $$X\,mol = 126\,g\left(\frac{1\,mol}{63\,g}\right) = 2.0\,mol\,HNO_3 \quad \rightarrow \quad 6.00\,M = \frac{2.0\,mol}{X\,L} \quad \rightarrow X\,L = 0.333\,L$$

3. Calculate the mass of solute in the following solutions.

    A. 250.0 mL of 2.00 M $Na_2SO_4\,7H_2O$ solution

    $$X\,mol = 2\,M\,(0.25\,L) = 0.5\,mol \quad \rightarrow \quad X\,g = 0.5\,mol\left(\frac{268.1\,g}{1\,mol}\right) = 134\,g\,Na_2SO_4 \bullet 7\,H_2O$$

    B. 1.500 L of 0.240 M KH_2PO_4 solution

    $$X\,mol = 0.24\,M\,(1.5\,L) = 0.36\,mol \quad \rightarrow \quad X\,g = 0.36\,mol\left(\frac{136.1\,g}{1\,mol}\right) = 49\,g\,KH_2PO_4$$

    C. 25,000 mL of 4.00 M HCl solution

    $$X\,mol = 4.0\,M\,(25\,L) = 100\,mol \quad \rightarrow \quad X\,g = 100\,mol\left(\frac{36.5\,g}{1\,mol}\right) = 3650\,g\,HCl$$

4. What volume of 2.50 M H_2SO_4 can be made from 4.00 L of 12.3 M H_2SO_4?
    $$12.3\,M\,(4\,L) = 2.50\,M\,(V_{dilute}) \quad \rightarrow \quad V_{dilute} = 19.7\,L$$

5. Given the balanced chemical equation: 2 Al(s) + 3 $CuSO_4$(aq) → 3 Cu(s) + $Al_2(SO_4)_3$(aq)
    What volume of 0.25 M $CuSO_4$ is required to completely react with 125 g of aluminum?

    $$X\,mol\,CuSO_4 = 125\,g\,Al\left(\frac{1\,mol\,Al}{27\,g\,Al}\right)\left(\frac{3\,mol\,CuSO_4}{2\,mol\,Al}\right) = 6.94\,mol\,CuSO_4$$

    $$0.25\,M = \frac{6.94\,mol}{X\,L} \quad \rightarrow \quad X\,L = 27.8\,L$$

Chemistry: *Equilibrium*

Answer each question below by writing SHIFT LEFT (or ←), SHIFT RIGHT (or →), or NO SHIFT to indicate what happens to the equilibrium position when the indicated stress or condition change occurs.

1. For the balanced chemical equation: $N_2(g)$ + $3 H_2(g)$ ←→ $2 NH_3(g)$ + energy

   remove $NH_3(g)$ **SHIFT RIGHT**

   decrease pressure   **SHIFT LEFT**

2. For the balanced chemical equation: $CO_2(g)$ + $H_2(g)$ + energy ←→ $CO(g)$ + $H_2O(l)$

   decrease temperature   **SHIFT LEFT**

   add a catalyst   **NO SHIFT**

3. For the balanced chemical equation: $2 SO_2(g)$ + $O_2(g)$ ←→ $2 SO_3(g)$ + energy

   increase $SO_2(g)$ concentration   **SHIFT RIGHT**

   increase temperature   **SHIFT LEFT**

4. For the balanced chemical equation: $CO_2(g)$ + $C(s)$ + energy ←→ $2 CO(g)$

   increase temperature   **SHIFT RIGHT**

   increase CO concentration   **SHIFT LEFT**

5. For the balanced chemical equation: $N_2O_4(g)$ + energy ←→ $2 NO_2(g)$

   decrease pressure   **SHIFT RIGHT**

   remove $N_2O_4(g)$ **SHIFT LEFT**

6. For the balanced chemical equation: $H_2(g)$ + $Cl_2(g)$ ←→ $2 HCl(g)$ + energy

   increase $H_2(g)$ concentration   **SHIFT RIGHT**

   increase pressure   **NO SHIFT**

7. For the balanced chemical equation: $N_2(g)$ + $O_2(g)$ + energy ←→ $2 NO(g)$

   decrease $O_2(g)$ concentration   **SHIFT LEFT**

   add a catalyst   **NO SHIFT**

8. For the balanced equation: $CO_2(aq)$ + $2 NH_3(aq)$ ←→ $NH_2CONH_2(aq)$ + $H_2O(l)$ + energy

   remove $NH_2CONH_2(aq)$ **SHIFT RIGHT**

   increase CO_2 concentration   **SHIFT RIGHT**

   increase temperature   **SHIFT LEFT**

   add a catalyst   **NO SHIFT**

Chemistry: *Acids and Bases*

Solve each of the problems below, showing your work and using correct units.

