SCH3U: Final Exam Review

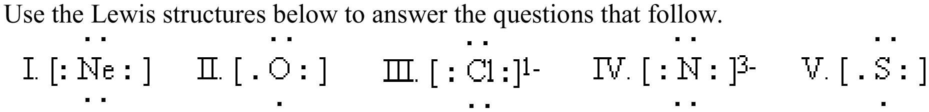
Note: These questions are just to help you prepare for the exam. This review should be the minimum that you do to prepare for the exam. The solutions to the review questions are at the back of the handout.

UNIT: Matter and Chemical Bonding

A) Elements and the Periodic Table

1. 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) $^{3}_{1}H^{1+}$
2. Draw Lewis structures for lithium chlorine, chloride, sulfur, magnesium, and aluminum.
3. Use the Lewis structures below to answer the questions that follow.



   a) Which of these species have identical electron configurations?
   b) Which are stable?
   c) Which are in the same period?
   d) Which are in the same group?
4. Ionisation Energies

A	B
____i. lowest ionisation energy in Group 1 (IA)	a. iodine
____ii. lowest ionisation energy of all the elements	b. neon
____iii. highest first ionisation energy in Period 2	c. hydrogen
____iv. element with the highest second ionisation energy	d. cesium
____v. halogen with the highest first ionisation energy	e. fluorine
	f. iodine
	g. helium
	h. lithium

5. Terminology

A	B
____i. outer energy level in an atom	a. transition metals
____ii. energy needed to remove the third electron	b. third energy level
____iii. energy released when an atom gains an electron	c. main group elements
____iv. stable electron configuration	d. radioisotopes
____v. elements in Groups 1, 2, and 13 to 18	e. electron affinity
	f. electronegativity
	g. halogens
	h. transuranium elements
	i. valence shell
	j. third ionisation energy
	k. octet

B) Chemical Compounds and Bonding

6. a) Write the long and short form electron configuration for the following elements: N, P, S, Ne, and Ca.
   b) Show using electron dot diagrams how Ca and O can bond. Give the ions that are formed.
   c) Show using electron dot diagrams how Ca and P can bond. Give the ions that are formed.
7. Draw Lewis Diagrams for the following and determine if the bonds are polar, non-polar, or ionic.

   a) H_2O b) CBr_4 c) O_2
8. Chemical Formulas ***(For a more complete review of nomenclature, go to unit review in your class nomenclature notes. Remember, that a periodic table, and the basic polyatomic ions will be given to you for the exam.)***

A	B
____i. dinitrogen tetroxide	a. Sn_3P_4
____ii. carbon monoxide	b. $Au(ClO_3)_3$
____iii. mercury(II) sulfate	c. CO
____iv. lead(IV) fluoride	d. $MeSO_4$
____v. tin(IV) phosphate	e. $AuClO_3$
____vi. gold(I) chlorate	f. N_2O_4

Don't forget to study your polyatomic ion derivatives

g. C_2O_2
h. $HgSO_4$
i. $Sn_3(PO_4)_4$
j. NO_2
k. PbF_4

9. More Chemical Formulas

A
____i. zinc hydrogen carbonate
____ii. calcium phosphide
____iii. ferrous hydroxide
____iv. tin(II) nitrate
____v. lead(II) thiocyanate
____vi. mercuric silicate

B
a. $Sn(NO_3)_2$
b. $Ca_3(PO_4)_2$
c. $Sn(SCN)_2$
d. $Zn(HCO_3)_2$
e. $Fe(OH)_2$
f. $ZnCO_3$
g. Ca_3P_2
h. $Fe(OH)_3$
i. $Sn(NO_2)_2$
j. $HgSiO_3$
k. $Pb(SCN)_2$

10. Chemical Formulas of Anions

A
____i. hydride
____ii. carbonate
____iii. nitrite
____iv. nitride
____v. sulfate
____vi. nitrate
____vii. phosphite
____viii. hydroxide

B
a. PO_4^{3-}
b. NO_3^-
c. OH^-
d. CO_3^{2-}
e. P^{3-}
f. NO_2^-
g. H^-
i. N^{3-}
j. PO_3^{3-}
k. SO_3^{2-}
l. C^{4-}
m. SO_4^{2-}

C) Classifying Chemical Reactions

11. Types of Reactions

A.
____i. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$
____ii. $2HI_{(g)} \rightarrow I_{2(g)} + H_{2(g)}$
____iii. $C_7H_{16(l)} + 11O_{2(g)} \rightarrow 7CO_{2(g)} + 8H_2O_{(g)}$
____iv. $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
____v. $HNO_{3(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3(aq)} + HOH_{(l)}$

