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PRELAB 1: The Bohr Model of the Atom

1. What is the purpose of a calibration curve?

2. What data would you take to generate a calibration curve for your spectrograph? What will be plotted on the x-axis and on the y-axis?

3. The three main series of spectral lines that can be experimentally observed are ultraviolet, visible and infrared. What series are you observing in this experiment?

4. At what energy level (quantum number) do these transitions end?

LAB 1: The Bohr Model of the Atom

I. Purpose: In this lab, you will use a handheld spectroscope to observe the emission lines produced from a photon that is emitted when an electron moves from a higher energy state to a lower one. This is physical evidence that atomic line spectra originate from the movement of electrons between quantized energy states.

Read the procedure IN ADVANCE and prepare a data table (straight lines drawn with a ruler) to record the data you will be collecting. You will need a SECOND data table to record the results of your calculations (see III, below).

II. Procedure:

a) **Using the spectroscope**: Examine the spectroscope carefully so you can identify the various parts:
   - i) Narrow, vertical slit at the front of the box (this will face the light source)
   - ii) Diffraction grating at the rear of the box
   - iii) Ruler visible INSIDE the box, to the right of the slit

b) Check the condition of the diffraction grating as follows:
   - i) Point the slit at the room lights and look through the hole covered with diffraction grating. If the grating is the right way up and in decent condition, you will see a rainbow-like spectrum under the ruler inside the box.
   - ii) If you can't see anything, the diffraction grating is missing. Return the spectroscope to your instructor.

c) Calibrating the spectroscope
   - i) Use the mercury tube light under the hood to collect calibration data.
   - ii) Face the slit towards the mercury light. Instead of a continuous, rainbow-like spectrum, you will see at least 3 sharp lines positioned at different locations along the ruler.
   - iii) Record the ruler numbers corresponding to the BLUE, GREEN and ORANGE lines.
   - iv) Plot the data accurately as you described in the first prelab question.

Hg line spectra

Color	Wavelength
Blue	4.36×10^{-5} cm
Green	5.46×10^{-5} cm
Orange	5.80×10^{-5} cm

   - v) Draw a best-fit straight line. If your points deviate grievously from a straight line, you may have to redo the previous steps. Be patient, and always measure the same way.

vi) Check your plot with the helium light: face the narrow slit towards the helium light. You will see several lines of different colors. Record the ruler number corresponding to the ORANGE line.
vii) Face the narrow slit towards the helium light. You will see several lines of different colors. Record the ruler number corresponding to the ORANGE line.
viii) From the Hg calibration plot, locate the value of wavelength (x) that corresponds to the cm you measured and record.
ix) Report the wavelength you determined to your teacher before proceeding. If your value is way off, you will have to repeat the calibration.

d) **Observing the spectral lines of hydrogen**: Using the spectroscope just as you did for the sodium spectrum, determine the wavelengths of hydrogen's α (red) , β(green) , and γ(blue) lines. You should be able to see the first three without difficulty, but Hδ(violet) is right on the edge of the visible spectrum. Assume the wavelength of that line to be 4.10×10^{-5} cm. These results should be recorded in the data table.

III. Calculations. Prepare a "calculations" data table with columns for symbol, color of line, λ, ν, ΔE, and energy level, n. Enter the symbols and colors of line (given in (d), above), and the corresponding observed wavelength values.

A. With your values for λ, calculate the frequency of each line. Record these values in the data table. (Recall that $C = \lambda\nu$, where C is the speed of light, in cm/s, and ν is its frequency, in s^{-1}).
B. From Einstein's equation, calculate the energy values for each line, and record these in your data table. ($\Delta E = h\nu\eta$, where ΔE = change in energy (J/mol of electrons; h= Planck's constant, and η = number of electrons in one mole).
C. Assign "n" (quantum numbers) to the energy level from which each emission line *originates* based on your observations and calculated values, recalling that higher energy emissions result from larger changes in n and that all the emissions end at the same n level.

