Chemistry 20 Final Exam Review Questions

Unit A: Chemical Bonding

1. What are the forces that keep molecules together called?

   Intermolecular forces

2. What are the forces that keep atoms within a molecule together called?

   Intramolecular forces

3. Ionic bonds
   a. Describe ionic bonds:

      Involves the complete transfer of electrons forming a cation and an anion. Ions are held together by charge attraction.

   b. List properties of ionic compounds:

      - Form electrolytic solutions
      - Hard and brittle
      - High melting and boiling points
      - Soluble in water

4. Covalent bonds
   a. Describe covalent bonds:

      Sharing of electrons between two or more nonmetal atoms.

   b. List and describe the types of covalent bonds:

      Nonpolar covalent - equal sharing of electrons

      Polar covalent - unequal sharing of electrons

5. London Dispersion Forces
   a. Describe London Dispersion Forces (LDF).

      Weak intermolecular forces that result from momentary dipoles caused by electron movement within a molecule.

   b. What substances exhibit London Dispersion force?

      All substances because all substances have electrons.

   c. Explain why larger molecules have greater LDFs than smaller molecules.

      LDF increases as the number of electrons increases.

6. Dipole-Dipole Forces
   a. Describe intermolecular dipole-dipole forces.

      Attractive forces between oppositely charged permanent dipoles on molecules.

   b. What substances exhibit dipole Forces?

      Polar molecules

7. Hydrogen Bonding
   a. Describe hydrogen bonding.

      Occurs between molecules that contain F–H, O–H, or N–H bonds. Highly electronegative atom pulls electrons away from hydrogen, leaving the nucleus unshielded, which attracts the lone pair on neighboring N, F, or O.

   b. What elements must hydrogen be bonded to in order for hydrogen bonds to occur?

      F–H O–H N–H

8. If substance A has a higher melting and boiling point than substance B, what can you say about the substances' intermolecular forces?

   Substance A has stronger intermolecular forces.

9. Nitrogen has 7 protons and 7 electrons, sulfur has 16 protons and 16 electrons. Which of the two have a greater London dispersion forces? Explain.

   Sulfur because it has stronger LDF due to greater number of electrons.

10. Describe metallic bonding.

    Mobile electrons are shared between all atoms, holding the positive nuclei of all the metal atoms together.

11. Describe the bonding structure of network covalent structures.

    Composed entirely of covalent bonds forming a giant molecule.

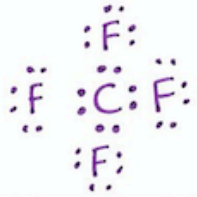
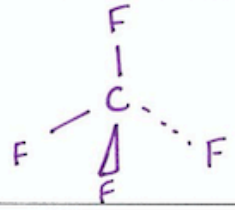
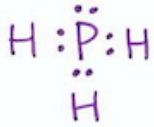
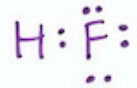
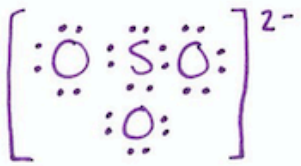
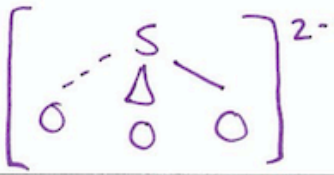
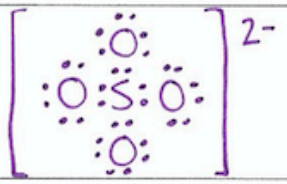
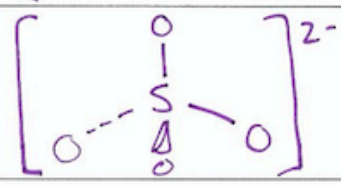
12. Rank the IMFs from strongest to weakest.

    Hydrogen bonds → Dipole-dipole → LDF

13. Complete the following table on atom characteristics.

Atomic Number	Atom Symbol	Group Number	Number of Valence Electrons	Number of Occupied Energy Levels	Lewis Diagram of atom	Number of Lone Electron Pairs	Number of Bonding Electrons
16	S	16	6	3		2	2
14	Si	14	4	3		0	4
15	P	15	5	3		1	3
17	Cl	17	7	3		3	1
35	Br	17	7	4		3	1
32	Ge	14	4	4		0	4
1	H	1	1	1		0	1
6	C	14	4	2		0	4
7	N	15	5	2		1	3
8	O	16	6	2		2	2

14. Complete the following table on atom characteristics.

Molecule or Ion Formula	# of Bonding Electrons	# of Lone Pairs	Lewis Structure	VSEPR Diagram	Name of VSEPR Shape
CF_4	4	0			Tetrahedral
PH_3	3	1			Trigonal Pyramidal
H_2S	2	2			Bent
CO_2	2	0			Linear
HF	1	3			Linear
SO_2	2	1			Bent
SO_3^{2-}	3	1			Trigonal Pyramidal
SO_4^{2-}	4	0			Tetrahedral

Unit B: Gases

1. Convert the following:
   a. 235 torr to kPa

$$235 \text{ torr} \times \frac{101.325 \text{ kPa}}{760 \text{ torr}} = 31.3 \text{ kPa}$$

   b. 180 kPa to mm Hg

$$180 \text{ kPa} \times \frac{760 \text{ mm Hg}}{101.325 \text{ kPa}} = 1.35 \times 10^3 \text{ mm Hg}$$

   c. 2.34 atm to kPa

$$2.34 \text{ atm} \times \frac{101.325 \text{ kPa}}{1 \text{ atm}} = 237 \text{ kPa}$$

   d. 24ºC to Kelvin

$$24^\circ C + 273.15 K = 297 K$$

   e. 987 K to ºC

$$987 K - 273.15 K = 714^\circ C$$

2. Give the conditions for STP.

273.15 K and 101.325 kPa

3. Give the conditions for SATP.

298.15 K and 100 kPa

4. An unknown gas has a pressure of 469 mm Hg and occupies 29.0 ml. What would be the new volume if the pressure was changed to 0.998 atm?

$$0.998 \text{ atm} \times \frac{760 \text{ mm Hg}}{1 \text{ atm}} = 758.48 \text{ mm Hg}$$

$P_1V_1 = P_2V_2$

$V_2 = \frac{P_1V_1}{P_2}$

$$V_2 = \frac{469 \text{ mm Hg} \times 29.0 \text{ mL}}{758.48 \text{ mm Hg}} = 17.93\ldots \text{ mL}$$

$V_2 = 17.9 \text{ mL}$

5. What would be the initial pressure (in mm Hg) of 80.9 L hydrogen gas if it was changed to 660 torr and had a final volume of 89.0 L?

