KEY

STEM Chemistry Semester Two Standards

ALT 1: I can describe the structure of the atom.

1.4: models of the atom over time.
1.7: electron configurations.
1.8/1.9: process of atoms emitting unique spectra of light.

ALT 2: I can describe the organization of the Periodic Table, find patterns, and predict properties of elements.

ALT 5: I can describe how and why atoms form bonds.

5.4/5.6: compare characteristics of bond types, relationship between electronegativity and bond type.
5.5: Lewis Dot Structures
5.7: VSEPR model, molecular geometry and polarity.
5.8/5.9: Intermolecular forces.

ALT 11: I can differentiate between physical and chemical changes (*SOLUTIONS*)

11.8a: I can explain relative concentrations of solutions
11.8b: I can calculate specific concentrations of solutions
11.8c: I can use solubility rules and create net ionic equations

ALT 12: I can explain the relationship between endothermic/exothermic processes and heat transfer.

12.4: I can describe the changes in energy in a chemical processes. (thermochemistry)
12.6: I can explain how the making or breaking of bonds is a process that absorbs or releases energy. (enthalpy diagrams)

ALT 9: I can explain how chemical changes demonstrate the law of conservation of mass.
(*EQUILIBRIUM AND RATE OF REACTION*)

9.9a: I can identify the factors that affect the rate of a reaction
9.9b: Reversible reactions and equilibrium calculations.

ALT 1 & 2

1. Why do we emphasize the valence electrons in an atom when discussing atomic properties?

The valence electrons are those that are involved in bonding. The atom is driven to have 8 valence electrons to reach full stability; the valence electrons contribute to the 8, but often the atom needs to interact with another atom to complete its octet. It will either gain/lose electrons to achieve this (become an ion) or it will share electrons to complete its octet (covalent).

2. Write an electron configuration for each of the following.
   a. The lightest halogen atom **$1s^2 2s^2 2p^5$**
   b. The alkali metal with only 2p and 3p electrons (in addition to the needed s electrons) **$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$**
   c. The three lightest alkaline earth metals **$1s^2 2s^2$** and **$1s^2 2s^2 2p^6 3s^2$** and **$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$**
   d. The Group 3A element in the same period as Sn **$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^1$**
   e. The nonmetallic elements in Group 4A **$1s^2 2s^2 2p^2$**
   f. The element with the largest atomic radius in the 5th period **$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$**

3. Draw the orbital diagram for the element in the 4th period that has four unpaired d electrons.

↑↓ (1s) ↑↓ (2s) ↑↓ ↑↓ ↑↓ (2p) ↑↓ (3s) ↑↓ ↑↓ ↑↓ (3p) ↑↓ (4s) ↑ ↑ ↑ ↑ __ (3d)

5s ___
4p ___ ___ ___
3d ↑ ↑ ↑ ↑ ___
4s ↑↓
3p ↑↓ ↑↓ ↑↓
3s ↑↓
2p ↑↓ ↑↓ ↑↓
2s ↑↓
1s ↑↓

4. After being excited, Barium emits a photon of light with an energy of 3.90×10^{-19}J. What is the color of the light emitted? Will this light be "more red or more blue" than a photon with an energy of 2.5×10^{-17}J?

3.90×10^{-19} Joules < 2.5×10^{-17} Joules
The smaller the Energy needed for the transition, the larger the corresponding wavelength of light emitted. Larger wavelengths are on the red end of the spectrum.

ALT 5

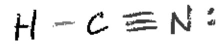
1. What two requirements should be satisfied for a molecule to be polar?

   The molecule is either not symmetrical or the bonds between elements are polar.

2. Consider the bonds that would form between hydrogen and elements 5-9, rank the bonds in order of increasing polarity. Determine which are ionic, polar covalent, and non-polar covalent.

