1. Determine the number of significant digits that should be present, and the units for, the answer to the following calculation. Explain your answer.

$$1.00\ \text{kg Br} \times \frac{1.00\times10^{3}\ \text{g Br}}{1.00\ \text{kg Br}} \times \frac{1.0\times10^{6}\ \text{g water}}{70.0\ \text{g Br}} \times \frac{1.00\ \text{cm}^3\ \text{water}}{1.025\ \text{g water}} =$$

2. How many significant digits should be in the answers for each of the following calculations? Explain your reasoning.
   a. 9.724 + 10.125
   b. 12.98426 - 0.0987
   c. $0.00094 \times 1.28 \times 10^{18}$
   d. $142.38 \div 9 \times 10^{9}$
3. Compare the trend for atomic radius with the trend for atomic mass in the periodic table. How do these trends relate to the trend for density?
4. a) Name the last element in the first transition element series.
   b) Sketch the Bohr-Rutherford diagram for this element.
   c) Sketch the Lewis structure for this element.
5. How many protons, neutrons, and electrons are in each atom or ion below?
   a) $^{79}_{34}Se$
   b) $^{59}_{28}Ni^{2+}$
   c) $^{128}_{52}Te^{1-}$
   d) $^{1}_{1}H^{1+}$
6. Arrange the following ions in order of decreasing size: Br^{1-}, Al^{3+}, Na^{1+}, Mg^{2+}, I^{1-}.
7. Arrange the following species from Period 2 in order of decreasing size: O^{2-}, Mg^{2+}, Ne, N^{3-}, F^-, Na^{+}.
8. Sketch an electron dot diagram and a structural formula for hydroxylamine, NH_3O.
9. Draw the Lewis structure for $AlCl_4^-$. Are the bonds ionic, polar covalent, or covalent?
10. Use a Lewis structure to represent aqueous aluminum hydroxide.
11. Sketch the structural formula for the molecule CH_2FOH. Indicate the polarity of each bond. State whether or not the molecule is polar.
12. Use what you know about ionic bonds to explain each property of ionic solids.
    a) They are not malleable.
    b) They cleave or break, along smooth, flat surfaces.
    c) They have high melting points.
    d) They are soluble in water.
13. When bismuth (III) oxide is roasted with carbon, a single displacement reaction occurs. Carbon monoxide is one of the products. Write the balanced equation for this reaction.
14. When aqueous solutions of sodium sulfate and mercury (II) nitrate are mixed, a precipitation reaction occurs. Write the balanced equation for this reaction. **Hint:** Nitrate compounds are always soluble.
15. The following equation represents the "combustion" of turpentine in chlorine:
    $C_{10}H_{16(l)} + Cl_{2(g)} \rightarrow HCl_{(g)} + C_{(s)}$
    Balance this equation, and classify the reaction.
16. Recall that elements in the same group have similar properties.
    a) Name the acid of selenium that is analogous to sulfuric acid. Write the formula for this acid.
    b) Write the word equation and balanced chemical equation for the double displacement reaction that occurs when this acid reacts with iron(III) hydroxide.
17. Platinum and gold do not react with either concentrated nitric acid or concentrated hydrochloric acid separately. They do react, however, with a mixture called aqua regia. Aqua regia is made of three parts HCl and one part HNO_3 by volume. Balance the following equation for the reaction of gold with aqua regia:
    $Au_{(s)} + HNO_{3(aq)} + HCl_{(aq)} \rightarrow HAuCl_{4(aq)} + H_2O_{(l)} + NO_{2(g)}$
18. Copper is commonly found in nature in the compound $CuFeS_2$. It is extracted by roasting $CuFeS_2$ in air. This reaction can be summarized by the following equation:
    $CuFeS_{2(s)} + O_{2(g)} \rightarrow Cu_{(s)} + FeO_{(s)} + SO_{2(g)}$
    Balance the equation. Then discuss whether or not the reaction can be classed as a single displacement reaction.
19. Concentrated nitric acid can decompose at high concentrations. Balance the following skeleton equation for the reaction. Then write the corresponding word equation, and classify the reaction.
    $HNO_{3(l)} \rightarrow NO_{2(g)} + H_2O_{(l)} + O_{2(g)}$
20. Examine the following reactants, and predict the type of reaction that will occur. Use the following classifications: synthesis, decomposition, single displacement, double displacement, neutralization, complete combustion, incomplete combustion, no reaction.
    a) $CuNO_{3(aq)} + BaCl_{2(aq)} \rightarrow$
    b) $HNO_{3(aq)} + Ca(OH)_{2(aq)} \rightarrow$
    c) $NH_4NO_{3(aq)} + KOH_{(aq)} \rightarrow$
    d) $Pb_{(s)} + CuCl_{2(aq)} \rightarrow$
    e) $HgO_{(s)}$ + heat $\rightarrow$
    f) $C_3H_{8(g)}$ + limited $O_{2(g)} \rightarrow$
    g) $Br_{2(l)} + CaCl_{2(aq)} \rightarrow$
    h) $CuO_{(s)} + H_{2(g)} \rightarrow$
    i) $Pt_{(s)} + Cl_{2(g)} \rightarrow$
    j) $NaNO_{3(aq)} + Ag_{(s)} \rightarrow$
21. Determine how many moles are in 67.5 g of sodium sulphate.
22. Determine the molar mass of potassium permanganate.
23. Calculate the number of oxygen atoms in 15.0 g of calcium nitrate, $Ca(NO_3)_2$.
24. Chromium has four isotopes: chromium-50 (49.9461 u, 4.31%), chromium-52 (51.9405 u, 83.76%), chromium-53 (52.9407 u, 9.55%), and chromium-54 (53.9389 u, 2.38%). Calculate the average atomic mass of chromium.
25. A 35.0 g sample of calcium chloride is analyzed and found to have 22.4 g of chlorine and 12.6 g of calcium. Calculate the mass percent of each element in the compound.
26. Calculate the mass percent of each element in copper(I) sulfate Cu_2SO_4.
27. The percentage composition of a compound is 88.8% copper and 11.2% oxygen. Calculate the empirical formula of the compound.
28. Draw a triangle diagram, similar to those in the textbook, for each formula. Label the diagram to show the meanings of the variables and the units.
    a) formula to convert moles to mass using the molar mass
    b) formula to convert a concentration to an amount, in moles, using the volume
    c) formula to convert a density to a volume using the mass of an object
29. Use the method of unit analysis to show how the units for each variable in question 73, parts a, b, and c, cancel out to give the correct answer.
30. Calculate the percentage composition of ammonium chloride.

31. A 5.015 g sample of a compound that contained hydrogen, carbon, and oxygen was combusted in a carbon-hydrogen analyzer. The combustion produced 7.35 g of carbon dioxide and 2.99 g of water.
a) Determine the empirical formula of the compound.
b) The molar mass of the compound is 60.05 g. What is the molecular formula of the compound?
c) Draw the structural formula for this compound, an acid that is common in the kitchen. Name the acid, and identify the common kitchen substance that contains it.

32. A compound contains 38.67% potassium, 13.85% nitrogen, and 47.48% oxygen. Determine the empirical formula of the compound.

33. Monosodium glutamate (MSG) is a controversial food additive. It is used to enhance flavours in many different foods, but it can cause headaches and chest pains. People who suffer from migraines are particularly sensitive to its effects. The composition by mass of MSG is 35.51% carbon, 4.77% hydrogen, 37.85% oxygen, 8.29% nitrogen, and 13.60% sodium. Its molar mass is 169 g. What is the molecular formula of MSG?

34. 25.0 g of calcium oxide reacts with water to produce calcium hydroxide. Calculate the mass of calcium hydroxide that is produced.

35. Iron reacts with antimony trisulfide in a single replacement reaction. Antimony and iron (II) sulfide are produced. Calculate the mass of iron that is needed to react with 15.6 g of antimony trisulfide.

36. The theoretical yield of a reaction is 62.9 g, but the actual yield is 47.8 g. Calculate the percentage yield.

37. Draw a flowchart that outlines the different steps that are needed to solve a stoichiometric problem. Include the steps that are needed when there are reactants in excess and when there is a limiting reactant.