$P_1V_1 = P_2V_2$

$P_2 = \frac{P_1V_1}{V_2}$

$$P_2 = \frac{660 \text{ torr} \times 89.0 \text{ L}}{80.9 \text{ L}}$$

$$= 726.08\ldots \text{ torr}$$

$P_2 = 726 \text{ torr}$

6. What does absolute zero mean?

Lowest possible temperature. No spaces between particles and the kinetic energy of particles is zero.

7. What would be the new volume of oxygen gas when pressure remains constant if the temperature changed from 39.0 ºC to 55.0 ºC and its initial volume was 685 ml?

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$V_2 = \frac{V_1 T_2}{T_1}$

$V_2 = \frac{685\,mL \times 328.15\,K}{312.15\,K}$

$= 720.11\ldots\,mL$

$V_2 = 720\,mL$

8. A sample of nitrogen gas exerts 52.6 kPa at 66.0 ºC. What pressure would the gas exert at 99.0ºC if the container's volume remains the same?

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

$= \frac{52.6\,kPa \times 372.15\,K}{339.15\,K}$

$= 57.718\ldots\,kPa$

$P_2 = 57.7\,kPa$

9. Helium gas in a hot air balloon experiences a temperature change from 21.0ºC to 55.0 ºC and an atmospheric pressure change from 100 kPa to 88.5 kPa. What would be the new volume of the hot air balloon if its initial volume was 125 kiloliters?

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

$= \frac{100\,kPa \times 125\,kL \times 328.15\,K}{294.15\,K \times 88.5\,kPa}$

$= 157.5688\ldots\,kL$

$V_2 = 158\,kL$

10. A 2.7-liter sample of nitrogen gas is collected at a temperature of 45 ºC and a pressure of 0.92 atm. What pressure would have to be applied to the gas to reduce its volume to 2.0 liters at a temperature of 25.0 ºC?

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

$= \frac{0.92\,atm \times 2.7\,L \times 298.15\,K}{318.15\,K \times 2.0\,L}$

$= 1.163\ldots\,atm$

$P_2 = 1.2\,atm$

11. A sample of argon gas occupies a volume of 2.0 L at -35ºC at 1.2 atm. What would its Celsius temperature be at 2.0 atm if its volume decreases to 1.5 L?

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

$$= \frac{2.0\,atm \times 1.5\,L \times 238.15\,K}{1.2\,atm \times 2.0\,L}$$

$$= 297.6875\,K$$

$297.6875\,K - 273.15\,K$

$= 24.5375°C$

$T_2 = 25°C$

12. What pressure would 2.00 Kmol of fluorine gas exert under 45ºC with a volume of 985 ml?

$$P = \frac{nRT}{V}$$

$$= \frac{2000\,mol \times 8.314\,kPa \cdot L/mol \cdot K \times 318.15\,K}{0.985\,L}$$

$$= 5.3707\ldots \times 10^6\,kPa$$

$P = 5.37 \times 10^6\,kPa$

13. What would be the volume of 3.52 mg of chlorine gas at 21.0ºC under 99.2 kPa of pressure?

$$n = \frac{m}{M}$$

$$= \frac{3.52 \times 10^{-3}\,g}{70.90\,g/mol}$$

$$= 4.96 \times 10^{-5}\,mol$$

$$V = \frac{nRT}{P}$$

$$= \frac{4.96 \times 10^{-5}\,mol \times 8.314\,kPa \cdot L/mol \cdot K \times 294.15\,K}{99.2\,kPa}$$

$= 0.001223\ldots\,L$

$= 1.223\ldots\,mL$

$V = 1.22\,mL$

14. What volume of oxygen gas would occupy at STP that has a mass of 9.45 grams?

$$n = \frac{m}{M}$$

$$= \frac{9.45\,g}{32.00\,g/mol}$$

$$= 0.295\,mol$$

$$V = \frac{nRT}{P}$$

$$= \frac{0.295\,mol \times 8.314\,kPa \cdot L/mol \cdot K \times 273.15\,K}{101.325\,kPa}$$

$= 6.6117\ldots\,L$

$V = 6.61\,L$

OR

$$V = nV_m$$

$$= 0.295\ldots\,mol \times 22.4\,L/mol$$

$= 6.615\,L$

$V = 6.62\,L$

15. Oxygen gas and magnesium react to form 2.43 g of magnesium oxide. What volume of oxygen gas at 94.9 kPa and 25.0ºC would be consumed to produce this amount of MgO(s)?

$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

$n_{O_2} = 0.060028...\text{mol} \times 1/2$

$= 0.03014...\text{mol}$

$V = \frac{nRT}{P}$

$= \frac{0.03014...\text{mol} \times 8.314\ \text{kPa}\cdot\text{L/mol}\cdot\text{K} \times 298.15\text{K}}{94.9\ \text{kPa}}$

$= 0.7873...\text{L}$

$n = \frac{m}{M}$

$= \frac{2.43\text{g}}{40.31\ \text{g/mol}}$

$= 0.060028...\text{mol}$

$V = 0.787\text{L}$

16. Nitrogen triodide decomposes into explosive nitrogen gas and iodine. Calculate the volume of the gas produced at STP when 395 mg of NI_3 (g) decomposes.