B.
a. neutralisation
b. synthesis
c. double displacement
d. single displacement
e. transmutation
f. combustion
g. decomposition
h. ionic

12. Balancing Equations

A
____i. __$Na_3PO_4 + 3Pb(NO_3)_2 \rightarrow Pb_3(PO_4)_2 + 6NaNO_3$
____ii. __ $NO_2 + H_2O \rightarrow 2HNO_3 + NO$
____iii. $2C_2H_6$ + __ $O_2 \rightarrow 4CO_2 + 6H_2O$

B
a. 1
b. 2
c. 3

____iv. $Cu + 2H_2SO_4 \rightarrow CuSO_4 + 2H_2O +$ __ SO_2 d. 4

____v. $Al_2C_6 +$ __ $H_2O \rightarrow 2Al(OH)_3 + 3C_2H_2$ e. 5

f. 6

g. 7

h. 8

13. Examine the following reactants, and predict the type of reaction that will occur. Use the following classifications: synthesis, decomposition, single displacement, double displacement, neutralisation, complete combustion, incomplete combustion, or 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) $NaNO_{3(aq)} + Ag_{(s)} \rightarrow$

UNIT: Chemical Quantities

A) Counting Atoms and Molecules/Chemical Proportions in Compounds

14. Calculating Molar Mass

A	B
____ i. NaCl	a. 45.95 g/mol
____ ii. $Ca(OH)_2$	b. 278.02 g/mol
____ iii. Li_2S	c. 342.15 g/mol
____ iv. $Mg(NO_3)_2$	d. 58.44 g/mol
____ v. $Al_2(SO_4)_3$	e. 74.10 g/mol
	f. 57.09 g/mol
	g. 148.33 g/mol

15. Calculating Number of Moles

A	B
____ i. 56.0 g of NCl_3	a. 0.0120 mol of N atoms
____ ii. 5.32×10^{22} atoms of N	b. 0.0241 mol of N atoms
____ iii. 7.25×10^{21} molecules of N_2	c. 1.35 mol of N atoms
____ iv. 124 g of N_2O_4	d. 0.0884 mol of N atoms
____ v. 6.30×10^{22} molecules of NO_2	e. 0.105 mol of N atoms
	f. 0.465 mol of N atoms
	g. 2.70 mol of N atoms

16. Calculate the number of oxygen atoms in 15.0 g of calcium nitrate, $Ca(NO_3)_2$.
17. Calculate the mass of 7.53 □ 10^{22} molecules of calcium hydroxide, $Ca(OH)_2$.
18. Empirical Formulas

A	B
____i. 40% C, 6.7% H, 53.3% O	a. $C_8H_8O_3$
____ii. 92.3% C, 7.7% H	b. CH_2O
____iii. 12.5% H, 37.5% C, 50.0% O	c. CH_4O
____iv. 75.0 % C, 25.0% H	d. CH_3
____v. 63.2% C, 5.30% H, 31.5%, O	e. CH

f. CH_4

g. C_2H_6O

19. Analysis of a lactic acid sample shows that its % composition by mass is 40.00 % carbon, 6.71 % hydrogen, and 53.29 % oxygen. The molar mass is know to be 90.0 g/mol. Determine the empirical formula and molecular formula of the lactic acid.
20. The percentage composition of a compound is 88.8% copper and 11.2% oxygen. Calculate the empirical formula of the compound.

B) Quantities in Chemical Reactions

21. Mole Ratio Calculations

The following reaction takes place with 3.00 g of copper and excess sulfuric acid.

$$Cu_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)} + SO_{2(g)}$$

Calculate the amount of each substance that is used or formed in the reaction.

A	B
____i. moles of Cu	a. 0.0944 mol
____ii. moles of H_2SO_4	b. 0.425 g
____iii. moles of $CuSO_4$	c. 0.0472 mol
____iv. mass of sulfur dioxide	d. 1.70 g
____v. mass of water	e. 0.0236 mol
	f. 3.02 g

22. Mole Ratio Calculations

The following reaction takes place when heat is added to 26.5 g of calcium phosphate, 16.8 g of silicon oxide, and excess carbon.

$$Ca_3(PO_4)_{2(s)} + SiO_{2(s)} + C_{(s)} \rightarrow P_{(s)} + CaSiO_{3(s)} + CO_{(g)}$$

Determine the limiting factor. Then calculate the amount of each substance that is used or formed in the reaction.