38. 1 mol of any gas occupies 22.4 L. If 39.2 g of nitrogen gas reacts completely with 8.60 g of hydrogen gas, calculate the volume of ammonia gas that is produced.

39. One reaction that is used in the smelting of copper sulfide ores involves copper(I) oxide and copper(I) sulfide. These two compounds react to produce copper and sulfur dioxide.
a) 86.0 g of copper(I) oxide reacts with 46.0 g of copper(I) sulfide. Determine the mass of copper that is produced.
b) If 98.0 g of copper is recovered, determine the percentage yield.

40. 8.93 g of lead (II) nitrate is mixed in solution with 1.05 g of sodium chloride. A double displacement reaction takes place.
a) Name the excess reactant.
b) Calculate the mass of the excess reactant that will remain when the reaction is complete.
c) How much more of the limiting reactant is needed to have stoichiometric amounts of the reactants?

41. Ammonia is an important raw material in the production of fertilizers. It is formed by the reaction of nitrogen and hydrogen:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

490 g of nitrogen are placed in a reaction vessel with 100 g of hydrogen. Calculate the mass of ammonia that is formed.

42. Explain the statement "Like dissolves like."

43. Discuss three ways to increase the rate of dissolving of a solid in a liquid. Explain how each method works on a molecular level.

44. a) Draw the Lewis structure of a water molecule. Show the shape and charge distribution.
b) Explain why water is a polar molecule.
c) Why is water called the universal solvent?
d) Describe the properties of water that make it a good solvent.

45. What are three factors that affect solubility? Briefly discuss how each factor relates to the solubility of a solute.

46. 0.25 mol of potassium nitrate is added to enough water to make a 175 mL solution. What is the molar concentration of potassium nitrate?

47. What is the mass/volume percentage of 3.0 g in 50.0 mL of solution?

48. Calculate the mass (in grams) of sodium sulfide that is needed to make 350 mL of a 0.50 mol/L solution

49. Calculate the concentration of 5.0 g of copper(II) chloride in 75 mL of solution. Express the concentration as a mass/volume percentage.

50. Calculate the concentration of 0.575 g of magnesium acetate in 265 g of water. Express the concentratic as a mass/mass percentage.

51. Calculate the mass of solute, Na_2CO_3, contained in 50.0 mL of a 2.5% (m/v) sodium carbonate solution

52. Calculate the molar concentration of 58.5 g of aluminum sulfate in 855 mL of solution.

53. 35 mL of a 0.250 mol/L solution of hydrochloric acid is mixed with an excess of silver nitrate. A white precipitate of silver chloride forms. What is the mass of the silver chloride precipitate?

54. 10.0 mL of a 0.10 mol/L solution of copper(II) sulfate is reacted with 25.0 mL of a 0.20 mol/L solution of sodium sulfide. This reaction creates a brown precipitate, copper(II) sulfide. What is the mass of the copper(II) sulfide precipitate?

55. 42.6 mL of sulfuric acid precipitates exactly 3.260 g of barium sulfate from a solution of barium hydroxide. What is the molar concentration of the sulfuric acid?

56. A solution of sodium sulfide is mixed with a solution of copper(II) chloride. Write the total ionic equatio and the net ionic equation for the reaction. Identify the spectator ions in the reaction.

57. Solutions of potassium carbonate and copper(II) sulfate are mixed. Write the total ionic equation and the net ionic equation for the reaction. Name the spectator ions.

58. 365 mL of a 0.11 mol/L solution of barium nitrate is added to 255 mL of a 0.18 mol/L solution potassiu sulfate.
a) Write the total ionic equation and the net ionic equation for this reaction. Identify the spectator ions.
b) Calculate the mass of precipitate that is formed.

59. Calculate the volume of 0.110 mol/L sodium sulfate that is needed to precipitate the maximum mass of barium sulfate from 60.0 mL of 0.145 mol/L barium chloride.

60. A 90.0 mL sample of 0.325 mol/L iron(II) chloride is added to an excess of sodium sulfide. Identify the precipitate, and determine the mass of this precipitate that is formed.

61. Define an acid and a base, according to the Arrhenius theory.

62. What is a hydronium ion?

63. Define a strong base and a weak base. Give examples of each.

64. Define a strong acid and a weak acid. Give examples of each.

65. Name each acid.
a) $HBr_{(aq)}$
b) $H_3PO_{2(aq)}$
c) $H_2SO_{3(aq)}$
d) $HIO_{3(aq)}$
e) $HBrO_{4(aq)}$

66. Write the chemical formula of each acid.
a) carbonic acid
b) hyponitrous acid
c) sulfurous acid
d) hydrocyanic acid
e) perchloric acid

67. A titration is performed on a 25.0 mL sample of calcium hydroxide. A volume of 46.0 mL of a 0.15 mol/L solution of nitric acid is used to reach the end point. Calculate the concentration of the calcium hydroxide.

68. Calculate the volume of 0.250 mol/L sulfuric acid that is needed to react completely with 10.0 mL of 1.5 mol/L potassium hydroxide.

69. 8.54 mL of 0.50 mol/L phosphoric acid is needed to neutralize 30.0 mL of a barium hydroxide solution. What was the concentration of the barium hydroxide solution?

70. 20.0 mL of 0.15 mol/L sodium hydroxide is reacted with 30.0 mL of 0.20 mol/L sulfuric acid.
a) How many grams of salt are produced?
b) What is the concentration of hydronium ions in the resulting solution?
c) What is the pH of the resulting solution?

71. A 4.50 g tablet of magnesium hydroxide neutralizes 400.0 mL of stomach acid, HCl. What is the concentration of HCl in the stomach?

72. Detemine the pH of each solution, given the concentration of hydronium ions.
a) lemon juice, if the concentration of hydronium ions is 1.0×10^{-2} mol/L
b) baking soda solution. if the concentration of hydronium ions is 6.3×10^{-9} mol/L
c) normal rain, if $[H_3O^+]$ is 2.5×10^{-6} mol/L

73. Determine the concentration of hydronium ions in each solution, given the pH.
a) seawater, with pH 7.90
b) wine, with pH 3.80
c) stomach acid, with pH 1.50

74. What does STP stand for? State the temperature in two units and the pressure in four units.

75. Explain Charles' law in your own words. State one real-life example of Charles' law.

76. Explain why the following statement is false: As temperature increases, the volume of a gas increases because the size of the gas molecules increases.

77. Which sample of gas would react faster, a sample of gas at 25°C or a sample of gas at 500°C? Explain your answer.

78. Create a concept map for the following gas laws: Charles' law, Boyle's law, Gay-Lussac's law, the combined gas law, and Dalton's law of partial pressure.

79. The fuel supply for a course-correcting rocket engine on a communications satellite is contained in a steel sphere. The volume of the sphere is 10.0 L. The sphere is able to deliver 1400 L of gas at room temperature (25°C) and 101.3 kPa. Calculate the pressure that the sphere can withstand if the normal operating temperature of the sphere is -10°C.

80. A car tire contains air at a pressure of 1520 mm Hg and 25°C. When the car is driven, the tire heats up and the pressure increases to 1900 mm Hg. Assuming that the tire does not expand, calculate the new temperature inside the tire.

81. Use a diagram to explain, at the molecular level, why an inflated balloon expands when sitting in the Sun.

82. Water boils faster at the top of Mount Everest that at sea level. An egg boiling in water on the top of the mountain cooks slower, however, than an egg boiling in water at sea level. Explain why, using your knowledge of the kinetic molecular theory.

83. An aerosol can explodes when it is thrown into a fire. Identify the relationship that this shows, and explain your answer. Which gas law does this show?

84. A sample of gas has a volume of 30 mL at 1.5 atm. The gas is allowed to expand until its volume is 100 mL. Calculate the new pressure, assuming that the temperature remains constant.

85. A sample of gas has a volume of 40 mL at 5.0 atm. The gas is allowed to expand until its volume is 100 mL. Calculate the new pressure.