$2NI_{3(s)} \rightarrow N_{2(g)} + 3I_{2(s)}$

$n = \frac{m}{M}$

$= \frac{0.395\text{g}}{394.71\ \text{g/mol}}$

$= 0.00100...\text{mol}$

$n = 0.00100\text{mol} \times 1/2$

$= 5.003... \times 10^{-4}\text{mol}$

$V = nVm$

$= 5.003... \times 10^{-4}\text{mol} \times 22.4\ \text{L/mol}$

$= 0.011208...\text{L}$

$V_{N_2} = 11.2\text{mL}$

17. A 2.00 liter of sample of ethane, C_2H_6, is burned at 1.00 atm and 25.0 ºC with an excess of oxygen. What mass of water vapor will be produced from the burning of ethane? What would be the volume of the water vapor under the same conditions?

$2C_2H_{6(g)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 6H_2O_{(g)}$

$n = \frac{PV}{RT}$

$= \frac{101.325\ \text{kPa} \times 2.00\text{L}}{8.314\ \text{kPa}\cdot\text{L/mol}\cdot\text{K} \times 298.15\text{K}}$

$= 0.08175...\text{mol}$

$n_{H_2O} = 0.08175...\text{mol} \times 6/2$

$= 0.24525...\text{mol}$

$m = nM$

$= 0.024525...\text{mol} \times 18.02\ \text{g/mol}$

$= 4.4195...\text{g}$

$V_{O_2} = 2.00\text{L} \times 6/2$

$= 6.00\text{L}$

$m_{O_2} = 4.42\text{g}$

$V_{O_2} = 6.00\text{L}$

18. If 15 L of methane gas undergoes complete combustion, what volume of oxygen gas will be required? What volume of carbon dioxide will be produced?

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

$V = 15\text{L}$

$V = 15\text{L} \times 2/1$

$= 30\text{L}$

$V = 15\text{L} \times 1/1$

$= 15\text{L}$

$V_{O_2} = 30\text{L}$

$V_{CO_2} = 15$

Unit C: Solutions, Acids, and Bases

1. Define the following
   a. Solute
      Substance that gets dissolved.
   b. Solvent
      Substance that the solute is dissolved in.
   c. Saturated solution
      Solution that contains the maximum amount of solute at a given temperature.
   d. Miscible
      A liquid that will form a solution with another liquid in all proportions. E.g. ethanol and water.
   e. Immiscible
      A liquid that will not form a solution with another liquid in any proportion. E.g. oil and water.
   f. Endothermic reaction
      Requires more energy to break bonds than is released when new bonds form.
   g. Exothermic reaction
      Releases more energy when new bonds form than is required to break the initial bonds.
   h. Solubility Equilibrium
      When the rate of crystallization is equal to the rate of dissolving in a saturated solution.

2. What is the difference between gases and solids in terms of temperature and solubility?
   Increased temperature results in increased solubility for solids, but decreased solubility in gases.

3. What is the molar concentration of a solution that has 4.4 grams of sucrose in 990 ml of solution?

$$n = \frac{m}{M}$$
$$= \frac{4.4\text{g}}{342.34\text{g/mol}}$$
$$= 0.01285\ldots\text{mol}$$

$$c = \frac{n}{V}$$
$$= \frac{0.01285\ldots\text{mol}}{0.990\text{L}}$$
$$= 0.01298\ldots\text{mol/L}$$

$c = 0.013\ \text{mol/L}$

4. What is the volume of a 0.750 mol/L solution containing 2.50 grams of salt (sodium chloride)?

$n = \frac{m}{M}$

$= \frac{2.50\,g}{58.44\,g/mol}$

$= 0.04277...\,mol$

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

$= \frac{0.04277...\,mol}{0.750\,mol/L}$

$= 0.05703...\,L$

$\boxed{V = 0.0570\,L}$

5. How many liters of 1.50 mol/L solution of magnesium hydroxide would contain 40.0 g of solute? $Mg(OH)_2$

$n = \frac{m}{M}$

$= \frac{40.0\,g}{58.33\,g/mol}$

$= 0.6857...\,mol$

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

$= \frac{0.6857...\,mol}{1.50\,mol/L}$

$= 0.4571...\,L$

$\boxed{V = 0.457\,L}$

6. Sodium phosphate solution is used to remove the scales at the bottom of a tea kettle. Calculate the mass of sodium phosphate needed to make 4.00 L of a 0.500 mol/L cleaning solution. Na_3PO_4

$n = cV$

$= 0.500\,mol/L \times 4.00\,L$

$= 2.00\,mol$

$m = nM$

$= 2.00\,mol \times 163.94\,g/mol$

$= 327.88\,g$

$\boxed{m = 328\,g}$

7. Express the following in % (v/v) or % (m/v).
   a. 6.0 g of potassium chromate in 100 mL solution

$c = \frac{m_{solute}}{V_{solution}} \times 100\% = \frac{6.0\,g}{100\,mL} \times 100\% = 6\%\,m/V$

$\boxed{c = 6.0\%\,m/V}$

   b. 0.75 ml of methanol in 12.0 ml of solution

$c = \frac{V_{solute}}{V_{solution}} \times 100\% = \frac{0.75\,mL}{12.0\,mL} \times 100\% = 6.25\%\,V/V$

$\boxed{c = 6.3\%\,V/V}$

   c. 4.5 g of calcium chloride in 0.0500 L of solution

$c = \frac{m_{solute}}{V_{solution}} \times 100\% = \frac{4.5\,g}{50.0\,mL} \times 100\% = 9\%\,m/V$

$\boxed{c = 9.0\%\,m/V}$

8. What mass or volume of solute is contained in the following solutions?
   a. 150.0 ml of 2.2% (m/v) solution containing sulfuric acid

$C = \frac{m_{solute}}{V_{solution}} \times 100\%$ $\quad m_{solute} = \frac{C \times V_{solution}}{100\%}$