A	B
____i. moles of $Ca_3(PO_4)_2$	a. 0.0854 mol
____ii. moles of SiO_2	b. 0.170 mol
____iii. moles of C	c. 0.280 mol
____iv. moles of P	d. 0.427 mol
____v. moles of CO	e. 0.256 mol
	f. 0.467 mol
	g. 0.123 mol

23. 25.0 g of calcium oxide reacts with water to produce calcium hydroxide. Calculate the mass of calcium hydroxide that is produced.
24. Iron reacts with antimony trisulphide in a single replacement reaction. Antimony and iron (II) sulphide are produced. Calculate the mass of iron that is needed to react with 15.6 g of antimony trisulphide.
25. The theoretical yield of a reaction is 62.9 g, but the actual yield is 47.8 g. Calculate the percentage yield.
26. 0.987 mol of potassium chlorate decompose into potassium chloride and oxygen, according to the following equation:

$$KClO_{3(s)} \rightarrow KCl_{(s)} + O_{2(g)}$$

Calculate the moles of potassium chloride and the moles of oxygen that are formed.

27. Iron reacts with water to form hydrogen gas and iron(III) oxide.

a) Write a balanced chemical equation for the reaction.

b) 4.5 g of iron is used in the reaction. Calculate the mass of hydrogen gas that is produced.

c) Name the type of reaction.

UNIT: Solutions and Solubility

A) Solutions and Their Concentrations

28. Terms and Definitions

A	B
____i. a substance that has other substances dissolved in it	a. immiscible
____ii. a substance that is present in a smaller amount in a solution	b. aqueous
____iii. a solution in which water is the solvent	c. solute
____iv. liquids that readily dissolve in each other	d. miscible
____v. liquids that do not readily dissolve in each other	e. solvent
	f. solubility
	g. alloy

29. Units of Concentration

A	B
____i. mass solubility	a. mol/L
____ii. molar concentration	b. g/100mL
____iii. parts per billion	c. ppm
____iv. mass/volume percentage	d. ppb
____v. volume/volume percentage	e. % (v/v)
	f. % (m/v)
	g. 1 mg/mL

30. Calculating Concentration

A	B
____i. 30 g of NaCl in 500 mL of solution	a. 46% (m/v)
____ii. 46 g of NaOH in 100 mL of water	b. 25% (m/m)
____iii. 5.25 g of $AgNO_3$ in 50 g of water	c. 1.03 mol/L
____iv. 3 mL of hydrogen peroxide in 10 mL of water	d. 5.25% (m/m)
____v. 125 g of copper(II) sulfate in 500 g of water	e. 30% (v/v)
	f. 10.5% (m/m)

31. Explain the statement “Like dissolves like.”
32. 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?
33. What is the mass/volume percentage of 3.0 g in 50.0 mL of solution?
34. Calculate the mass (in grams) of sodium sulfide that is needed to make 350 mL of a 0.50 mol/L solution.
35. Calculate the concentration of 0.75 mL of hydrogen peroxide in 10 mL of solution. Express the concentration as a volume/volume percentage.
36. Calculate the concentration of 0.575 g of magnesium acetate in 265 g of water. Express the concentration as a mass/mass percentage.
37. 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?
38. 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?
39. What volume of 0.20 mol/L acetic acid solution is needed to make 100 mL of 0.015 mol/L acetic acid solution?

B) Aqueous Solutions

40. Using the Solubility Table

A	B
____i. magnesium sulfate	a. soluble
____ii. lithium hydroxide	b. insoluble
____iii. calcium carbonate	
____iv. silver nitrate	
____v. iron(II) sulfite	

41. Precipitation Reactions

A	B
____i. silver nitrate and sodium chloride	a. precipitation
____ii. silver nitrate and sodium acetate	b. no reaction
____iii. magnesium bromide and zinc sulfate	
____iv. ammonium hydroxide and strontium sulfide	
____v. mercury nitrate and lithium iodide	

42. A solution of sodium sulfide is mixed with a solution of copper(II) chloride. Write the total ionic equation and the net ionic equation for the reaction. Identify the spectator ions in the reaction.
43. 65 mL of a 2.5 mol/L solution of silver nitrate is added to an excess of calcium chloride. Identify the precipitate, and calculate the mass of this precipitate that is formed.
44. An excess of sodium carbonate solution is added to 75.0 mL of calcium chloride solution. 7.50 g of precipitate is formed. Calculate the concentration of the calcium chloride solution.
45. Suppose that you are given a sample that contains Ag^{+}, Ba^{2+}, and Fe^{3+} ions. Outline a procedure to separate these ions from each other. What will you add to precipitate out the different ions? Write the net ionic equation for each reaction.