86. A 250 mL sample of chlorine gas is collected at 24°C and 120 kPa. Calculate the new volume of the gas if the conditions of the gas are changed to STP.

87. A sample of gas has a volume of 30 mL at 1.5 atm. It is allowed to expand until its volume is 100 mL. Calculate the new pressure, assuming that the temperature remains constant.

88. Explain the relationship between moles and temperature of a gas?

89. What is molar volume? State the molar volume (including the units) of any gas.

90. Calculate the volume that is occupied by 5.05 mol of hydrogen chloride, HCl, gas at STP.

91. Calculate the number of moles of 10.0 L of nitrogen gas at 95.0 kPa and -5°C.

92. What is the pressure of 6.7 mol of carbon dioxide gas, in 35.0 L at 30°C?

93. Calculate the volume of water vapour that is produced from the combustion of 15.0 g of ethylene at 25°C and 100 kPa.

$$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(g)}$$

94. A 5.00 g sample of gas has a pressure of 1.20 atm and a volume of 750 mL, at a temperature of 35°C. Calculate the molar mass of the gas.

95. 3.55 g of potassium is needed to produce 0.448 L of hydrogen gas, measured at 117 kPa. Calculate the temperature at which the hydrogen gas is produced.

$$2K_{(s)} + 2H_2O_{(l)} \rightarrow 2KOH_{(aq)} + H_{2(g)}$$

96. Aluminum metal reacts with excess hydrochloric acid, according to the following balanced equation:
$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$
Calculate the mass of aluminum that reacts to produce 1.50 L of hydrogen gas at 21.0°C and 103 kPa.

97. Iron pyrite, FeS_2, when roasted in air, reacts to produce sulfur dioxide and iron(III) oxide as follows:
$4FeS_{2(s)} + 11O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)} + 8SO_{2(g)}$
25.2 g of iron pyrite reacts with 5.50 L of oxygen gas at 20°C and 100 kPa. Calculate the mass of iron(III) oxide that is formed.

98. Butane gas burns in the presence of oxygen, according to the following equation:
$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(g)}$
Calculate the volume of oxygen that is needed to burn 1000 L of butane gas completely at STP.

99. Nitrogen gas and hydrogen gas combine to form ammonia gas, according to the following reaction:
$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$
60.0 g of nitrogen gas reacts with 9.00 g of hydrogen gas at STP. What volume of ammonia gas is produced?

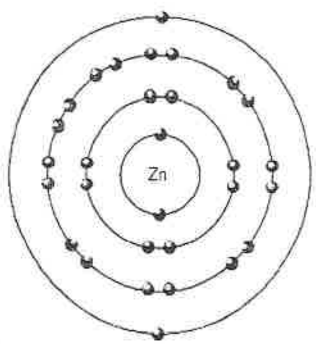
100. 20 g of aluminum reacts with 700 mL of 4.0 M HCl at 27°C and 800 mm Hg. What volume of hydrogen gas is produced?

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

101. What volume of 3.5 mol/L sulfuric acid solution is needed to make 100 mL of 0.45 mol/L sulfuric acid solution?

Answer Key

1. There should be two significant digits in the answer, because that is the least number of significant digits of any number in the question. The units of the answer would be cubic centimetres.
2. a. Five. The rule is to keep the leftmost placeholder, in this case the thousandths place.
   b. Six. The rule is to keep the leftmost placeholder, in this case the ten-thousandths place.
   c. Two. Keep the least number of significant digits of any number in the question.
   d. One. Keep the least number of significant digits of any number in the question.
3. The atomic radius increases down a group and from right to left across a period. The atomic mass increases down a group and from left to right across a period. The atomic mass undergoes a greater change than the atomic radius. For example, the atomic radius of uranium is about 5 times larger than the atomic radius of hydrogen. However, the atomic mass of uranium is 238 times larger than the atomic mass of hydrogen. This leads to a great increase in density down a group.
4. a) The element is zinc.
   b)



   c) $\cdot \dot{Zn}$
5. a) p = 34, n = 45, e = 34
   b) p = 28, n = 31, e = 26
   c) p = 52, n = 76, e = 53
   d) p = 1, n = 2, e = 0
6. I^{1-} Br^{1-} Na^{1+} Mg^{2+} Al^{3+}
7. $N^{3-} > O^{2-} > F^{-} > Ne > Na^{+} > Mg^{2+}$
8.

```
  ..  ..
H:N:O:H      H-N-O-H
  ..  ..         |
  H              H
```

9.

```
     ..
    :Cl:    1-
  ..  |  ..
 :Cl-Al-Cl:
  ..  |  ..
    :Cl:
     ..
```


The Δ *EN* for the Al-Cl bond is 2.83 - 1.47 = 1.36. This is a polar covalent bond.

10. $Al(OH)_3$ is an ionic compound.

   $Al^{3+}_{(aq)}$ + 3 :Ö:H$^{1-}_{(aq)}$

11.

```
    H
 → ↓|  →  ←
 H - C - O - H   tetrahedral shape, polar, with the F-OH end δ -
   ↓|
    F
```

12. a) The ions are held in position by strong electrostatic forces of attraction. They cannot change position by sliding over one another.
   b) The ions are held in a regular crystalline pattern by strong electrostatic forces of attraction. If enough pressure is applied, the positive ions are forced closer together and the negative ions are forced closer together. This results in an increase in the repulsive force, which causes the crystal to shatter. The crystal only shatters, however, along the axes where ions are aligned.
   c) The process of melting requires that particles become free to move about as their kinetic energy increases. For this to happen, the attractions between the ions must be overcome. Since these attractions are very strong, a high temperature is needed to cause melting.
   d) Water is a polar molecule. It is attracted to the charged ions.
13. $Bi_2O_{3(s)} + 3C_{(s)} \rightarrow 3CO_{(g)} + 2Bi_{(s)}$
14. Sodium sulfate, Na_2SO_4, provides Na^+ and SO_4^{2-} ions. Mercury (II) nitrate, $Hg(NO_3)_2$, provides Hg^{2+} and NO_3^- ions. $HgSO_4$ must be the insoluble precipitate, since the question states all nitrate compounds are soluble.
   $Na_2SO_{4(aq)} + Hg(NO_3)_{2(aq)} \rightarrow 2Na^+_{(aq)} + 2NO_3^-{}_{(aq)} + HgSO_{4(s)}$
15. $C_{10}H_{16(l)} + 8Cl_{2(g)} \rightarrow 16HCl_{(g)} + 10C_{(s)}$ single displacement
16. a) selenic acid, H_2SeO_4
   b) aqueous selenic acid + aqueous iron(III) hydroxide → aqueous iron(III) selenate + water
   $3H_2SeO_{4(aq)} + 2Fe(OH)_{3(aq)} \rightarrow Fe_2(SeO_4)_{3(aq)} + 6H_2O_{(l)}$
17. $Au_{(s)} + 3\ HNO_{3(aq)} + 4\ HCl_{(aq)} \rightarrow HAuCl_{4(aq)} + 3\ H_2O_{(l)} + 3\ NO_{2(g)}$
18. $2CuFeS_{2(s)} + 5O_{2(g)} \rightarrow 2Cu_{(s)} + 2FeO_{(s)} + 4SO_{2(g)}$
   This reaction does not follow the pattern of single displacement seen in examples in the textbook. The copper is displaced, however, and the oxygen combines with the iron and the sulfur. Therefore, this is a displacement reaction, although calling it single displacement is not quite adequate. Calling it double displacement is incorrect. It is a variation of the standard single displacement.
19. $4HNO_{3(aq)} \rightarrow 4NO_{2(g)} + 2H_2O_{(l)} + O_{2(g)}$ decomposition reaction
   aqueous nitric acid → gaseous nitrogen dioxide + liquid water + oxygen gas
20. a) double displacement
   b) neutralization, double displacement
   c) double displacement
   d) single displacement
   e) decomposition
   f) incomplete combustion
   g) no reaction

h) single displacement
i) synthesis
j) no reaction

21.

$$\text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{67.5\text{ g}}{142.05\text{ g/mol}} = 0.475\text{ mol}$$

22. Molar mass = (1 × molar mass of K) + (1 × molar mass of Mn) + (4 × molar mass of O)
= [(1 × 39.10) + (1 × 54.94) + (4 × 16.00)] g/mol = 158.04 g/mol

23. Molar mass $Ca(NO_3)_2$ = (1 × 40.08) + (2 × 14.01) + (6 × 16.00) = 164.10 g/mol

$$\text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{15.0\text{ g}}{164.10\text{ g/mol}} = 0.0914\text{ mol}$$

Number of molecules = Number of moles x N_A

Number of molecules = Number of moles $\times N_A$ =

$$0.0914\text{ mol} \times \frac{6.02\times10^{23}\text{ molecules}}{1\text{ mol}} = 5.50\times10^{22}\text{ molecules}$$

$$\text{Number of oxygen atoms} = \frac{6\text{ atoms of O}}{1\text{ molecule}} \times \text{Number of molecules of } Ca(NO_3)_2$$

$= 6\times5.50\times10^{22} = 3.30\times10^{23}$ atoms of oxygen

There are 3.30×10^{23} atoms of oxygen in the sample.