$= \frac{2.2\% \times 150.0mL}{100\%} = 3.3g$ $\boxed{m = 3.3g}$

   b. 50.0 ml of 6.5% (m/v) solution of ammonium phosphate

$m_{solute} = \frac{C \times V_{solution}}{100\%}$

$= \frac{6.5\% \times 50.0mL}{100\%} = 3.25g$ $\boxed{m = 3.3g}$

   c. 89.0 ml of 75% (v/v) solution of ethanol

$V_{solute} = \frac{C \times V_{solution}}{100\%}$

$= \frac{75\% \times 89.0mL}{100\%} = 66.75mL$ $\boxed{V = 67mL}$

9. What volume would be needed for the following?
   a. 3.6 g from a 5.5% (m/v) solution of sodium acetate

$V_{solution} = \frac{m_{solute} \times 100\%}{C}$

$= \frac{3.6g \times 100\%}{5.5\%} = 65.\overline{45}mL$ $\boxed{V = 65mL}$

   b. 25.0 ml from a 10.5% (v/v) solution of hydrogen peroxide

$V_{solution} = \frac{V_{solute} \times 100\%}{C}$

$= \frac{25.0mL \times 100\%}{10.5\%} = 238.09...mL$ $\boxed{V = 238mL}$

   c. 9.6 g from a 30% (m/v) solution of calcium chloride

$V_{solution} = \frac{m_{solute} \times 100\%}{C}$

$= \frac{9.6g \times 100\%}{30\%} = 32mL$ $\boxed{V = 32mL}$

10. What is the % (m/v) concentration of 2.50 mol/L of hydrogen peroxide?

$m = nM$ $\quad H_2O_2$

$= 2.50mol \times 34.02g/mol$

$= 85.05g$

$C = \frac{m_{solute}}{V_{solution}} \times 100\%$

$= \frac{85.05g}{1000mL} \times 100\%$

$= 8.505\%\ m/V$ $\boxed{C = 8.51\%\ m/V}$

11. What is the % (m/v) concentration of 433 ppm of sodium chloride?

$433ppm = \frac{433mg}{L} = \frac{0.433g}{1000mL}$ $\boxed{C = 0.0433\%\ m/V}$

$C = \frac{m_{solute}}{V_{solution}} \times 100\% = \frac{0.433g}{1000mL} \times 100\% = 0.0433\%\ m/V$

12. You are diluting a solution and you want to prepare 0.500 mol/L at 200.0 ml from a stock solution of 1.00 mol/L, what volume do you need from your stock solution?

$V_i C_i = V_f C_f$

$V_i = \frac{V_f C_f}{C_i}$

$= \frac{200.0\text{mL} \times 0.500\text{mol/L}}{1.00\text{mol/L}}$

$= 100\text{mL}$

$\boxed{V_i = 100\text{mL}}$

13. Commercial sulfuric acid is 17.6 mol/L. If one uses 170 ml of the concentrated acid and dilutes it to a volume of 1.50 L, what is the concentration of the diluted sulfuric acid solution?

$V_i C_i = V_f C_f$

$C_f = \frac{V_i C_i}{V_f}$

$= \frac{0.170\text{L} \times 17.6\text{mol/L}}{1.50\text{L}}$

$= 1.9946\ldots\ \text{mol/L}$

$\boxed{C_f = 1.99\ \text{mol/L}}$

14. Calculate the mass of solute needed to prepare a 500 ml of a 0.800 mol/L solution of potassium chromate. $K_2Cr_2O_7$

$n = cV$

$= 0.800\text{mol/L} \times 0.500\text{L}$

$= 0.4\text{mol}$

$m = nM$

$= 0.4\text{mol} \times 255.10\ \text{g/mol}$

$= 102.04\ \text{g}$

$\boxed{m = 100\text{g}}$

15. Suppose the solution in the previous question was the stock solution and you wanted to make a secondary solution that is 250.0 ml that is 0.4500 mol/L in concentration, what will be the volume needed to make it?

$V_i C_i = V_f C_f$

$V_i = \frac{V_f C_f}{C_i}$

$= \frac{250.0\text{mL} \times 0.4500\text{mol/L}}{0.800\text{mol/L}}$

$= 140.625\text{mL}$

$\boxed{V_i = 141\text{mL}}$

16. Outline the process of making a standard solution from a mass.

1) Measure the required mass of solute and dissolve in 1/2 the solvent volume required.
2) Transfer to volumetric flask.
3) Rinse glassware 3 times and transfer into volumetric flask.
4) Add solute to volume mark on flask using a dropper for final portion and a meniscus finder.
5) Invert flask several times

17. Write the dissociation equation for the following and give the ion concentrations for each ion.

a. 2.50 mol/L of calcium nitrate

$Ca(NO_3)_2(aq) \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$

$C = 2.50\ mol/L$ | $C = 2.50\ mol/L \times 1/1 = 2.50\ mol/L$ | $C = 2.50\ mol/L \times 2/1 = 5.00\ mol/L$

b. 3.00 mol/L of cobalt (III) acetate

$Co(CH_3COO)_3(aq) \rightarrow Co^{3+}(aq) + 3CH_3COO^-(aq)$

$C = 3.00\ mol/L$ | $C = 3.00\ mol/L \times 1/1 = 3.00\ mol/L$ | $C = 3.00\ mol/L \times 3/1 = 9.00\ mol/L$

c. 1.25 mol/L of zinc chloride

$ZnCl_2(aq) \rightarrow Zn^{2+}(aq) + 2Cl^-(aq)$

$C = 1.25\ mol/L$ | $C = 1.25\ mol/L \times 1/1 = 1.25\ mol/L$ | $C = 1.25\ mol/L \times 2/1 = 2.50\ mol/L$

d. 0.750 mol/L of ammonium sulfate

$(NH_4)_2SO_4(aq) \rightarrow 2NH_4^+(aq) + SO_4^{2-}(aq)$

$C = 0.750\ mol/L$ | $C = 0.750\ mol/L \times 2/1 = 1.50\ mol/L$ | $C = 0.750\ mol/L \times 1/1 = 0.750\ mol/L$

e. 0.250 mol/L of acetic acid

$CH_3COOH(aq) \rightarrow CH_3COO^-(aq) + H^+(aq)$

$C = 0.250\ mol/L$ | $C = 0.250\ mol/L$ | $C = 0.250\ mol/L$

* assume the acid completely ionizes *

18. Give three properties each of acids and bases.

Acids - sour, turn litmus red, corrosive, react with metals to produce $H_{2(g)}$, neutralize bases.