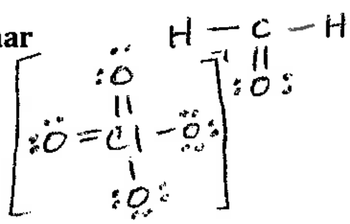
   H – B < H – C < H – N < H – O < H – F
   HB and HC are non-polar covalent because the difference in the electronegativity values is less than 0.4
   HN, HO and HF are all polar covalent. Their differences lie between 0.4 and 2.

3. Draw Lewis dot structures and determine the molecular shape for each of the following:
   a. HCN **Linear**

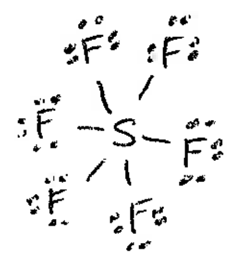
   

   b. H_2CO **Trigonal planar**

   c. ClO_4^- **Tetrahedral**

   d. SF_6 **Octahedral**

4. List the three main types of intermolecular forces in order of increasing strength, what causes them and what effect do they have on the bulk properties of the substances that have them?

H-bonding > dipole-dipole > Dispersion Forces
H-bonding occurs when Hydrogen bonds to either N, O, or F. It is a strong IMF and causes an increase in the boiling point of the substance because the molecules are strongly attracted to one another. In dipole-dipole there is a partial separation of charge between the elements in a bond and those partial charges attract one another between molecules. The partial positive end of one dipole attracts to the partial negative end of another. Dispersion forces occur in any molecule and it is the weakest IMF. It is caused by an instantaneous dipole, which then disappears.

ALT 11

1. How many grams of solid $NaNO_3$ would you use to make a 150mL solution of 0.1M $NaNO_3$? Would this solution be saturated, unsaturated, or supersaturated? How could you alter the conditions to change your answer to the second part of this problem?

   0.1 M = X/0.150 L X = 0.0150 mol

0.0150 mol x 85 grams/mole = 1.275 grams

1.275 grams / 1000 mL = 0.1275 grams / 100 mL

When looking at the solubility curves graph, a value of 0.1275 grams in 100 mL of water is very unsaturated at any temperature. To make the solution either saturated or supersaturated, you could add a lot more solute or decrease the temperature a lot or evaporate off a lot of water.

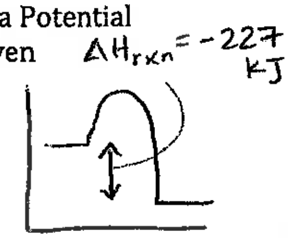
2. What products would you get if you mixed aqueous lead (II) nitrate with aqueous potassium chloride? Write the balanced chemical equation and the net ionic equation.
   $Pb(NO_3)_2$ + KCl → $PbCl_2$ + KNO_3

   Ionic: Pb^{+2} + NO_3^{-1} + K^{+1} + Cl^{-1} → $PbCl_2$ (s) + K^{+1} + NO_3^{-1}

   Net Ionic: Pb^{+2} + 2 Cl^{-1} → $PbCl_2$ (s)

ALT 12

1. The following reaction has a ΔH° of -227 KJ, is it endo or exothermic? Draw a Potential energy diagram showing this reaction to the best of your ability with the given information.
   SO_3(g) + H_2O(l) → H_2SO_4(aq)
   If we hadn't given you the ΔH° value how could you have determined it?



The reaction is exothermic as evidenced by the negative ΔH value.
The heats of formation values could be used [products – reactants] to determine the Heat of the reaction.

2. Given the following data:

S(s) + 1.5O_2(g) → SO_3(g)	ΔH = -1300 kJ
2SO_2(g) + O_2(g) → 2SO_3(g)	ΔH = -198.2 kJ

   Calculate ΔH for the reaction:
   S(s) + O_2(g) → SO_2(g)

Flip the second reaction and divide it by 2. Add the two reactions together. ΔH_{rxn} = -1200.9 KJ (-1300) + (198.2/2) = -1200.9 KJ

ALT 9

1. What does collision theory tell us about chemical reactions? List the things that can effect the rate of a reaction.

   Substances must collide effectively in order for a reaction to take place. An effective collision occurs with the right amount of energy and the correct

orientation (alignment). Many collisions occur that are not effective for one or both of the listed reasons, and they just bounce off of one another unaffected.