IV. Interpretation

Make a diagram of the excited H atom, showing the wavelength, color and energy for each emission. The Lyman series (ultraviolet region) results from transitions to n=1. The Balmer series of lines appears in the visible region (transitions to n=2), which is what you observed. Which transition leads to emission of the least amount of energy in the Balmer series?

PRELAB 2: Blueprint Photography

1. Most photographic work involving light-sensitive film or paper must be done in a darkroom. Why can the cyanotype paper be handled in the classroom?

2. What difference would you expect to see between the exposure made with clear glass and with sunscreen-coated glass? What accounts for the difference?

3. What would you expect to happen if you used a sunglass lens instead of clear glass while making the exposure?

4. The ozone layer in the upper atmosphere protects us from most, but not all, UV radiation. Why is UV light harmful to living organisms, but visible and infrared light not?

LAB 2: Blueprint Photography

I. Purpose: This lab will demonstrate how ultraviolet (UV) light can be a catalyst for a chemical reaction. This is the same process that is used to prepare traditional blueprints (cyanoprints). Exposure of the cyanotype paper to UV light causes reduction of Fe^{+3} ions to Fe^{+2} ions. A blue image is produced when the Fe^{+2} ions react with ferricyanide ions to form insoluble iron(III) hexacyanoferrate(II), otherwise known as Prussian Blue.

II. Materials:

Sensitizer solution: equal amounts of ammonium ferric citrate and potassium ferricyanide

Watercolor quality paper	Paintbrush
Piece of clear glass	Paper clips
3% H_2O_2	Black and white negative or other object
Piece of blue glass	

III. Safety: Rinse off any chemicals immediately, or you will turn into a frog. Wear safety goggles whenever handling chemicals.

IV. Procedure: perform away from direct sunlight and fluorescent lights unless otherwise instructed!

1. Write your name on two pieces of paper. Use a brush to apply sensitizer solution to one side of each piece of paper. Apply evenly, with horizontal brush strokes. Then, *without applying more solution*, brush in the vertical direction and finally once more horizontally. Do not allow excess solution to remain on the paper.
2. Let dry overnight in a dark place.
3. Place black and white negative (glossy side up) or other objects (fern branches and lace work well) on the paper. Cover with a piece of glass, then cover with a piece of paper to block out light.
4. Take the assembly to a place where it can be exposed to direct sunlight and remove cover. Expose for 15 minutes.
5. When the exposure is complete, cover assembly and remove from direct sunlight. Remove the negative or object and wash paper in sink under cool running water.
6. Using the second piece of paper and a piece of blue glass, repeat steps 3,4 and 5.
7. Finish by immersing the papers in H_2O_2 and rinse again with water. Let the papers dry.

V. Conclusion/analysis:

Did your results agree with your predictions in prelab question 2 or not? Why or why not?

Lab 3: Flame Test!

Purpose: To identify the elements in a solution of unknown composition.

Background: Scientists are always trying to determine what molecules and elements are in unknown substances. They use a host of analytical methods to do this, such as the reactivity of the material, what the material dissolves in and, most importantly, spectroscopy, which is the study of the light absorbed and emitted by molecules and elements. Examples of these are the helium and hydrogen lamps you looked at in the Bohr's model lab. Each element emitted specific color lines that are unique to the element and can be used in its identification. In this lab, you will be given a solution of two unknown elements from the list of possible known elements below. It is your job to determine which elements you have.

Procedure: You will have available wooden splints soaked in solutions of individual metal ions-calcium, lithium, strontium, potassium and copper. You will be given a wooden splint soaked in a solution containing TWO of those ions. Develop and execute a procedure to determine the composition of this solution.

Safety:
1. Minimize skin contact with solutions of metal ions. Wash your hands after completing lab!
2. Keep hair, clothing and other materials away from open flame (Bunsen burner).
3. After reviewing your procedure, the teacher will discuss any safety precautions specific to your experiment.

Question for further thought: How would using a colored glass filter assist in identifying a solution's composition? Give two examples.