Bases - bitter, turn litmus blue, feel slippery, corrosive, neutralize acids.

19. Define the following:

a. Acid according to Arrhenius

Molecular substance that ionizes in water to produce $H^+_{(aq)}$.

b. Base according to Arrhenius

Ionic compounds that dissociate in water to produce $OH^-_{(aq)}$.

c. Acid according to modified Arrhenius theory

Substance that reacts with water to produce $H_3O^+_{(aq)}$.

d. Base according to modified Arrhenius theory

Substances that dissociate in water to produce $OH^-_{(aq)}$ or react with water to produce $OH^-_{(aq)}$.

20. What is the difference between strong acids and weak acids?

Strong acids react completely with water resulting in strong acidic properties. Weak acids do not react completely with water, resulting in weaker acidic properties. Must memorize strong acids.

21. What is the difference between strong bases and weak bases?

Strong bases react/dissociate completely in water, resulting in strong basic properties. All ionic hydroxides and oxides are strong bases. Weak bases do not react completely with water, resulting in weaker basic properties.

22. Why is an equilibrium arrow given in some of the equations for acids and bases?

An equilibrium arrow ($\rightleftharpoons$) is used for weak acid and weak base reactions to indicate that the reaction is less than 50% complete.

23. Why is a straight arrow given in some of the equations for acids and bases?

A straight arrow ($\rightarrow$) is used for strong acid and strong base reactions to show that the reaction is more than 99% complete.

24. What is the difference between a diluted acid and a concentrated acid?

A diluted acid has a very small amount of acid per unit volume.
A concentrated acid has a greater volume of acid per unit volume.

25. Write modified Arrhenius equations for the following acids:

a. boric acid

$H_3BO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2BO_3^-(aq)$

b. acetic acid

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$

c. sulfurous acid

$H_2SO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_3^-(aq)$

d. carbon dioxide

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

e. hydrobromic acid

$HBr(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Br^-(aq)$

26. Write modified Arrhenius equations for the following bases:

a. sodium carbonate

$Na_2CO_3(aq) \rightarrow 2Na^+(aq) + CO_3^{2-}(aq)$

$CO_3^{2-} + H_2O(l) \rightleftharpoons OH^-(aq) + HCO_3^-(aq)$

b. strontium oxide

$SrO(aq) + H_2O(l) \rightarrow Sr(OH)_2(aq)$

$Sr(OH)_2(aq) \rightarrow Sr^{2+}(aq) + 2OH^-(aq)$

c. sodium hydrogen sulfate

$NaHSO_4(aq) \rightarrow Na^+(aq) + HSO_4^-(aq)$

$HSO_4^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_2SO_4(aq)$

d. lithium hydroxide

$LiOH(aq) \rightarrow Li^+(aq) + OH^-(aq)$

e. calcium oxide

$CaO(aq) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

$Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$

27. Calculate the pH for the following hydronium ion concentrations: $pH = -\log[H_3O^+_{(aq)}]$

a. 0.02 mol/L

$pH = -\log[0.02\,mol/L] = 1.7$

b. 2.5 mol/L

$pH = -\log[2.5\,mol/L] = -0.40$

c. 0.0065 mol/L

$pH = -\log[0.0065\,mol/L] = 2.19$

d. 9.67 x 10-9 mol/L

$pH = -\log[9.67 \times 10^{-9}\,mol/L] = 8.015$

e. 0.0874 mol/L

$pH = -\log[0.0874\,mol/L] = 1.058$

28. Calculate the pH for the following hydroxide ion concentrations: $pOH = -\log[OH^-_{(aq)}]$ $pH = 14 - pOH$

a. 0.36 mol/L

$pOH = -\log[0.36\,mol/L] = 0.4436...$ $pH = 14 - 0.4436... = 13.56$

b. 0.559 mol/L

$pOH = -\log[0.559\,mol/L] = 0.2525...$ $pH = 14 - 0.2525... = 13.747$

c. 1.90 x 10-5 mol/L

$pOH = -\log[1.90 \times 10^{-5}\,mol/L] = 4.7212...$ $pH = 14 - 4.7212.. = 9.279$

d. 3.9 mol/L

$pOH = -\log[3.9\,mol/L] = -0.5910...$ $pH = 14 - (-0.5910...) = 14.59$

e. 0.004 mol/L

$pOH = -\log[0.004\,mol/L] = 2.3979...$ $pH = 14 - 2.3979... = 11.6$

29. Calculate the hydronium ion concentrations for the following pH or pOH values: $pH + pOH = 14$ $[H_3O^+_{(aq)}] = 10^{-pH}$

a. pH = 2.45

$[H_3O^+_{(aq)}] = 10^{-2.45} = 3.5 \times 10^{-3}\,mol/L$

b. pH = 6.550

$[H_3O^+_{(aq)}] = 10^{-6.550} = 2.818 \times 10^{-7}\,mol/L$

c. pOH = 2.990

$pH = 14 - 2.990 = 11.01$ $[H_3O^+_{(aq)}] = 10^{-11.01} = 9.772 \times 10^{-12}\,mol/L$

d. pH = 8.35

$[H_3O^+_{(aq)}] = 10^{-8.35} = 4.5 \times 10^{-9}\,mol/L$

30. Predict the pH of the solution made by dissolving 925 mg of nitric acid in enough water to make 850 mL.

$HNO_3(aq) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$

$m = 0.925\,g$

$n = \frac{m}{M} = \frac{0.925\,g}{63.02\,g/mol} = 0.0146...\,mol$

$n = 0.0146...\,mol$

$c = \frac{n}{V} = \frac{0.0146...\,mol}{0.850\,L} = 0.01726...\,mol/L$

$pH = -\log[H_3O^+(aq)] = -\log[0.01726...\,mol/L] = 1.7625...$

$\boxed{pH = 1.763}$

31. Predict the pH of the solution prepared by dissolving 3.589 grams of magnesium hydroxide in 1.50 liters of water (assume all the magnesium hydroxide dissolves).