C) Acids and Bases

46. Classifying Acids and Bases

A	B
____i. is a proton acceptor	a. Arrhenius acid
____ii. remains when a proton is removed from an acid	b. Arrhenius base
____iii. dissociates to form $H^+_{(aq)}$ in solution	c. Brønsted-Lowry acid
____iv. is a proton donor	d. Brønsted-Lowry base
____v. results when a base receives a proton	e. conjugate acid
____vi. results when water receives a proton	f. conjugate base
	g. hydronium ion

47. pH Calculations

A	B
____i. 2.3×10^{-8}	a. 8.90
____ii. 1.0×10^{-5}	b. 11.35
____iii. 4.5×10^{-12}	c. 7.64
____iv. 7.9×10^{-2}	d. 1.10
____v. 1.2×10^{-9}	e. 4.53
	f. 5.00

48. Identify the conjugate acid-base pairs in the following reaction:

$$H_3PO_{4\,(aq)} + H_2O_{(l)} \rightarrow H_2PO_4^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

49. Name each acid.
a) $HBr_{(aq)}$ b) $H_3PO_{2(aq)}$ c) $H_2SO_{3(aq)}$ d) $HIO_{3(aq)}$ e) $HBrO_{4(aq)}$
50. Write the chemical formula of each acid.
a) carbonic acid b) hyponitrous acid c) sulfurous acid d) hydrocyanic acid e) perchloric acid
51. What are two major flaws with the Arrhenius definition of an acid and a base? Explain how the Brønsted-Lowry theory of acids and bases improves on these flaws.
52. 34.2 mL of 0.200 mol/L sulfuric acid neutralizes 23.8 mL of lithium hydroxide. Determine the concentration of the base.
53. 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?
54. When 15 mL of 0.20 mol/L potassium hydroxide is reacted with 25 mL of 0.20 mol/L hydrochloric 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?

UNIT: Gases and Atmospheric Chemistry

A) Behaviour of Gases

55. Temperature and Pressure Units Conversion

A	B
____ i. 760 torr	a. 757 mm Hg
____ ii. -19°C	b. 292 K
____ iii. 1.27 atm	c. 965 mm Hg
____ iv. 352 K	d. 101.3 kPa
____ v. 100.9 kPa	e. 254 K
	f. 79°C
	g. 434 mm Hg
	h. 625°C

56. Gas Laws

A	B
____ i. When the volume of a gas is doubled, the pressure is halved.	a. Charles' law
____ ii. When the pressure of a gas is tripled, the temperature is tripled.	b. Boyle's law
____ iii. When the volume of a gas is decreased by a factor of 5, the temperature is decreased by a factor of 5.	c. Gay-Lussac's law

____ iv. When the pressure of a gas is halved, the temperature is halved.
____ v. When the volume of a gas is increased by a factor of 5,the temperature is decreased by a factor of 5.

B) Combined Gas Laws

57. What does STP stand for? State the temperature in two units and the pressure in four units.
58. 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.
59. 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.
60. 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.

C) Ideal Gas Laws

61. Constants and Standards

A	B
____ i. standard pressure	a. 6.02×10^{-23}
____ ii. standard temperature	b. $8.314 \frac{kPa \cdot L}{mol \cdot K}$
____ iii. the Avogadro constant	c. 1 atm
____ iv. molar volume	d. 22.4 L/mol
____ v. the ideal gas constant	e. 0°C
	f. 760 mm Hg
	g. 6.02×10^{23}
	h. 2.24 L/mol

62. Gas Laws

A	B
____ i. Equal volumes of all ideal gases, at the same temperature and pressure, contain the same number of molecules.	a. law of multiple proportions
____ ii. When gases react, the volumes of the reactants and the products, measured at equal temperatures and pressures, are always in whole number ratios.	b. Avogadro's law
____ iii. $PV = nRT$	c. law of combining gas volumes
____ iv. Decreasing the pressure in a rigid closed container will result in a cooler temperature.	d. law of conservation of mass
____ v. There is the same quantity of matter before and after a chemical reaction.	e. ideal gas law
	f. Boyle's law
	g. Gay-Lussac's law

63. What is molar volume? State the molar volume (including the units) of any gas at STP.
64. Calculate the volume that is occupied by 5.05 mol of hydrogen chloride, HCl, gas at STP.
65. What is the pressure of 6.7 mol of carbon dioxide gas, in 35.0 L at 30°C?
66. Calculate the volume of water vapour that is produced from the combustion of 15.0 g of ethylene at 25°C and 100 kPa.