24. Average atomic mass = Sum of all [atomic mass x isotopic abundance]
= (49.9461 u)(0.0431) + (51.9405 u)(0.8376) + (52.9407 u)(0.0955) + (53.9389 u)(0.0238) = 52.0 u
The average atomic mass of chromium is 52.0 u.

25.

$$\text{Mass percent of chlorine} = \frac{22.4\text{g}}{35.0\text{g}} \times 100\% = 64.0\%$$

$$\text{Mass percent of calcium} = \frac{12.6\text{g}}{35.0\text{g}} \times 100\% = 36.0\%$$

26. Molar mass of Cu_2SO_4 = 223.17 g/mol

$$\text{Mass percent Cu} = \frac{2\times63.55\text{g}}{223.17\text{g}} \times 100\% = 56.95\%$$

$$\text{Mass percent S} = \frac{32.07\text{g}}{223.17\text{g}} \times 100\% = 14.37\%$$

$$\text{Mass percent O} = \frac{4\times16.00\text{g}}{223.17\text{g}} \times 100\% = 28.68\%$$

The mass percents of the elements in the compound are 56.95% copper, 14.37% sulfur, and 28.68% oxygen.

27. Using a 100 g sample,

$$\text{Moles Cu} = \frac{88.8\text{g}}{63.55\text{g/mol}} = 1.40\text{ mol}$$

$$\text{Moles O} = \frac{11.2\text{g}}{16.00\text{g/mol}} = 0.700\text{ mol}$$

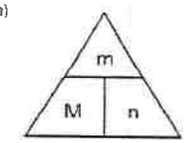
$$\text{Simple ratio for Cu} = \frac{1.40}{0.700} = 2$$

$$\text{Simple ratio for O} = \frac{0.700}{0.700} = 1$$

Therefore, the empirical formula is Cu_2O.

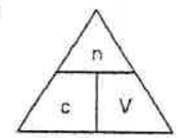
28.

a)



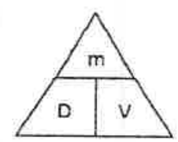
m = mass in grams
M = molar mass in grams per mole
n = amount in moles

b)



n = amount in moles
c = concentration in moles per litre
V = volume in litres

c)



m = mass in grams
D = density in grams per millilitre
V = volume in millilitres

Units other than those given may be acceptable: for example, kg/m^3.

29. a) $m = Mn \Rightarrow g = g/\cancel{mol} \times \cancel{mol}$
b) $n = cV \Rightarrow n = mol/\cancel{L} \times \cancel{L}$
c) $m = dV \Rightarrow g = g/\cancel{mL} \times \cancel{mL}$

30. Molar mass of NH_4Cl = 53.50 g/mol

$$\text{Mass percent N} = \frac{14.01\text{g}}{53.50\text{g/mol}} \times 100\% = 26.19\%$$

$$\text{Mass percent H} = \frac{4\times1.01\text{g}}{53.50\text{g/mol}} \times 100\% = 7.55\%$$

$$\text{Mass percent Cl} = \frac{35.45\text{g}}{53.50\text{g/mol}} \times 100\% = 66.26\%$$

31. a)

Mass C in $CO_2 = \frac{12.01g}{44.01g} \times 7.35g = 2.006g$

Mass H in $H_2O = \frac{2.02g}{18.02g} \times 2.99g = 0.335g$

Mass O in sample $= 5.015g - 2.006g - 0.335g = 2.674g$

Moles C $= \frac{2.006g}{12.01g/mol} 0.167$ mol

Moles H $= \frac{0.335g}{1.01g/mol} = 0.332$ mol

Moles O $= \frac{2.674g}{16.00g/mol} = 0.167$ mol

Simple ratio C:H:O $= \frac{0.167}{0.167} : \frac{0.332}{0.167} : \frac{0.167}{0.167} \Rightarrow 1:2:1$

The empirical formula is CH_2O.

b)

Multiplying factor $= \frac{60.05g/mol}{30.03g/mol} = 2$

Therefore, the molecular formula is $C_2H_4O_2$.

c) The structural formula of acetic acid is CH_3COOH. Acetic acid is found in vinegar.

32. Using a 100 g sample,

Moles K $= \frac{38.67g}{39.10g/mol} = 0.989 \text{ mol} \approx 1$

Moles N $= \frac{13.85g}{14.01g/mol} = 0.988 \text{ mol} \approx 1$

Moles O $= \frac{47.48g}{16.00g/mol} = 2.97 \text{ mol} \approx 1$

Simple whole number ratio of K:N:O = 1:1:3

Therefore, the empirical formula is KNO_3.

33. Assuming a 100 g sample,

Moles C $= \frac{35.51g}{12.01g/mol} = 2.96$ mol

Moles H $= \frac{4.77g}{1.01g/mol} = 2.73$ mol

Moles O $= \frac{37.85g}{16.00g/mol} = 2.37$ mol

Moles N $= \frac{8.29g}{14.01g/mol} = 0.59$ mol

Moles Na $= \frac{13.60g}{22.99g/mol} = 0.59$ mol

Simple ratio for C $= \frac{2.96}{0.59} \approx 5$

Simple ratio for H $= \frac{4.73}{0.59} \approx 8$

Simple ratio for O $= \frac{2.37}{0.59} \approx 4$

Simple ratio for N and Na $= \frac{0.59}{0.59} \approx 1$

Therefore, the empirical formula is $C_5H_8O_4NNa$.

Empirical formula mass = 169.11 g/mol

Molecular formula factor $= \frac{169g/mol}{169.11g/mol} \approx 1$

Therefore, the molecular formula is the same as the empirical formula, which is $C_5H_8O_4NNa$.

34. $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

Moles CaO $= \frac{25.0g}{56.08g/mol} = 0.446$ mol CaO

$\frac{\chi \text{ mol } Ca(OH)_2}{0.446 \text{ mol CaO}} = \frac{1 \text{ mol } Ca(OH)_2}{1 \text{ mol CaO}}$

$\chi = 0.446$ mol Ca $(OH)_2$

Mass $Ca(OH)_2 = 0.446$ mol × 74.10g/mol = 33.0g

Therefore, 46.2 g of $Ca(OH)_{2(s)}$ is produced.

35. $3Fe_{(s)} + Sb_2S_{3(s)} \rightarrow 2Sb_{(s)} + 3FeS_{(s)}$

Moles $Sb_2S_3 = \frac{15.6g}{339.73g/mol} = 0.0460$ mol Sb_2S_3

$\frac{\chi \text{ mol Fe}}{0.0460 \text{ mol } Sb_2S_3} = \frac{3 \text{ mol Fe}}{1 \text{ mol } Sb_2S_3}$

$\chi = 0.138$ mol Fe

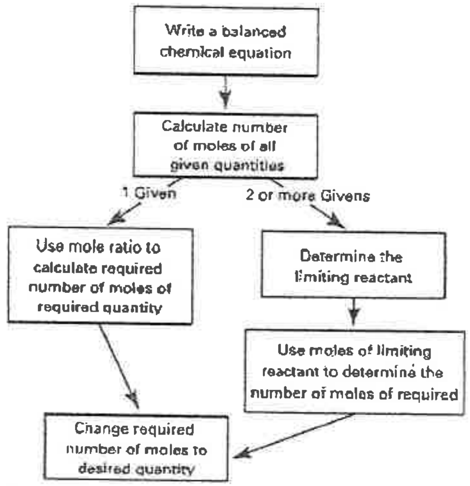
Mass Fe = 0.138 mol × 55.85 g/mol = 7.71g

Therefore, 7.71 g of Fe is needed.