$Mg(OH)_2(aq) \rightarrow Mg^{2+}(aq) + 2OH^-(aq)$

$n = \frac{m}{M} = \frac{3.589\,g}{58.33\,g/mol} = 0.0615...\,mol$

$n = 0.0615...\,mol \times 2/1 = 0.1230...\,mol$

$c = \frac{n}{V} = \frac{0.1230...\,mol}{1.50\,L} = 0.0820...\,mol/L$

$pOH = -\log[OH^-(aq)] = -\log[0.0820...\,mol/L] = 1.0859...$

$pH = 14 - pOH = 14 - 1.0859... = 12.914...$

$\boxed{pH = 12.914}$

32. How much solvent will you have to add to 150 ml of perchloric acid that has a pH of 3.500 to change it to a pH of 4.000?

$[H_3O^+(aq)] = 10^{-pH} = 10^{-3.5000} = 3.16... \times 10^{-4}\,mol/L$

$[H_3O^+(aq)] = 10^{-4.000} = 1 \times 10^{-4}\,mol/L$

$V_i C_i = V_f C_f \quad V_f = \frac{V_i C_i}{C_f}$

$V_f = \frac{150\,mL \times 3.16 \times 10^{-4}\,mol/L}{1 \times 10^{-4}\,mol/L} = 474.341...\,mL$

$V_{added} = 474.341...\,mL - 150\,mL = 324.34...\,mL$

$\boxed{V = 324\,mL}$

33. A student wants to make a solution with a pH of 7.900. What mass of sodium hydroxide will the student require to make 4.50 L of solution?

$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$

$pOH = 14 - pH = 14 - 7.900 = 6.100$

$[OH^-(aq)] = 10^{-pOH} = 10^{-6.100} = 7.943... \times 10^{-7}\,mol/L$

$n = cV = 7.943... \times 10^{-7}\,mol/L \times 4.50\,L = 3.574... \times 10^{-6}\,mol$

$n = 3.574... \times 10^{-6}\,mol \times 1/1 = 3.574... \times 10^{-6}\,mol$

$m = nM = 3.574... \times 10^{-6}\,mol \times 40.00\,g/mol = 1.429... \times 10^{-4}\,g$

$\boxed{m = 1.43 \times 10^{-4}\,g}$

Unit D: Quantitative Analysis

1. What color of flame does the following show?
   a. Lithium red
   b. Sodium yellow
   c. Lead blue-white

2. How many moles of hydrogen gas are produced if 0.500 mol of water are decomposed?

$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

$n = 0.500\,mol \quad n = 0.500\,mol \times 2/2 = 0.500\,mol$

$n_{H_2} = 0.500\,mol$

3. Sulfur reacts with barium oxide to produce barium sulfide and oxygen gas.
   a. How many moles of elemental sulfur are needed if 2.00 mol of barium oxide are used?

$S_{8(s)} + 8BaO_{(s)} \rightarrow 8BaS_{(s)} + 4O_{2(g)}$

$n = 2.00\,mol \times 1/8 = 0.25\,mol \quad n = 2.00\,mol$

$n_{S_8} = 0.250\,mol$

   b. How many moles of barium sulfide are produced from 0.100 mol of sulfur?

$n_{BaS} = 0.100\,mol \times 8/1 = 0.8\,mol$

$n_{BaS} = 0.800\,mol$

4. The combustion of methane gas takes place in the presence of oxygen gas to produce carbon dioxide and water vapor (the compounds produced when you burn a hydrocarbon)
   a. How many moles of oxygen gas are needed to completely burn 3.00 mol of methane gas?

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

$n = 3.00\,mol \quad n = 3.00\,mol \times 2/1 = 6.00\,mol$

$n_{O_2} = 6.00\,mol$

   b. How many moles of water vapor are produced from 0.0400 mole of methane gas?

$n_{H_2O} = 0.0400\,mol \times 2/1 = 0.08\,mol$

$n_{H_2O} = 0.0800\,mol$

5. Iron (II) phosphate reacts with tin (IV) nitride to produce iron (II) nitride and tin (IV) phosphate.
   a. How many moles of tin (IV) nitride are needed to produce 0.500 mol of iron (II) nitride?

$2Fe_3(PO_4)_{2(s)} + Sn_3N_{4(aq)} \rightarrow 2Fe_3N_{2(aq)} + Sn_3(PO_4)_{4(s)}$

$n = 0.500\,mol \times 1/2 = 0.250\,mol \quad n = 0.500\,mol$

$n_{Sn_3N_4} = 0.250\,mol$

   b. How many moles of iron (II) phosphate are used when 0.045 mol of tin (IV) nitride also react?

$n_{Fe_3(PO_4)_2} = 0.045\,mol \times 2/1 = 0.09\,mol$

$n_{Fe_3(PO_4)_2} = 0.090\,mol$

6. When 6.5 mol of potassium chlorate solid breaks down to the simpler compound of potassium chloride and oxygen gas, what mass of KCl (s) would be produced?

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

$n = 6.5\,mol$

$n = 6.5\,mol \times 1/1 = 6.5\,mol$

$m = nM$

$= 6.5\,mol \times 74.55\,g/mol$

$= 484.575\,g$

$\boxed{m = 4.8 \times 10^2\,g}$

7. When an excess of silver reacts with 3.45 moles of zinc phosphate, what mass of silver phosphate would be produced?

$6Ag_{(s)} + Zn_3(PO_4)_{2(s)} \rightarrow 2Ag_3PO_{4(s)} + 3Zn_{(s)}$

$n = 3.45\,mol$

$n = 3.45\,mol \times 2/1$

$= 6.9\,mol$

$m = nM$

$= 6.9\,mol \times 418.58\,g/mol$

$= 2888.202\,g$

$\boxed{m = 2.89 \times 10^3\,g}$

8. In neutralization of sulfuric acid solution, 4.56 g of sodium hydroxide was used. What mass of water would be produced in this reaction?