1. Calculate the concentration of hydroxide ion in an aqueous solution in which the hydrogen ion concentration is 2.42 x 10^{-12} M. Then calculate the pH and pOH, and tell whether the solution is an acid or a base.

$$2.42x10^{-12}\,M\,[OH^{1-}] = 1x10^{-14} \rightarrow [OH^{1-}] = 4.13x10^{-3}\,M$$
$$pH = -\log [2.42x10^{-12}] = 11.62$$
$$pOH = 2.38 \qquad\qquad\qquad\qquad\qquad\qquad \textbf{BASE}$$

2. Find the hydronium ion concentration in a water solution in the hydroxide ion concentration is 5.11 x 10^{-8} M. Then calculate the pH and pOH, and tell whether the solution is an acid or a base.

$$[H_3O^{1+}]\,5.11x10^{-8}\,M = 1x10^{-14} \rightarrow [H_3O^{1+}] = 1.96x10^{-7}\,M$$
$$pH = -\log [1.96x10^{-7}] = 6.71$$
$$pOH = 7.29 \qquad\qquad\qquad\qquad\qquad\qquad \textbf{ACID}$$

3. Calculate the hydronium and hydroxide ion concentrations in a solution having a pH of 5.46. Also find the pOH, and tell whether the solution is an acid or a base.
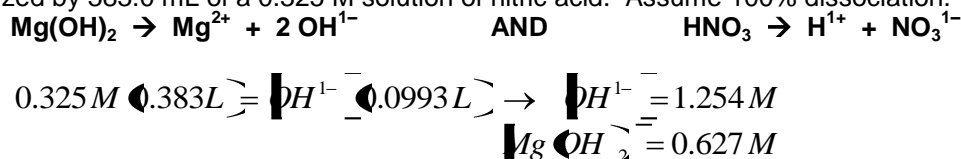
$$[H_3O^{1+}] = 10^{-5.46} = 3.48x10^{-6}\,M$$
$$pOH = 8.54$$
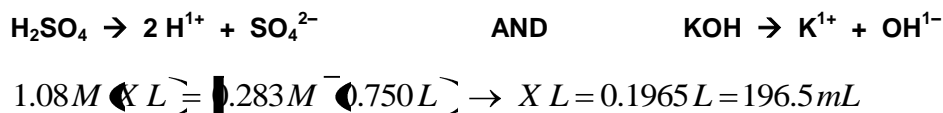$$[OH^{1-}] = 10^{-8.54} = 2.88x10^{-9}\,M \qquad\qquad\qquad \textbf{ACID}$$

4. Calculate the concentration of a magnesium hydroxide solution, given that 99.3 mL of the basic solution is neutralized by 383.0 mL of a 0.325 M solution of nitric acid. Assume 100% dissociation.

$$Mg(OH)_2 \rightarrow Mg^{2+} + 2\,OH^{1-} \qquad\qquad \textbf{AND} \qquad\qquad HNO_3 \rightarrow H^{1+} + NO_3^{1-}$$

$$0.325\,M\,(0.383L) = [OH^{1-}](0.0993\,L) \rightarrow [OH^{1-}] = 1.254\,M$$
$$[Mg(OH)_2] = 0.627\,M$$

5. Calculate the number of milliliters of 0.540 M sulfuric acid required to neutralize 0.750 L of 0.283 M potassium hydroxide. Assume 100% dissociation.

$$H_2SO_4 \rightarrow 2\,H^{1+} + SO_4^{2-} \qquad\qquad \textbf{AND} \qquad\qquad KOH \rightarrow K^{1+} + OH^{1-}$$

$$1.08\,M\,(X\,L) = 0.283\,M\,(0.750\,L) \rightarrow X\,L = 0.1965\,L = 196.5\,mL$$

6. Find the pH of a solution consisting of 0.0023 g of H_2SO_4 that is dissolved in 7.38 L of solution.

$$X\,mol = 0.0023\,g\left(\frac{1\,mol}{98.1\,g}\right) = 2.34x10^{-5}\,mol \rightarrow M = \frac{2.34x10^{-5}\,mol}{7.38\,L} = 3.177x10^{-6}\,M\,H_2SO_4$$
$$[H^{1+}] = 6.354x10^{-6}\,M \rightarrow pH = -\log [6.354x10^{-6}] = 5.20$$

7. If 956 mL of 5.8 x 10^{-5} M lithium hydroxide solution are added to the solution of Question 6, find the new pH of the resulting mixture.

$$2.34x10^{-5}\,mol\,H_2SO_4 \rightarrow 4.68x10^{-5}\,mol\,H^{1+}$$
$$X\,mol\,LiOH = 5.8x10^{-5}\,M\,(0.956\,L) = 5.54x10^{-5}\,mol\,LiOH \rightarrow 5.54x10^{-5}\,mol\,OH^{1-}$$

$$\textbf{EXTRA OH}^{1-} \rightarrow \qquad 8.56x10^{-6}\,mol\,OH^{1-} \rightarrow [OH^{1-}] = \frac{8.56x10^{-6}\,mol}{8.336\,L} = 1.03x10^{-6}\,M\,[OH^{1-}]$$

$$pOH = -\log [1.03x10^{-6}] = 5.99$$
$$pH = 8.01$$