36.

Percentage yield $= \frac{47.8g}{62.9g} \times 100 = 76.0\%$

37.



38. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

$$\text{Moles } N_2 = \frac{39.2\,g}{28.02\,g/mol} = 1.40\text{ mol}$$

$$\text{Moles } H_2 = \frac{8.60\,g}{2.02\,g/mol} = 1.42\text{ mol}$$

$$\frac{x\text{ mol }NH_3}{1.40\text{ mol }N_2} = \frac{2\text{ mol }NH_3}{1\text{ mol }N_2}$$

$x = 2.80$mol

Volume occupied = 2.80mol × 22.4L/mol = 62.7L
The volume of ammonia gas that is produced is 62.7 L.

39. a) $2Cu_2O_{(s)} + Cu_2S_{(s)} \rightarrow 6Cu_{(s)} + SO_{2(g)}$

$$\text{Moles } Cu_2O = \frac{86.0g}{143.10g/mol} = 0.601\text{ mol}$$

$$\frac{x\text{ mol copper}}{0.601\text{ mol }Cu_2O} = \frac{6\text{ mol Cu}}{2\text{ mol }Cu_2O}$$

$x = 1.803$ mol

$$\text{Moles } Cu_2S = \frac{46.0g}{159.17g/mol} = 0.289\text{ mol}$$

$$\frac{x\text{ mol copper}}{0.289\text{ mol }Cu_2S} = \frac{6\text{ mol Cu}}{1\text{ mol }Cu_2S}$$

$x = 1.73$ mol

Copper(I) sulfide is the limiting reactant. 1.73mol of copper is produced.

Mass of copper = 1.73mol × 63.55g/mol = 110g
The theoretical yield is 110g of copper.
b)

$$\text{Percentage yield} = \frac{98.0g}{110g} \times 100 = 89.1\%$$

The percentage yield is 89.1%.

40. a) $Pb(NO_3)_{2(aq)} + 2NaCl_{(aq)} \rightarrow PbCl_{2(s)} + 2NaNO_{3(aq)}$

$$\text{Moles } Pb(NO_3)_2 = \frac{8.93g}{331.22g/mol} = 0.0270\text{ mol}$$

$$\text{Moles NaCl} = \frac{m}{M} = \frac{1.05g}{58.44g/mol} = 0.0180\text{ mol}$$

Moles NaCl needed = 2 × mol $Pb(NO_3)_2$ = 2 × 0.0270 mol = 0.0540 mol

There is not enough sodium chloride avaiable. Therefore, sodium chloride is the limiting reactant and lead(II) nitrate is the reactant in excess.
b) Moles of lead(II) nitrate remaining = 0.0270mol - ½(0.0180)mol = 0.0180mol
Mass of lead(II) nitrate remaining = 0.0180mol × 331.22g/mol = 5.96g
The mass of lead(II) nitrate remaining is 5.96g
c) Moles of NaCl still needed = 2 × 0.0270 mol $Pb(NO_3)_2$ - 0.0180 mol = 0.0360 mol
Mass of sodium chloride needed for stoichiometric amounts = 0.0360mol × 58.44g/mol = 2.10g
Therefore, 2.10 g of sodium chloride is needed.

41.

$$\text{Moles of nitrogen} = \frac{490g}{28.02g/mol} = 17.5\text{ mol}$$

$$\frac{x\text{ mol }NH_3}{17.5\text{ mol }N_2} = \frac{2\text{ mol }NH_3}{1\text{ mol }N_2}$$

$x = 35.0$ mol

$$\text{Moles of hydrogen} = \frac{100g}{2.02g/mol} = 49.5\text{ mol}$$

$$\frac{x\text{ mol }NH_3}{49.5\text{ mol }H_2} = \frac{2\text{ mol }NH_3}{3\text{ mol }H_2}$$

$x = 33.0$ mol

Using the number of moles of hydrogen (the limiting reactant), 33.0 mol of ammonia are produced.
Mass NH_3 = 33.0 mol × 17.04g/mol = 562g
Therefore, 562 g of ammonia is formed.

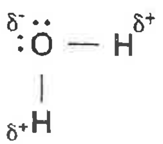
42. "Like dissolves like" refers to the fact that polar and ionic substances dissolve better in polar solvents than in non-polar solvents. Non-polar solutes dissolve better in non-polar solvents.

43. Grinding the solid into a powder increases the rate of dissolving because it increases the surface area that comes in contact with the solvent. Increasing the temperature usually increases the collisions between solvent molecules and undissolved solid molecules, because it increases the kinetic energy of the molecules. Agitating the mixture by stirring or shaking brings fresh solvent in contact with undissolved solid.

44. a)

shape = bent

charge disribution:



b) Water is a polar solvent because of the electronegativity difference between hydrogen and oxygen. The electrons in the O-H bonds are unequally shared. As well, the water molecule is not symmetrical. The oxygen has a slightly negative charge, and the hydrogens have a slightly positive charge. The presence of these two "poles" results in an overall polar molecule.

c) Water is referred to as the universal solvent because it is able to dissolve a large number and variety of solutes.

d) Water is a good solvent because it is polar. It can attract the ions of ionic substances as well as the polar ends of the molecules of polar substances. Hydrogen bonding creates strong attractions between solute and solvent particles in any solutes that contain nitrogen, oxygen, or fluorine.

45. Solubility depends on molecular size, temperature, and pressure.
Molecular size: Small molecules are often more soluble than large molecules. Most of a large molecule may be non-polar. Thus, a large molecule may not be attracted to water molecules. The weaker the overall attraction between a molecule and water molecules, the lower the solubility is.
Temperature: The solubility of a solid usually increases as the temperature of the solution increases. Particles at higher temperatures have greater kinetic energy. They are better able to break the bonds that hold the solid together and intermingle with the solute particles. The solubility of a gas, on the other hand, decreases as the temperature increases. The greater kinetic energy causes the particles to prefer to exist in the gaseous state rather than being held dissolved in a liquid.
Pressure: Pressure hardly affects the solubility of a liquid or a solid. The solubility of a gas, however, is directly proportional to the pressure. The higher the pressure, the higher the solubility of the gas is. This is because the greater pressure forces the gas molecules out of the air space in a container and into the solution.

46. Molar concentration = 0.25 mol/0.175 L = 1.4 mol/L

$$\frac{x}{100\text{ mL}} = \frac{3.0\text{ g}}{50.0\text{ mL}}$$

47. $x = \frac{6.0\text{ g}}{100\text{ ml}} = 6.0\%$

Therefore, the mass/volume percentage is 6.0%.

48. Moles Na_2S = Concentration × Volume = 0.50 mol/L × 0.350 L = 0.175 mol
Mass = Moles × Molar mass = 0.175 mol × 78.05 g/mol = 14 g
The mass of sodium sulfide that is needed is 14 g.

49.

$$\frac{x}{100\text{ mL}} = \frac{5.0\text{ g}}{75\text{ mL}}$$

$x = 6.7\%$ (m/v)
The concentration is 6.7% (m/v).

50.

$$\frac{x}{100\text{ g}} = \frac{0.575\text{ g}}{265\text{ g}}$$

$x = 0.217\%$ (m/m)
The concentration is 0.217 (m/m).

51.

$$\text{Mass} = 50.0\text{ mL} \times \frac{2.5\text{g}}{100\text{ mL}} = 1.25\text{g}$$

The mass of Na_2CO_3 in the solution is 1.25 g.