$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2HOH_{(l)}$

$m = 4.56\,g$

$n = \frac{m}{M}$

$= \frac{4.56\,g}{40.00\,g/mol}$

$= 0.114\,mol$

$n = 0.114\,mol \times 2/2$

$= 0.114\,mol$

$m = nM$

$= 0.114\,mol \times 18.02\,g/mol$

$= 2.05428\,g$

$\boxed{m = 2.05\,g}$

9. When iron (II) hydroxide reacts with cobalt (II) phosphate, iron (II) phosphate and cobalt (II) hydroxide are formed. If 3.00 g of iron (II) hydroxide react, what mass of cobalt (II) phosphate is needed?

$3Fe(OH)_{2(s)} + Co_3(PO_4)_{2(s)} \rightarrow Fe_3(PO_4)_{2(s)} + 3Co(OH)_{2(s)}$

$m = 3.00\,g$

$n = \frac{m}{M}$

$= \frac{3.00\,g}{89.87\,g/mol}$

$= 0.03338...\,mol$

$n = 0.03338...\,mol \times 1/3$

$= 0.01112...\,mol$

$m = nM$

$= 0.01112...\,mol \times 366.73\,g/mol$

$= 4.0806...\,g$

$\boxed{m = 4.08\,g}$

10. Calcium acetate is added to 10.0 ml of 0.0200 mol/L silver nitrate. What is the mass of the precipitate produced?

$Ca(CH_3COO)_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgCH_3COO_{(s)} + Ca(NO_3)_{2(aq)}$

$n = cV$
$= 0.0200 mol/L \times 0.01L$
$= 2 \times 10^{-4} mol$

$n = 2 \times 10^{-4} mol \times 2/2$
$= 2 \times 10^{-4} mol$

$m = nM$
$= 2 \times 10^{-4} mol \times 166.92 g/mol$
$= 0.033384 g$

$\boxed{m = 0.0334 g}$

11. Predict the volume of the base (0.250 mol/L of sodium hydroxide) needed to be added to neutralize 75.0 ml of nitric acid at 0.500 mol/L.

$HNO_{3(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3(aq)} + HOH_{(l)}$

$V = 0.075L$
$c = 0.500 mol/L$
$n = cV$
$= 0.500 mol/L \times 0.075L$
$= 0.0375 mol$

$c = 0.250 mol/L$
$n = 0.0375 mol \times 1/1 = 0.0375 mol$
$V = \frac{n}{c}$
$= \frac{0.0375 mol}{0.250 mol/L}$
$= 0.15L$

$\boxed{V = 0.150L \text{ or } 150mL}$

12. A 150.0 ml sample of 0.7500 mol/L of aqueous solution of sodium sulfate is added to 250.0 ml of strontium hydroxide at 0.350 mol/L. Predict the mass of the precipitate.

$Na_2SO_{4(aq)} + Sr(OH)_{2(aq)} \rightarrow SrSO_{4(s)} + 2NaOH_{(aq)}$

$V = 0.150L$
$c = 0.750 mol/L$
$n = cV$
$= 0.750 mol/L \times 0.15L$
$= 0.1125 mol$

$V = 0.250L$
$c = 0.350 mol/L$
$n = cV$
$= 0.350 mol/L \times 0.250L$
$= 0.0875 mol$ LR

$n_{required} = 0.0875 mol \times 1/1$
$= 0.0875 mol$ ER

$\hookrightarrow n = 0.0875 mol \times 1/1$
$= 0.0875 mol$

$m = nM$
$= 0.0875 mol \times 183.69 g/mol$
$= 16.0728... g$

$\boxed{m = 16.1g}$

13. What volume of boric acid at 0.025 mol/L will be needed to neutralize 90 ml of 0.055 mol/L magnesium hydroxide?

$2H_3BO_{4(aq)} + 3Mg(OH)_{2(aq)} \rightarrow Mg_3(BO_4)_{2(aq)} + 6HOH_{(l)}$

$c = 0.025 mol/L$
$n = 0.00495 mol \times 2/3$
$= 0.0033 mol$
$V = \frac{n}{c}$
$= \frac{0.0033 mol}{0.025 mol/L}$
$= 0.132L$

$c = 0.055 mol/L$
$V = 0.09L$
$n = cV$
$= 0.055 mol/L \times 0.09L$
$= 0.00495 mol$

$\boxed{V = 0.132L}$

14. For each of the following questions indicate which reactant is the limiting reagent, and which is the reagent in excess. You may need to complete a balanced chemical equation before answering the question.

a. 25 grams of zinc reacts with 75 g of nitric acid. What mass of zinc nitrate is produced?

$Zn_{(s)} + 2HNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + H_{2(g)}$

$n = \frac{m}{M}$

$= \frac{25g}{65.41g/mol}$

$= 0.3822...mol$

$n_{required} = 1.190...mol \times 1/2$

$= 0.5950...mol$

LR

$n = \frac{75g}{63.02g/mol}$

$= 1.190...mol$

ER

$n = 0.3822...mol \times 1/1$

$= 0.3822...mol$

$m = nM$

$= 0.3822...mol \times 189.43g/mol$

$= 72.401...g$

$m = 72g$

b. 15 g of sodium hydroxide reacts with 26 g of hydrochloric acid. What mass of sodium chloride is produced?

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + HOH_{(l)}$

$n = \frac{m}{M}$

$= \frac{15g}{40.00g/mol}$

$= 0.375mol$

LR

$n = \frac{26g}{36.46g/mol}$

$= 0.7131...mol$

ER

$n = 0.375mol \times 1/1$

$= 0.375mol$

$m = nM$

$= 0.375mol \times 58.44g/mol$

$= 21.915g$

$m = 22g$

c. 2.0 g of methane reacts with 7.0 g of oxygen. How many grams of carbon dioxide is produced?