Things that can affect reaction rate:

- **Increase concentration, increases collisions, increases effective collisions**
- **Increase temperature, increases collisions, increases effective collisions**
- **Increase agitation, increases collisions, increases effective collisions**
- **Increase pressure, increases collisions, increases effective collisions**
- **Increase # of particles by crushing it up, increases collisions, increases effective collisions**
- **Use a catalyst, lowers Ea, increases effective collisions**

2. A 1.0L flask was filled with 2.00 moles of gaseous SO_2 and 2.00 moles of gaseous NO_2. After equilibrium was reached it was found that 1.30 moles of gaseous NO was present. Using the equation for this reaction (below) calculate the value of K_{eq} for this reaction.

	$SO_2(g)$	+ $NO_2(g)$	←→ $SO_3(g)$	+ NO (g)
I	2.00	2.00	0	0
C	-1.30	-1.30	+1.30	+1.30
E	0.70	0.70	1.30	1.30

$$K_{eq} = \frac{[1.30][1.30]}{[0.70][0.70]}$$

$$K_{eq} = 3.44897$$

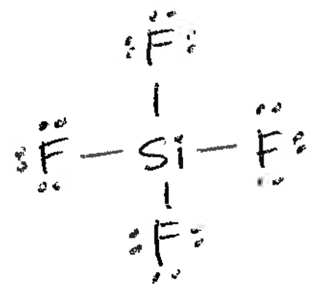
$$\boxed{K_{eq} = 3.4}$$

STEM Chemistry – Semester 2 Final Review
Practice Challenge Problems

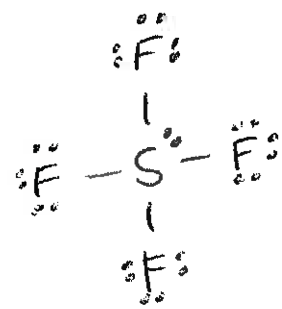
ALT 5

1. The molecules of SiF_4, SF_4 and XeF_4 all have molecular formulas of the type AF_4, but the molecules have different molecular geometries. Predict the shape of each molecule and explain the origin of the differing shapes.

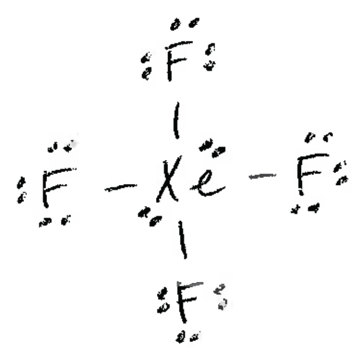
SiF_4
4+4(7) = 32
Molecular Geometry: Tetrahedral
Shape: Tetrahedral



SF_4
6+4(7) = 34
Molecular Geometry: Trigonal Bipyramidal
Shape: ~~Trigonal Bipyramidal~~ See Saw



XeF_4
8+4(7) = 36
Molecular Geometry: Octahedral
Shape: Square Planar



Each molecule has an increasing number of electrons which shows up as an increasing number of lone pairs. Each lone pair is an additional electron domain which changes the angles of repulsion and therefore dictates new geometries and shapes.

ALT 11 & 5

2. Most gases are sparingly soluble in water. For example, a liter of water saturated with oxygen gas at room temperature contains only 0.05 grams of O_2. Conversely, ammonia gas can dissolve in water to produce a 15M solution. Why is ammonia gas so much more soluble in water than oxygen gas?

a) prove that the final statement in the question is true by comparing the mass of O_2 to the mass of NH_3 present in the 1 Liter sample, and the molarity of both solutions.
b) What would happen to the concentration of the ammonia solution if the temperature was increased?
c) Determine and explain the reason for the difference in solubility based on the VESPR geometry and intermolecular forces.

a)