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

67. How many fluorine gas molecules are in 9.2 L of fluorine gas at STP?
68. 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.
69. 148 L of hydrogen gas reacts with nitrogen gas to produce ammonia gas at 65°C and 350 kPa. Calculate the volume of ammonia gas that is produced at 700 mm Hg and 34°C.

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

70. Iron pyrite, FeS_2, when roasted in air, reacts to produce sulfur dioxide and iron(III) oxide as follows:

$$4FeS_{2(s)} + 11O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)} + 8SO_{2(g)}$$

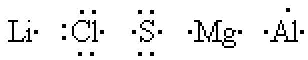
25.2 g of iron pyrite reacts with 5.50 L of oxygen gas at 20°C and 100 kPa. Calculate the mass of iron(III) oxide that is formed.

Answer Key -- exam review sch3u

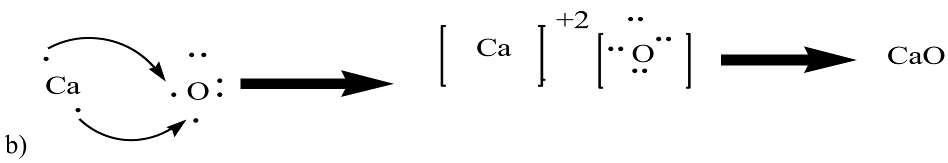
1. a) p = 34, n = 45, e = 34
b) p = 28, n = 31, e = 26

c) p = 52, n = 76, e = 53
d) p = 1, n = 2 , e = 0

2.

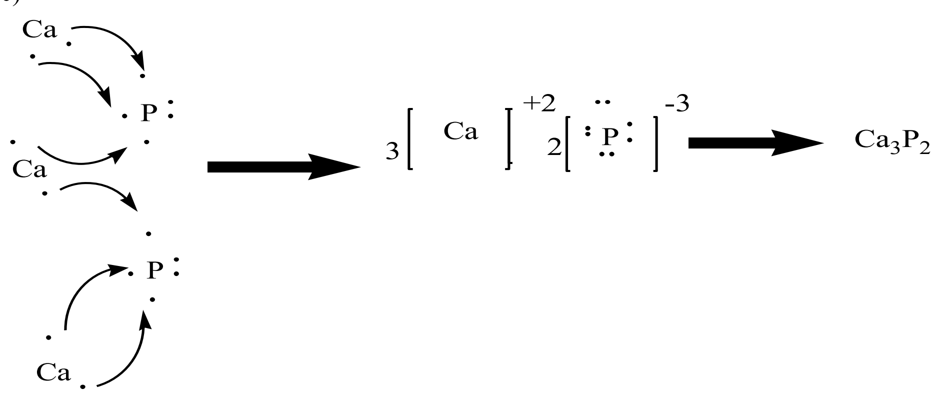


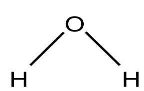
3. a) I, IV
b) I, III, IV
c) I, II, IV and III, V
d) II, V
4. i. d; ii. d; iii. b; iv. h; v. e
5. i. i; ii. j; iii. e; iv. k; v. c
6. a) $N=1s^2 2s^2 2p^3$, $[He]2s^2 2p^3$; $P=1s^2 2s^2 2p^6 3s^2 3p^3$, $[Ne]3s^2 3p^3$; $S=1s^2 2s^2 2p^6 3s^2 3p^4$, $[Ne]3s^2 3p^4$; $Ne=1s^2 2s^2 2p^6$, $[He]2s^2 2p^6$; $Ca=1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$, $[Ar]4s^2$



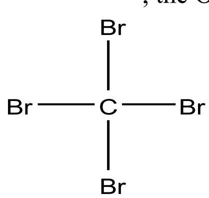
b)

c)

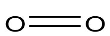


7.a) 

, the O-H bond is polar due to ΔEN difference.

b) 

, the C-Br bond is polar due to the ΔEN difference.

c) 

, the O-O bond is non-polar due to the ΔEN difference being zero. It's a purely covalent bond.