52.

$$\text{Moles } Al_2(SO_4)_3 = \frac{58.5\text{g}}{342.17\text{g / mol}} = 0.171\text{ mol}$$

$$\text{Concentration} = \frac{0.171\text{ mol}}{0.855\text{ L}} = 0.200\text{ mol / L}$$

The concentration of the solution is 0.200 mol/L.

53. $HCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + HNO_{3(aq)}$
Moles HCl = 0.035 L × 0.250 mol/L = 0.00875 mol

$$\frac{x\text{ mol AgCl}}{0.008\ 75\text{ mol HCl}} = \frac{1\text{ mol AgCl}}{1\text{ mol HCl}}$$

x = 0.008 75 mol
Mass AgCl = 0.008 75 mol × 143.32 g/mol = 1.25 g
The mass of the silver chloride precipitate is 1.25 g.

54. $CuSO_{4(aq)} + Na_2S_{(aq)} \rightarrow CuS_{(s)} + Na_2SO_{4(aq)}$
Moles $CuSO_4$ = 0.010 L × 0.10 mol/L = .0010 mol
Moles Na_2S = 0.025 L × 0.20 mol/L = .0050 mol

$$\frac{\text{moles CuS}}{0.0010\text{ mol } CuSO_4} = \frac{1\text{ mol CuS}}{1\text{ mol } CuSO_4}$$

x = 0.0010 mol

$$\frac{\text{moles CuS}}{0.0050\text{ mol } Na_2S} = \frac{1\text{ mol CuS}}{1\text{ mol } Na_2S}$$

x = 0.0050 mol
Therefore, 0.0010 mol of CuS is produced.
Mass = 0.0010 mol × 95.62 g/mol = 0.0956 g
Therefore, the mass of the copper(II) sulfide precipitate is 0.096 g.

55. $H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \rightarrow BaSO_{4(s)} + 2H_2O_{(l)}$

$$\text{Moles } BaSO_4 = \frac{3.260\text{ g}}{233.40\text{ g/mol}} = 0.0140\text{ mol}$$

$$\frac{x\text{ mol } H_2SO_4}{0.0140\text{ mol } BaSO_4} = \frac{1\text{ mol } H_2SO_4}{1\text{ mol } BaSO_4}$$

$x = 0.0140$ mol

$$\text{Concentration} = \frac{0.0140\text{ mol}}{0.0426\text{ L}} = 0.329\text{ mol/L}$$

The concentration of the sulfuric acid is 0.329 mol/L.

56. $2Na^+_{(aq)} + S^{2-}_{(aq)} + Cu^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + CuS_{(s)}$
$S^{2-}_{(aq)} + Cu^{2+}_{(aq)} \rightarrow CuS_{(s)}$
The spectator ions are $Na^+_{(aq)}$ and $Cl^-_{(aq)}$.

57. $2K^+_{(aq)} + CO_3^{2-}{}_{(aq)} + Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2K^+_{(aq)} + SO_4^{2-}{}_{(aq)} + CuCO_3^{2-}{}_{(s)}$
$CO_3^{2-}{}_{(aq)} + Cu^{2+}_{(aq)} \rightarrow CuCO_3^{2-}{}_{(s)}$
The spectator ions are $K^+_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$

58. a) $Ba^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2K^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2K^+_{(aq)} + 2NO_3^-{}_{(aq)} + BaSO_{4(s)}$
$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$
The spectator ions are $2K^+_{(aq)}$ and $2NO_3^-{}_{(aq)}$.
b) Moles $Ba(NO_3)_2 = 0.11$ mol/L x 0.365 L = 0.040 mol

$$\frac{x\text{ mol } BaSO_4}{0.040\text{ mol } Ba(NO_3)_2} = \frac{1\text{ mol } BaSO_4}{1\text{ mol } Ba(NO_3)_2}$$

Therefore, 0.040 mol of $Ba(NO_3)_2$ can produce 0.040 mol of $BaSO_{4(s)}$.

Moles $K_2SO_4 = 0.18$ mol/L x 0.255 L = 0.046 mol

$$\frac{x\text{ mol } BaSO_4}{0.046\text{ mol } K_2SO_4} = \frac{1\text{ mol } BaSO_4}{1\text{ mol } K_2SO_4}$$

Therefore, 0.046 mol of potassium sulfate is enough to produce 0.046 mol of $BaSO_{4(s)}$.
Mass $BaSO_{4(s)} = 0.040$ mol × 233.40 g/mol = 9.3 g
Using the limiting reactant, 9.3 g of $BaSO_{4(s)}$ is formed.

59. $Na_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + BaSO_{4(s)}$
Moles $BaCl_2 = 0.0600$ L x 0.145 mol/L = 0.008 70 mol

$$\frac{x\text{ mol } Na_2SO_4}{0.00870\text{ mol } BaCl_2} = \frac{1\text{ mol } Na_2SO_4}{1\text{ mol } BaCl_2}$$

$x = 0.00870$ mol Na_2SO_4

$$\text{Volume } Na_2SO_4 = \frac{0.00870\text{ mol}}{0.110\text{ mol/L}} = 0.0791\text{ L or } 79.1\text{ mL}$$

The volume of Na_2SO_4 needed is 79.1 mL.

60. $FeCl_{2(aq)} + Na_2S_{(aq)} \rightarrow FeS_{(s)} + 2NaCl_{(aq)}$
Sodium compounds are always soluble, so the precipitate is FeS.
Moles $FeCl_2 = 0.0900$ L × 0.325 mol/L = 0.0293 mol

$$\frac{x\text{ mol FeS}}{0.0293\text{ mol } FeCl_2} = \frac{1\text{ mol FeS}}{1\text{ mol } FeCl_2}$$

$x = 0.0293$ mol FeS
Mass FeS = 0.0293 mol × 87.92 g/mol = 2.57 g
Therefore, 2.57 g of FeS is formed.

61. An acid is a substance that dissociates in water to produce one or more hydrogen ions. A base is a substance that dissociates in water to form one or more hydroxide ions.

62. A hydronium ion is a hydrated proton, $H_3O^+_{(aq)}$.

63. A strong base dissociates completely into ions in water. One of the ions is hydroxide. Examples are NaOH and $Ca(OH)_2$.
A weak base dissociates very slightly in water. Examples are aqueous ammonia and $Cu(OH)_2$.

64. A strong acid dissociates completely into ions in water. One of the ions is the hydrogen or hydronium ion. Examples are HCl and $HClO_4$.
A weak acid is an acid that dissociates only very slightly in water. An example is CH_3COOH.

65. a) hydrobromic acid
b) hypophosphorous acid
c) sulfurous acid
d) iodic acid
e) perbromic acid

66. a) $H_2CO_{3(aq)}$
b) $HNO_{(aq)}$
c) $H_2SO_{3(aq)}$
d) $HCN_{(aq)}$
e) $HClO_{4(aq)}$

67. $Ca(OH)_{2(aq)} + 2HNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2H_2O_{(l)}$
Moles $HNO_{3(aq)} = 0.0460$ L × 0.15 mol/L = 0.0069 mol

$$\frac{x\text{ mol } Ca(OH)_2}{0.0069\text{ mol } HNO_3} = \frac{1\text{ mol } Ca(OH)_2}{2\text{ mol } HNO_3}$$

$x = 0.0035$ mol

$$\text{Concentration } Ca(OH)_2 = \frac{0.0035\text{ mol}}{0.025\text{ L}} = 0.14\text{ mol/L}$$

The concentration of the calcium hydroxide was 0.14 mol/L.

68. $H_2SO_{4(aq)} + 2KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$
Moles KOH(aq) = 0.010 L × 1.5 mol/L = 0.015 mol

$$\frac{x\text{ mol } H_2SO_4}{0.015\text{ mol KOH}} = \frac{1\text{ mol } H_2SO_4}{2\text{ mol KOH}}$$

$x = 0.0075$ mol

$$\text{Volume } H_2SO_4 = \frac{0.0075\text{ mol}}{0.250\text{ mol/L}} = 0.030\text{ L}$$

30 mL of $H_2SO_{4(aq)}$ is needed.