	O_2		NH_3
Grams	$\frac{0.05g}{1L}$	<<	$15 = \frac{x}{1L}$, $x = 15\,mol$; $15\,mol\left(\frac{17.034g}{1\,mol}\right) = 255.51g$
Molarity	$.05g\left(\frac{1\,mol}{32\,g}\right) = \frac{.00156\,mol}{1L} = .00156\,M$	<<	15M

b) the concentration of NH_3 would decrease because the NH_3 gas will bubble out of solution as the temperature is increased.

c)

O_2	NH_3
Non-polar	**Polar**
Dispersion forces only	**Dipole-Dipole (dominant) & Dispersion**
Water is polar and does not attract O_2. Therefore, very little O_2 dissolves	**"Like dissolves like" Water and NH_3 are both polar and so they attract one another.**

ex: 0.115 mol $Ba(NO_3)_2$ $\left(\frac{2\ NO_3^-}{1\ Ba(NO_3)_2}\right)$ = 0.23 mol NO_3^-

ALT 11 & 12

3. 250 mL of a 0.459 molar solution of barium nitrate is added to 289 mL of a 0.892 molar solution of aluminum fluoride. Complete the following:

$Ba(NO_3)_2$: $0.25\ L \left(\frac{0.459\ mol}{1\ L}\right) = 0.115$ mol $Ba(NO_3)_2$

∴ 0.115 mol Ba^{2+}
0.23 mol NO_3^-

AlF_3: $0.289\ L \left(\frac{0.892\ mol}{1\ L}\right) = 0.258$ mol AlF_3

∴ 0.258 mol Al^{3+}
0.773 mol F^-

a) Write the complete, balanced equation.

$3\ Ba(NO_3)_2 + 2\ AlF_3 \rightarrow 3\ BaF_2 + 2\ Al(NO_3)_3$

b) write the ionic equation

$Ba^{+2} + NO_3^{-1} + Al^{+3} + F^{-1} \rightarrow BaF_2\ (s) + Al^{+3} + NO_3^{-1}$

c) write the balanced net ionic equation

$Ba^{+2} + 2\ F^{-1} \rightarrow BaF_2\ (s)$

d) determine the *starting* mole values of the ions present in the combined solutions before the reaction begins.

~~$0.459\ M = \frac{x}{0.539}$~~ ~~$x = 0.2474$ mol Ba^{+2}~~ ~~0.4948 mol NO_3^{-1}~~

~~$0.892 = \frac{x}{0.539}$~~ ~~$x = 0.4807$ mol Al^{+3}~~ ~~1.442 mol F^{-1}~~

e) determine the *ending* molarity of each ion present in the solution.

First the LR needs to be determined

$Ba^{+2} : F^{-1}$ is a 1:2 ratio so we will always need twice as much F^{-1}.

If we use all of Ba^{+2} (~~0.2474 mol~~ 0.115 mol) then we will need ~~0.4948~~ 0.23 mol of F^{-1}, we have ~~1.442~~ 0.773 mol of F^{-1} so there is plenty of F^{-1}. Ba^{+2} is the LR.

$[Ba^{+2}] = 0$ All is used in the reaction.

~~1.442~~ 0.773 mol F^{-1} (Have) − ~~0.4948~~ 0.23 mol F^{-1} (Need) = ~~0.9472~~ 0.543 mol F^{-1} Left over

$[F^{-1}] = \frac{\text{~~0.9472 mol~~ 0.543 mol}}{0.539}$ = ~~1.8 M~~ **1.0 M**

These are unused spectator ions.