8. i. f; ii. c; iii. h; iv. k; v. i; vi. e
9. i. d; ii. g; iii. e; iv. a; v. k; vi. j
10. i. g; ii. d; iii. f; iv. i; v. m; vi. b; vii. j; viii. c
11. i. b; ii. g; iii. f; iv. d; v. a or c
12. i. b; ii. c; iii. g; iv. a; v. f
13. 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

14. i. d; ii. e; iii. a; iv. g; v. c
15. i. f; ii. d; iii. b; iv. c; v. e
16. 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

$$\text{Number of molecules} = \text{Number of moles} \times N_A =$$

$$0.0914\ \text{mol} \times \frac{6.02 \times 10^{23}\ \text{molecules}}{1\ \text{mol}} = 5.50 \times 10^{22}\ \text{molecules}$$

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

$$= 6 \times 5.50 \times 10^{22} = 3.30 \times 10^{23}\ \text{atoms of oxygen}$$

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

17.

$$\text{Number of moles of } Ca(OH)_2 = \frac{\text{Number of molecules}}{N_A} = \frac{7.53 \times 10^{22}\ \text{molecules}}{6.02 \times 10^{23}\ \text{molecules / mol}} = 0.125\ \text{mol}$$

Mass of $Ca(OH)_2$ = Number of moles x Molar mass = 0.125 mol □ 74.10 g/mol = 9.26 g

18. i. b; ii. e; iii. c; iv. f; v. a
19. Assume 100 g of total sample. You should get approximately 3.33 moles of C, 6.71 moles of H, and 3.33 moles of O. The empirical formula or simplest formula is CH_2O while the molecular formula is $C_3H_6O_3$.
20. 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.

21. i. c; ii. a; iii. c; iv. f; v. d
22. i. a; ii. c; iii. d; iv. b; v. d
23. $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

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

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

□ = 0.446 mol Ca $(OH)_2$

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

24. $3Fe_{(s)} + Sb_2S_{3(s)} \rightarrow 2Sb_{(s)} + 3FeS_{(s)}$

$$\text{Moles Sb}_2\text{S}_3 = \frac{15.6\text{g}}{339.73 g / mol} = 0.0460 \text{ mol Sb}_2\text{S}_3$$

$$\frac{\chi \text{ mol Fe}}{0.0460 \text{ mol Sb}_2\text{S}_3} = \frac{3 \text{ mol Fe}}{1 \text{ mol Sb}_2\text{S}_3}$$

x = 0.138 mol Fe
Mass Fe = 0.138 mol x 55.85 g/mol = 7.71g
Therefore, 7.71 g of Fe is needed.

25.

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

26.

$$\frac{0.987 \text{ mol KClO}_3}{x \text{ mol KCl}} = \frac{2 \text{ mol KClO}_3}{2 \text{ mol KCl}}$$

 = 0.987 mol KCl

$$\frac{0.987 \text{ mol KClO}_3}{y \text{ mol O}_2} = \frac{2 \text{ mol KClO}_3}{3 \text{ mol O}_2}$$

y = 1.481 mol O_2

Therefore, 0.987 mol of potassium chloride and 1.481 mol of oxygen are formed.

27. a) $2Fe_{(s)} + 3H_2O_{(l)} \rightarrow 3H_{2(g)} + 1Fe_2O_{3(s)}$

b)

$$\text{moles Fe} = \frac{4.5 \text{ g}}{55.85 \text{ g/mol}} = 0.081 \text{ mol}$$

$$\frac{\text{X mol of H}_2}{0.081 \text{ mol of Fe}} = \frac{3 \text{ mol H}_2}{2 \text{ mole of Fe}}$$

X = 0.1215 mol
Mass of H_2 = 2.02 g/mol x 0.1215 = 0.245 g

c) single displacement reaction

28. i. e; ii. c; iii. b; iv. d; v. a
29. i. b; ii. a; iii. d; iv. f; v. e; vi. d
30. i. c; ii. a; iii. f; iv. e; v. b
31. "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.
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 hydrogen's 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.
32. Molar concentration = 0.25 mol/0.175 L = 1.4 mol/L

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

33.

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

Therefore, the mass/volume percentage is 6.0%.

34. 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.

35.

$$\frac{x}{100 \text{ mL}} = \frac{0.75 \text{ mL}}{10 \text{ mL}}$$

x = 7.5% (v/v)

The concentration is 7.5% (m/v).

36.

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

x = 0.217% (m/m)

The concentration is 0.217 (m/m).

37. $HCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + HNO_{3(aq)}$

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.