69. $2H_3PO_{4(aq)} + 3Ba(OH)_{2(aq)} \rightarrow Ba_3(PO_4)_{2(aq)} + 6H_2O_{(l)}$
Moles $H_3PO_4 = 0.008$ 54 L × 0.50 mol/L = 0.0043 mol

$$\frac{x \text{ mol Ba(OH)}_2}{0.0043 \text{ mol H}_3\text{PO}_4} = \frac{3 \text{ mol Ba(OH)}_2}{2 \text{ mol H}_3\text{PO}_4}$$

$x = 0.0065$ mol

$$\text{Concentration Ba(OH)}_2 = \frac{0.0065 \text{ mol}}{0.030 \text{ L}} = 0.22 \text{ mol/L}$$

The concentration of the barium hydroxide solution was 0.22 mol/L.

70. a) $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

Moles NaOH = 0.020 L × 0.15 mol/L = 0.0030 mol

$$\frac{x \text{ mol Na}_2\text{SO}_4}{0.0030 \text{ mol NaOH}} = \frac{1 \text{ mol Na}_2\text{SO}_4}{2 \text{ mol NaOH}}$$

$x = 0.0015$ mol

Moles H_2SO_4 = 0.0300 L × 0.20 mol/L = 0.0060 mol

$$\frac{x \text{ mol Na}_2\text{SO}_4}{0.006 \text{ mol H}_2\text{SO}_4} = \frac{1 \text{ mol Na}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4}$$

$x = 0.006$ mol

0.0015 mol of Na_2SO_4 are produced.

Mass Na_2SO_4 = 0.0015 mol × 142.05 g/mol = 0.21 g

Therefore, 0.21 g of Na_2SO_4 is produced.

b) $$\frac{x \text{ mol H}_2\text{SO}_4 \text{ used}}{0.0030 \text{ mol NaOH}} = \frac{1 \text{ mol H}_2\text{SO}_4 \text{ used}}{2 \text{ mol NaOH}}$$

x = Moles H_2SO_4 used = 0.0015 mol

Moles H_2SO_4 used in excess = 0.006 mol - 0.0015 mol = 0.0045 mol

$$\frac{x \text{ mol H}_3\text{O}^+}{0.0045 \text{ mol H}_2\text{SO}_4} = \frac{2 \text{ mol H}_3\text{O}^+}{1 \text{ mol H}_2\text{SO}_4}$$

$x = 0.0090$ mol H_3O^+

$$[\text{H}_3\text{O}^+] = \frac{0.0090 \text{ mol}}{(0.020 + 0.030) \text{ L}} = 0.18 \text{ mol/L}$$

c) pH = -log $[H_3O^+]$ = -log 0.18 = 0.74

The pH of the resulting solution is 0.74.

71. $Mg(OH)_{2(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$

$$\text{Moles of Mg(OH)}_2 = \frac{4.50 \text{ g}}{58.33 \text{ g/mol}} = 0.0771 \text{ mol}$$

$$\frac{x \text{ mol HCl}}{0.0771 \text{ mol Mg(OH)}_2} = \frac{2 \text{ mol HCl}}{1 \text{ mol Mg(OH)}_2}$$

$x = 0.154$ mol

$$[\text{HCl}] = \frac{0.154 \text{ mol}}{0.400 \text{ L}} = 0.385 \text{ mol/L}$$

The concentration of HCl is 0.385 mol/L.

72. a) pH = -log $[H_3O^+]$ = -log (1.0×10^{-2}) = 2.00

The pH of the diluted solution is 2.00.

b) pH = -log $[H_3O^+]$ = -log (6.31×10^{-9}) = 8.20

The pH of the diluted solution is 8.20.

c) pH = -log $[H_3O^+]$ = -log (2.51×10^{-6}) = 5.60

The pH of the diluted solution is 5.60.

73. a) $[H_3O^+] = 10^{-pH} = 10^{-7.90} = 1.3 \times 10^{-8}$ mol/L

b) $[H_3O^+] = 10^{-pH} = 10^{-3.80} = 1.6 \times 10^{-4}$ mol/L

c) $[H_3O^+] = 10^{-pH} = 10^{-1.50} = 3.2 \times 10^{-2}$ mol/L

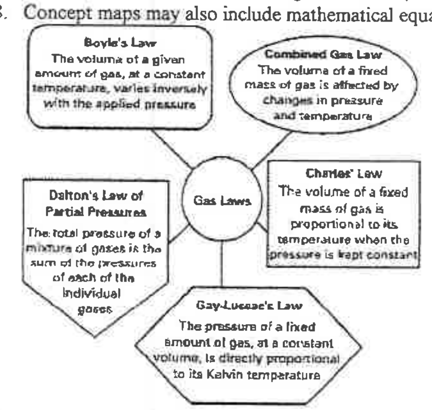
74. STP stands for standard temperature and pressure. The temperature values that are associated with STP are 0°C and 273 K. The pressure values that are associated with STP are 760 mm Hg, 760 torr, 101.3 kPa, and 1 atm.

75. Charles' law is the direct relationship between the volume and temperature (in kelvins) of a gas, when the pressure is constant. One real-life example of Charles' law is a hot air balloon.

76. The size of the gas molecules does not change. It is the size of the spaces between the gas molecules that changes. As temperature increases, the spaces between the gas molecules increase, causing the gas to take up more space.

77. The sample of gas at 500°C would react faster. The gas molecules in this gas sample are moving faster than the gas molecules in the gas sample at 25°C. The faster the gas molecules are moving, the greater is the chance of collisions between gas molecules, which cause the gas to react faster.

78. Concept maps may also include mathematical equations.



79.

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

$$\frac{101.3 \text{ kPa} \times 1400 \text{L}}{298 \text{ K}} = \frac{P_2 \times 10.0 \text{ L}}{263 \text{ K}}$$

$P_2 = 1.25 \times 10^4$ kPa

80.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{1520 \text{ mm Hg}}{298 \text{ K}} = \frac{1900 \text{ mm Hg}}{T_2} = 373 \text{ K}$$

81. The diagram should show the balloon before and after sitting in the Sun. The gas molecules in the balloon before sitting in the Sun are closer together than the gas molecules in the balloon after sitting in the Sun. The diagram of the balloon after sitting in the Sun should show the gas molecules moving a faster rate. The gas molecules move faster and press against the walls with more force when heated, which causes the balloon to expand.
82. The atmospheric pressure at high altitudes is lower than the atmospheric pressure at sea level because there are fewer gas molecules and therefore fewer collisions between gas molecules. At a lower atmospheric pressure, there is less force pressing down on the surface of the water that is being boiled. This allows the water vapour molecules to rise and break through the surface of the water more easily than at higher atmospheric pressure. Hence, the water boils at a lower temperature (faster), although the egg does not cook as quickly at this lower temperature. Adding salt to the water will raise the boiling temperature.
83. An aerosol can exploding in a fire shows a direct relationship between pressure and temperature. When the temperature increases, the gas molecules move faster and push against the walls of the can with more force. The volume of the can remains constant, until it explodes from the excessive pressure. This shows Gay-Lussac's law.
84.

$P_1 \times V_1 = P_2 \times V_2$

$1.5 \text{ atm} \times 30 \text{ mL} = P_2 \times 100 \text{ mL}$

$P_2 = 0.45 \text{ atm}$

85.

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

$$\frac{40 \text{ L}}{100 \text{ L}} = \frac{P_2}{5.0 \text{ atm}}$$

$P_2 = 2.0 \text{ atm}$

86.

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

$$\frac{250 \text{ mL} \times 120 \text{ kPa}}{297 \text{ K}} = \frac{101.3 \text{ kPa} \times V_2}{273 \text{ K}}$$

$V_2 = 272 \text{ mL}$

87. $P_1 \times V_1 = P_2 \times V_2$

$1.5 \text{ atm} \times 30 \text{ L} = P_2 \times 100 \text{ L}$

$P_2 = 0.45 \text{ atm}$

88. Using $PV = nRT$, moles and temperature are on the same side of the equals sign. Therefore, moles and temperature are inversely (or indirectly) proportional to each other.