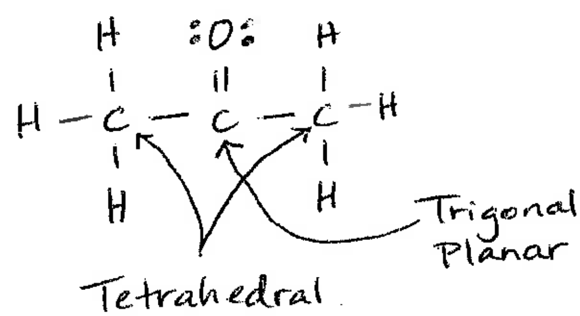
$[NO_3^{-1}] = \frac{\text{~~0.4948 mol~~ 0.23 mol}}{0.539}$ = ~~0.92 M~~ **0.427 M**

$[Al^{+3}] = \frac{\text{~~0.4807 mol~~ 0.258 mol}}{0.539}$ = ~~0.89 M~~ **0.479 M**

ALT 5

4. Acetone $(CH_3)_2CO$ is a substance widely used as an industrial solvent.
    a. Draw the LDS for the acetone molecule and predict the geometry around each carbon atom.
    b. Is the acetone molecule polar or nonpolar?
    c. What type of intermolecular attractive forces exist between acetone molecules?
    d. 1-propanol, $CH_3CH_2CH_2OH$, has a molecular weight that is very similar to that of acetone, yet acetone boils at 56.5 °C and 1-propanol boils at 97.2 °C. Explain the difference.

a)



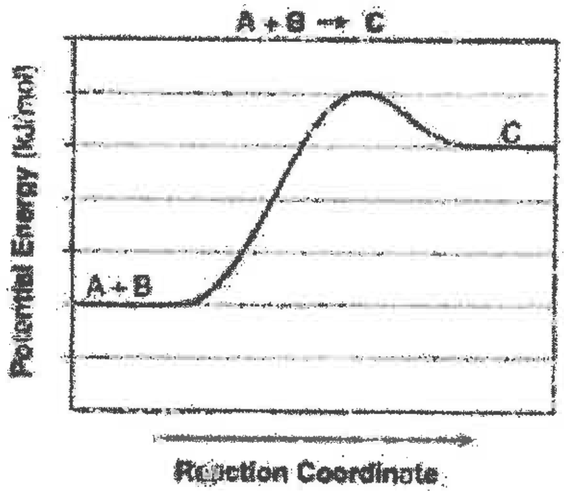
b) Acetone is polar. The C – O bond is polar.

c) Acetone has dipole-dipole intermolecular forces

d) 1-propanol has Hydrogen bonding and so it has a stronger intermolecular force which causes the molecules to be more attracted to each other. More energy is needed to break these attractions and so the boiling point is increased.

ALT 9

5. The hypothetical reaction A + B ←→ C occurs in the forward direction in a single step. The Potential Energy diagram of the reaction is shown.



   a. Is the forward or reverse reaction faster at equilibrium?
   b. Would you expect the equilibrium to favor reactants or products?
   c. In general, how would a catalyst affect the energy profile shown?
   d. How would a catalyst affect the ratio of the rate constants for the forward and reverse reactions?
   e. How would you expect the equilibrium constant of the forward reaction to change with increasing temperature?

a) At equilibrium both reactions are occurring at the same rate.

b) Reactants. It is endothermic.

c) It will lower Ea.

d) the ratio of Keq forward to Keq reverse would not change since Keq values are not impacted by the addition of a catalyst.

e) The reaction will shift to the right and make the Keq larger.

ALT 12

6. Burning methane in oxygen can produce three different carbon-containing products: C (s) (soot: very fine particles of graphite), CO (g) and CO_2 (g).

   a. Write three balanced equations for the reaction of methane gas with oxygen to produce these three products. In each case assume that H_2O (l) is the only other product.
   b. Determine the ΔH_{rxn} for each of the reactions
   c. Why, if the oxygen supply is adequate, is CO_2 (g) the predominant carbon-containing product of the combustion of methane?

a) **CH_4 (s) + O_2 (g) → 2 H_2O (L) + O_2 (g)**

2 CH_4 (s) + 3 O_2 (g) → 4 H_2O (L) + 2 CO (g)

CH_4 (g) + 2 O_2 (g) → 2 H_2O (L) + CO_2 (g)