38. $CuSO_{4(aq)} + Na_2S_{(aq)} \rightarrow CuS_{(s)} + Na_2SO_{4(aq)}$

Moles $CuSO_4$ = 0.010 L × 0.10 mol/L = .0010 mol

Moles Na_2S = 0.025 L × 0.20 mol/L = .0050 mol

$$\frac{\text{moles CuS}}{0.0010\text{ mol CuSO}_4} = \frac{1\text{ mol CuS}}{1\text{ mol CuSO}_4}$$

$$x = 0.0010\text{ mol}$$

$$\frac{\text{moles CuS}}{0.0050\text{ mol Na}_2\text{S}} = \frac{1\text{ mol CuS}}{1\text{ mol Na}_2\text{S}}$$

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.

39. Moles of acetic acid needed = 0.100 L × 0.015 mol/L = 0.0015 mol

$$\text{Volume of acetic acid} = \frac{0.0015\text{ mol}}{0.20\text{ mol / L}} = 0.0075\text{ L}$$

Therefore, 7.5 mL of the acetic acid solution is needed.

Another way to solve this problem involves using the formula $C_1V_1 = C_2V_2$.

0.20 mol/L × V_1 = 0.015 mol/L × 0.100 L

V_1 = 7.5 mL

40. i. a; ii. a; iii. b; iv. a; v. b

41. i. a; ii. b; iii. b; iv. b; v. a

42. $2Na^+_{(aq)} + S^{2-}_{(aq)} + Cu^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + CuS_{(s)}$

$S^{2-}_{(aq)} + Cu^{2+}_{(aq)} \rightarrow CuS_{(s)}$

The spectator ions are $Na^+_{(aq)}$ and $Cl^-_{(aq)}$.

43. $2AgNO_{3(aq)} + CaCl_{2(aq)} \rightarrow 2AgCl_{(s)} + Ca(NO_3)_{2(aq)}$

The precipitate is silver chloride.

Moles $AgNO_3$ = 0.065 L × 2.5 mol/L = 0.16 mol

$$\frac{x\text{ mol AgCl}}{0.16\text{ mol AgNO}_3} = \frac{1\text{ mol AgCl}}{1\text{ mol AgNO}_3}$$

There are 0.16 mol of AgCl.

Mass AgCl = 0.16 mol × 143.32 g/mol = 23 g

Therefore, 23 g of AgCl is formed.

44. Determine the number of moles of precipitate formed.

$CaCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + 2NaCl_{(aq)}$

$$\text{Moles CaCO}_3 = \frac{7.50\ \text{g}}{100.09\ \text{g/mol}} = 0.0749\ \text{mol}$$

$$\frac{x\ \text{mol CaCl}_2}{0.0749\ \text{mol CaCO}_3} = \frac{1\ \text{mol CaCl}_2}{1\ \text{mol CaCO}_3}$$

$$x = 0.0749\ \text{mol CaCl}_2$$

$$\text{Concentration CaCl}_2 = \frac{\text{Moles}}{\text{Volume}} = \frac{0.0749\ \text{mol}}{0.0750\ \text{L}} = 0.999\ \text{mol/L}$$

The concentration of $CaCl_2$ was 0.999 mol/L.

45. 1. Add sodium chloride for silver ions.
$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$
2. Add sodium sulfate for barium ions.
$Ba^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$
3. Add sodium hydroxide for iron(III) ions.
$Fe^{3+}_{(aq)} + 3OH^{-}_{(aq)} \rightarrow Fe(OH)_{3(s)}$

46. i. d; ii. f; iii. a; iv. c; v. e

47. i. c; ii. f; iii. b; iv. d; v. a

48. $H_3PO_4{}_{(aq)}$ and $H_2PO_4{}^{-}{}_{(aq)}$ are one conjugate acid-base pair. $H_2O_{(l)}$ and $H_3O^{+}_{(aq)}$ are the second conjugate acid-base pair.

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

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

51. Three major flaws are given below:
- According to the Arrhenius definition, an H^{+} dissociates and is responsible for the acidic properties of a solution. In the Brønsted-Lowry theory, protons do not exist alone in aqueous solution but as hydrated ions called hydronium ions, $H_3O^{+}_{(aq)}$. This is thought to be closer to the reality of the reactions.
- The Arrhenius definition cannot explain the basic properties of ammonia. Nor can it explain the fact that some other substances, such as salts that contain carbonate ions, also have basic properties. These are important bases, even though they do not have hydroxide. The Brønsted-Lowry definition of a base as a proton acceptor explains the basic properties of these compounds.
- The Arrhenius definition is limited to acid and base reactions in a single solvent, water. The Brönsted-Lowry definition still requires an acid to have a dissociable proton. However, any negative ion that has the ability to accept a proton (not just OH^{-}) can be a Brønsted-Lowry base.