89. Molar volume is the volume that is occupied by 1 mol of any gas at STP. The molar volume of any gas is 22.4 L/mol.
90.

$$V_m = \frac{V}{n}$$

$V = V_m \times n = 22.4 \text{ L/mol} \times 5.05 \text{ mol} = 113 \text{ L}$

91. $PV = nRT$

$$n = \frac{PV}{RT} = \frac{(95.0 \text{ kPa})(10.0 \text{ L})}{(8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}})(268)} = 0.426 \text{ mol}$$

92.

$$P = \frac{nRT}{V} = \frac{6.7 \text{ mol} \times 8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 303 \text{ K}}{3.5 \text{ L}} = 4.8 \times 10^2 \text{ kPa}$$

93. Find molar mass of C_2H_4. Then use $n = m/M$ to solve for n. Use a mole ratio to find the number of moles of H_2O, using the number of moles of C_2H_4 and the balanced equation. Use $PV = nRT$ to find V.

Mass of $C_2H_4 = (2 \times 12.01 \text{ g/mol}) + (4 \times 1.01 \text{ g/mol}) = 28.06 \text{ g/mol}$

$$n = \frac{m}{M} = \frac{15.0 \text{ g}}{28.06 \text{ g/mol}} = 0.535 \text{ mol}$$

Mole ratio: $\frac{1 \text{ mol } C_2H_4}{2 \text{ mol } H_2O} = \frac{0.535 \text{ mol}}{x}$

$x = 1.07 \text{ mol}$

$PV = nRT$

$$V = \frac{nRT}{P} = \frac{1.07 \text{ mol} \times 8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 298 \text{ K}}{100 \text{ kPa}} = 26.5 \text{ L}$$

94. Use $PV = nRT$ to find n. Use $n = m/M$ to find M.

$$n = \frac{PV}{RT} = \frac{122 \text{ kPa} \times 0.750 \text{ mol}}{8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 308 \text{ K}} = 0.0357 \text{ mol}$$

$$M = \frac{m}{n} = \frac{5.00 g}{0.0357 \text{ mol}} = 140 \text{ g / mol}$$

95. Use $n = m/M$ to find the number of moles of K. Use the mole ratio to find the number of moles of H_2. Use $PV = nRT$ to find the temperature of H_2.

$$n = \frac{m}{M} = \frac{3.55 \text{ g}}{39.10 \text{ g / mol}} = 0.0908 \text{ mol}$$

Mole ratio: $\frac{2 \text{ mol K}}{1 \text{ mol } H_2} = \frac{0.0908 \text{ mol}}{x}$

$x = 0.0454 \text{ mol}$

$$T = \frac{PV}{nR} = \frac{117 \text{ kPa} \times 0.448 \text{ L}}{0.0454 \text{ mol} \times 8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}}} = 139 \text{ K}$$

96. Use $PV = nRT$ to find the number of moles of H_2. Use the mole ratio to find the number of moles of Al

used. Use $n = m/M$ to find the mass of Al.

$$n = \frac{PV}{RT} = \frac{103\text{ kPa} \times 1.50\text{ L}}{294\text{ K} \times 8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}} = 0.0632\text{ mol H}_2$$

Mole ratio: $\frac{3\text{ mol H}_2}{2\text{ mol Al}} = \frac{0.0632\text{ mol H}_2}{x\text{ mol Al}}$

$x = 0.0421$ mol of Al

$m = n{\cdot}M = 0.0421$ mol x 26.98 g/mol $= 1.14$ g

97. First find the number of moles of both reactants. Use $n = m/M$ to find the number of moles of FeS. Use $PV = nRT$ to find the number of moles of O_2. Use the mole ratio to determine the limiting reactant. Then use the mole ratio to find the number of moles of Fe_2O_3. Use $n = m/M$ to find the mass of Fe_2O_3.

Moles FeS_2: $n = \frac{m}{M} = \frac{25.2\text{ g}}{119.99\text{ g / mol}} = 0.210$ mol

Moles O_2: $n\frac{PV}{RT} = \frac{100\text{ kPa} \times 5.50\text{ L}}{293\text{ K} \times 8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}} = 0.226$ mol

Mole ratio: $\frac{4\text{ mol FeS}_2}{11\text{ mol O}_2} = \frac{0.210\text{ mol}}{x}$

$x = 0.578$ mol of O_2

Only 0.226 mol of O_2 are available, however. Since there is not enough O_2 available, oxygen gas is the limiting reactant.

Mole ratio: $\frac{11\text{ mol O}_2}{2\text{ mol Fe}_2\text{O}_3} = \frac{0.226\text{ mol}}{x}$

$x = 0.0411$ mol

$m = n \times M = 0.0411$ mol x 159.70 g/mol $= 6.56$ g

98. Use $PV = nRT$ to find the number of moles of C_4H_{10}. Use the mole ratio to find the number of moles of O_2. Use $PV = nRT$ to find the volume of O_2.

$$n = \frac{PV}{RT} = \frac{101.3\text{ kPa} \times 1000\text{ L}}{8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 273\text{ K}} = 44.6\text{ mol}$$

Mole ratio: $\frac{2\text{ mol C}_4\text{H}_{10}}{13\text{ mol O}_2} = \frac{44.6\text{ mol}}{x}$

$x = 290$ mol O_2

$$V = \frac{nRT}{P} = \frac{290\text{ mol} \times 8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 273\text{ K}}{101.3\text{ kPa}} = 6.5 \times 10^3\text{ L}$$

99. Use $n = m/M$ to find the number of moles of N_2 and H_2. Use the mole ratio to find the limiting reactant. Use the mole ratio to find the number of moles of NH_3. Use $PV = nRT$ to find the volume of NH_3.

Moles N_2: $n = \frac{m}{M} = \frac{60.0\text{ g}}{17.04\text{ g / mol}} = 3.52$ mol

Moles H_2: $n = \frac{m}{M} = \frac{9.00\text{ g}}{2.02\text{ g / mol}} = 4.46$ mol

Mole ratio: $\frac{1\text{ mol N}_2}{3\text{ mol H}_2} = \frac{3.52\text{ mol}}{x}$

$x = 10.6$ mol of H_2

There is not enough H_2 available, so hydrogen gas is the limiting reactant.

Mole ratio: $\frac{3\text{ mol H}_2}{2\text{ mol NH}_3} = \frac{4.46\text{ mol}}{x}$

$x = 2.97$ mol of NH_3

$$V = \frac{nRT}{P} = \frac{2.97\text{ mol} \times 8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 273\text{ K}}{101.3\text{ kPa}} = 66.5\text{ L}$$

100.

$n = \frac{m}{M} = \frac{20\text{ g}}{26.98\text{ g/mol}} = 0.74$ mol

$n = cV = 4.0$ mol/L x 0.700 L $= 2.8$ mol

Mole ratio: $\frac{2\text{ mol Al}}{6\text{ mol HCl}} = \frac{0.74\text{ mol}}{x}$

$x = 2.2$ mol of HCl

2.8 mol of HCl is available, so HCl is in excess. Aluminum is the limiting reactant.

Mole ratio: $\frac{2\text{ mol Al}}{3\text{ mol H}_2} = \frac{0.74\text{ mol}}{x}$

$x = 1.1$ mol of H_2

$$V = \frac{nRT}{P} = \frac{1.1\text{ mol} \times 8.314\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 300\text{ K}}{107\text{ kPa}} = 26\text{ L}$$

101. Moles of sulfuric acid = 0.100 L × 0.45 mol/L = 0.045 mol

Volume of sulfuric acid $= \frac{0.045\text{ mol}}{3.5\text{ mol / L}} = 0.013$ L

Therefore, 13 mL of the 3.5 mol/L sulfuric acid solution is needed.
Another way to solve this problem involves using the formula $C_1V_1 = C_2V_2$

3.5 mol/L x $V_1 = 0.45$ mol/L × 0.100 L

$V_1 = 13$ mL