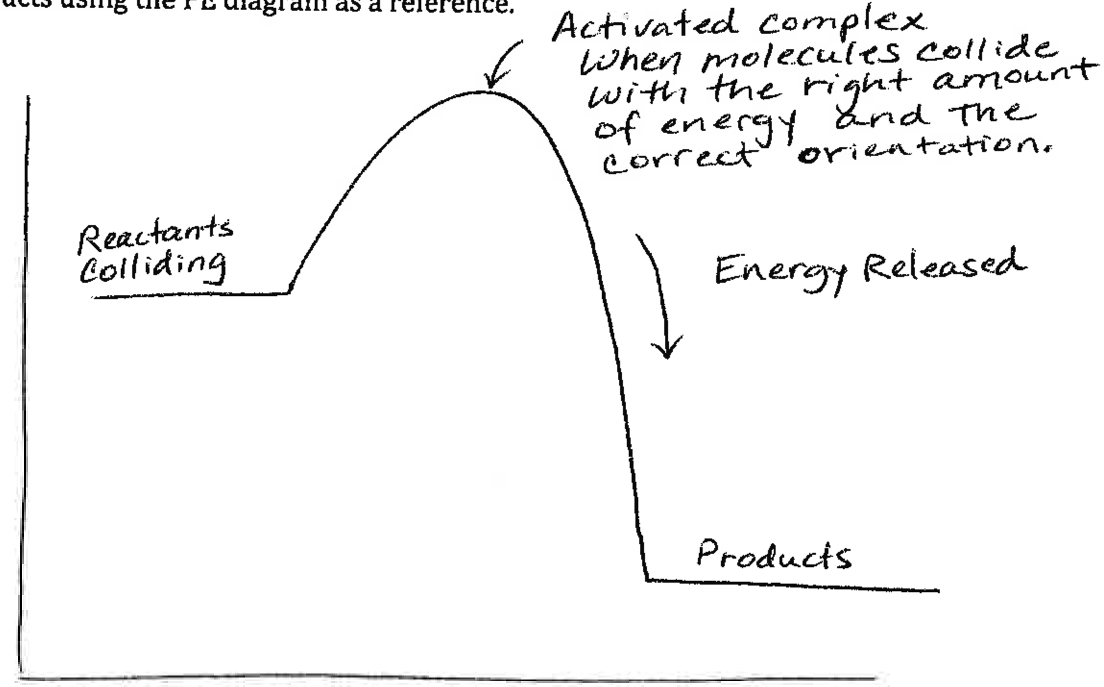
b) **[2(-285.8) + 0] – [(-74.8) + 0] = -496.8 KJ for one mole of CH_4 burned**

[4(-285.8) + 2(-110.5)] – [2(-74.8) + 3(0)] = -1214.6 KJ for two moles of CH_4 burned

[2(-285.8) + (-393.5)] – [(-74.8) + 2(0)] = -890.3 KJ for one mole of CH_4 burned

c) **In order to compare the reactions, each one must be burning the same amount of CH_4. In comparing each ΔH value per mole: -890.3 < -607.4 < -496.8 The value that is the largest negative value is the reaction that is the most exothermic and therefore the most "desired" or driven to go to products. Since that reaction is the one that produces CO_2, that explains why CO_2 is the predominant carbon-containing product of the combustion of methane.**

7. Explain, using collision theory what the molecules are doing as you go from reactants to products using the PE diagram as a reference.



ALT 2

8. Design a series of clues that correspond to the elements given in the table below.

H																	
														N		F	
												Al					
K					Cr									As			
																	Xe
	Ra																

Examples of clues (there are multiple options, I am giving one)

H: The lightest of the diatomic gases

K: An Alkali metal that needs three atoms when bonding to Nitrogen

Ra: An Alkaline Earth metal that is the largest of its family

Cr: A transition metal that has electrons in the 3d

Al: A metal that forms a +3 ion. It has a higher electronegativity than Gallium

N: A non-metal that forms a -3 ion and is a diatomic gas

F: A non-metal halogen that has the highest electronegativity of all of the elements

As: A metalloid that has 5 valence electrons

Xe: A Noble gas with valence electrons in the 5^{th} energy level