$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$n = \frac{m}{M}$

$= \frac{2.0g}{16.05g/mol}$

$= 0.1246...mol$

$n_{required} = 0.21875mol \times 1/2$

$= 0.1093...mol$

ER

$n = \frac{7.0g}{32.00g/mol}$

$= 0.21875mol$

LR

$n = 0.21875mol \times 1/2$

$= 0.1093...mol$

$m = nM$

$= 0.1093...mol \times 44.01g/mol$

$= 4.8135...g$

$m = 4.8g$

15. When 84.8 g of iron(III) oxide react with an excess of carbon monoxide, 57.8 g of iron is produced.

$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$

What is the percent yield of this reaction?

$n_{Fe_2O_3} = \frac{m}{M}$

$= \frac{84.8\,g}{159.70\,g/mol}$

$= 0.5309...\,mol$

$n_{Fe} = 0.5309...\,mol \times 2/1$

$= 1.0619...\,mol$

$m = nM$

$= 1.0619...\,mol \times 55.85\,g/mol$

$= 59.3122...\,g$

$\%\,yield = \frac{actual}{predicted} \times 100\%$

$= \frac{57.8\,g}{59.3122...\,g} \times 100\%$

$= 97.450...\%$

$\%\,yield = 97.5\%$

16. When 50.0 g of silicon dioxide are heated with an excess of carbon, 32.2 g of silicon carbide are produced.

$SiO_{2(g)} + 3C_{(s)} \rightarrow SiC_{(s)} + 2CO_{(g)}$

What is the percent yield of this reaction?

$n_{SiO_2} = \frac{m}{M}$

$= \frac{50.0\,g}{60.09\,g/mol}$

$= 0.8320...\,mol$

$n_{SiC} = 0.8320...\,mol \times 1/1$

$= 0.8320...\,mol$

$m = nM$

$= 0.8320...\,mol \times 40.10\,g/mol$

$= 33.366...\,g$

$\%\,yield = \frac{actual}{predicted} \times 100\%$

$= \frac{32.2\,g}{33.366...\,g} \times 100\%$

$= 96.503...\%$

$\%\,yield = 96.5\%$

17. What is the percent yield if 3.74 g of copper are produced when 1.87 g of aluminum are reacted with 14.5 g of copper (II) sulfate?

$2\,Al_{(s)} + 3CuSO_{4\,(aq)} \rightarrow 3Cu_{(s)} + Al_2(SO_4)_{3\,(aq)}$

$n = \frac{m}{M}$

$= \frac{1.87\,g}{26.98\,g/mol}$

$= 0.06931...\,mol$

$n = \frac{14.5\,g}{159.62\,g/mol}$

$= 0.09084...\,mol$

LR

$n_{required} = 0.09084...\,mol \times 2/3$

$= 0.060056...\,mol$

ER

$n = 0.09084...\,mol \times 3/3$

$= 0.09084...\,mol$

$m = nM$

$= 0.09084...\,mol \times 63.55\,g/mol$

$= 5.772...\,g$

$\%\,yield = \frac{actual}{predicted} \times 100\%$

$= \frac{3.74\,g}{5.772...\,g} \times 100\%$

$= 64.785...\%$

$\%\,yield = 64.8\%$

18. 50.0 ml of 0.250 mol/L potassium phosphate reacts with 25.0 ml of 1.00 mol/L lead (II) sulfate. What is the mass of the precipitate?

$2K_3PO_{4(aq)} + 3PbSO_{4(aq)} \rightarrow Pb_3(PO_4)_{2(s)} + 3K_2SO_{4(aq)}$

$n = cV$
$= 0.250\,mol/L \times 0.05L$
$= 0.0125\,mol$

$n_{required} = 0.025mol \times 2/3$
$= 0.01\overline{6}...\,mol$
LR

$n = 1.00mol/L \times 0.025L$
$= 0.025\,mol$
ER

$\hookrightarrow n = 0.0125mol \times 1/2$
$= 0.00625\,mol$

$m = nM$
$= 0.00625mol \times 604.34\,g/mol$
$= 3.777...\,g$

$\boxed{m = 3.78g}$

19. 75 ml of 1.25 mol/L of HCl (aq) is reacted with 125 ml of 1.00 mol/L KOH (aq), what is the concentration of potassium chloride produced?

$HCl_{(aq)} + KOH_{(aq)} \rightarrow KCl_{(aq)} + HOH_{(l)}$

$n = cV$
$= 1.25mol/L \times 0.075L$
$= 0.09375\,mol$
LR

$n = 1.00mol/L \times 0.125L$
$= 0.125\,mol$
ER

$\hookrightarrow n = 0.09375\,mol \times 1/1$
$= 0.09375\,mol$

$V = 75mL + 125mL = 200mL$

$c = \frac{n}{V}$
$= \frac{0.09375mol}{0.200L}$
$= 0.46875\,mol/L$

$\boxed{[KCl_{(aq)}] = 0.47\,mol/L}$

20. Use the following titration data to determine the concentration and pH of the sulfuric acid.

Titration of 20.00 ml sample of H_2SO_4 (aq) with 0.550 mol/L magnesium hydroxide

Trial	1	2	3	4
Initial Burette Reading (mL)	52.6	38.6	27.1	15.7
Final Burette Reading (mL)	38.6	27.1	15.7	4.1
Volume of Titration (mL)	14.0	11.5	11.4	11.6

$V_{avg} = 11.5m$

$H_2SO_{4(aq)} + Mg(OH)_{2(aq)} \rightarrow MgSO_{4(aq)} + 2HOH_{(l)}$

$V = 0.02L$
$n = 0.006325mol \times 1/1$
$= 0.006325\,mol$

$c = \frac{n}{V}$
$= \frac{0.006325mol}{0.02L}$
$= 0.31625\,mol/L$

$c = 0.550\,mol/L$
$V = 0.0115L$
$n = cV$
$= 0.550mol/L \times 0.0115L$
$= 0.006325\,mol$

$pH = -\log[H_3O^+_{(aq)}]$
$= -\log[0.31625mol/L]$
$= 0.49996...$

$\boxed{[H_2SO_{4(aq)}] = 0.316\,mol/L}$
$\boxed{pH = 0.500}$