52. $H_2SO_{4(aq)} + 2LiOH_{(aq)} \rightarrow Li_2SO_{4(aq)} + 2H_2O_{(l)}$
Moles H_2SO_4= 0.200 mol/L $\times$ 0.0342 L = 0.00 684 mol

$$\frac{x\ \text{mol LiOH}}{0.00\ 684\ \text{mol H}_2\text{SO}_4} = \frac{2\ \text{mol LiOH}}{1\ \text{mol H}_2\text{SO}_4}$$

$$x = 0.01\ 37\ \text{mol}$$

$$\text{Concentration LiOH} = \frac{0.01\ 37\ \text{mol}}{0.0238\ \text{L}} = 0.576\ \text{mol/L}$$

The concentration of the base was 0.576 mol/L.

53. a) $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$
Moles NaOH = 0.020 L $\times$ 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 $\times$ 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.

54. a) The KOH is the limiting reagent, and the HCl is in excess. The amount of KCl produced will be 4.02 x 10^{-5} g of the salt.
    b) The concentration of the hydronium ion will be 0.05 mol/L since HCl is in excess.
    c) The resulting pH will be 1.3.
55. i. d; ii. e; iii. c; iv. f; v. a
56. i. b; ii. c; iii. a; iv. c; v. a
57. STP stands for standard temperature and pressure. The temperature values that are associated with STP are 0C and 273 K. The pressure values that are associated with STP are 760 mm Hg, 760 torr, 101.3 kPa, and 1 atm.
58.

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

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

P_2 = 1.25 x 10^4 kPa

59.

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

$$\frac{1520 \text{ mm Hg}}{298 \text{ K}} = \frac{1900 \text{ mm Hg}}{\text{T}_2} = 373 \text{ K}$$

60.

$$P_1 \text{ x } V_1 = P_2 \text{ x } V_2$$

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

$$P_2 = 0.45 \text{ atm}$$

61. i. c, f; ii. e; iii. g; iv. d; v. b
62. i. b; ii. c; iii. e; iv. g; v. d
63. 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.
64.

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

$V = V_m$ □ n = 22.4 L/mol □ 5.05 mol = 113 L

65.

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

66. The ethylene is the limiting reagent, and 0.53 moles will produce 1.071 moles of water. Under the give conditions, this will be 26.5 L.

67.

$$\frac{22.4 \text{ L}}{1.00 \text{ mol}} = \frac{9.2 \text{ L}}{x \text{ mol}}$$

x = 0.41 mol

Number of molecules = $n_{compound}$ □ 6.02 □ 10^{23} = 0.41 mol □ 6.02 x 10^{23} molecules/mol = 2.5 □ 10^{23} molecules

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

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

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

69. Use $PV = nRT$ to find n. Use a mole ratio to convert the number of moles of hydrogen gas to the number of moles of ammonia gas. Use $PV = nRT$ to find V.

$$n = \frac{PV}{RT} = \frac{350 \text{ kPa} \times 148 \text{ L}}{8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 338 \text{ K}} = 18.4 \text{ mol}$$

$$\text{Mole ratio: } \frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3} = \frac{18.4}{x}$$

$$x = 12.3 \text{ mol}$$

$$V = \frac{nRT}{P} = \frac{12.3 \text{ mol} \times 8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 307 \text{ K}}{93.3 \text{ kPa}} = 336 \text{ L}$$

70. 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.

$$\text{Moles FeS}_2\text{: } n = \frac{m}{M} = \frac{25.2 \text{ g}}{119.99 \text{ g / mol}} = 0.210 \text{ mol}$$

$$\text{Moles O}_2\text{: } n\frac{PV}{RT} = \frac{100 \text{ kPa} \times 5.50 \text{ L}}{293 \text{ K} \times 8.314 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}}} = 0.226 \text{ mol}$$

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

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: $\frac{11 \text{ mol } O_2}{2 \text{ mol } Fe_2O_3} = \frac{0.226 \text{ mol}}{x}$

x = 0.0411 mol

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

71. i. b; ii. a; iii. b; iv. c; v. c
72. i. e; ii. d; iii. b; iv. f; v. g