Write up: A grading rubric is on the next page. Your write-up will need to include: your procedure and an explanation of any changes you made to your original; your data and/or observations; a conclusion explaining your results and your evidence for this and any possible errors you may have experienced; and how you think you may be able to avoid them if you were to do the lab again. You must also answer the question!

Available Materials:

Beakers	hot plate	test tubes	cobalt (blue) glass
Graduated cylinder	spectroscope	wooden splints	flashlight
Bunsen burner	pipettes	grating glasses	

Possible Unknowns:

Lithium	Calcium	Strontium	Potassium	Copper
Sodium	Sodium and Potassium			

Lab 3 : Flame Test!

Student Name: ______________________________

CATEGORY	4	3	2	1
Format	Report is legible and includes purpose, materials, procedure, data table, observations, conclusion and error analysis.	Report contains all required elements but is difficult to read.	Report is missing one of the required elements.	Report is missing two or more of the required elements.
Procedure	Procedure is listed in clear steps. Each step is numbered and is a complete sentence. Use of chemicals is minimized.	Procedure steps are listed in logical order, but steps are not numbered and/or are not in complete sentences. Use of chemicals is minimized.	Procedure steps are listed but are not in a logical order or are difficult to follow. No attempt is made to use materials efficiently.	Flow chart appears to have been scribbled on the back of a napkin during breakfast.
Cleanup	I can't tell you were here today.	I had to remind you to clean up.	I found trash in your sink.	I had to clean up your dishes (grr).
Analysis/ Conclusion	Conclusion is a one or two sentence statement and includes the composition of the unknown. At least two sources of error and how they would affect the result are cited correctly.	Conclusion is a one or two sentence statement and includes the composition of the unknown. Sources of error are included, but not how they would affect the result.	Conclusion is not written in complete sentences. Sources of error are included.	Conclusion does not include sources of error.
Question	Question is answered completely and correctly, in complete sentences.	Question is answered, but not in a complete sentence.	Question is answered in complete sentences, but incorrectly.	Oops! Forgot to answer the question!
Data	Data and observations are entered legibly in a table during real time. Tables are labeled and titled.	Data are transferred to a table after lab is complete. Tables are labeled and titled.	Data are accurately represented in written form, but no tables are presented.	Data are written in the margins of your lab instructions without any labels or identification and no observations included.

LAB 4: The Periodic Law

I. Purpose: In this lab you practice your detective skills, arranging the elements in Groups 1A-VIIIA according to a list of clues and your knowledge of periodic properties. You will predict the missing properties of each element based on location in the table, and finally explain the trends of properties in families and periods.

II. Materials

Sheet with encoded elements
Blank periodic table
Scissors
Glue, tape or stapler

III. Safety: Do not staple or glue each other to the desks.

IV. Procedure

1) Cut out the squares. They are not printed in correct order!
2) Collect blocks A-Z. Use the clues (listed below) to arrange the elements in their proper order. When you feel they are placed correctly, affix them permanently.
3) Use the information provided in the remaining 16 blocks and your knowledge of periodic properties to arrange these elements in their proper place, and glue them in.

CLUES!

- The following sets of elements belong together in groups: ZRD, PSIF, JXBE, LHT, QKA, WOV, GUN, YMC
- J has an atomic number three times that of T
- U has a total of 6 electrons
- I_2A is the simple formula of an oxide
- P is less dense than S
- S is an alkali metal
- E is a noble gas
- W is a liquid
- Z has the smallest atomic mass in its group
- B has 10 protons
- W has an atomic number larger than V
- D has the largest atomic mass of its group
- A neutral atom of C has 5 electrons in its outer energy level
- F is a gas
- X has an atomic number one higher than F
- L is an alkaline earth element with atomic mass of 40
- Y is a metalloid
- O is a halogen
- The atomic number of T is more than that of H
- Q has an atomic mass 2 times that of A
- Atoms of I are larger than those of S
- M has an atomic number one less than that of A
- The electrons of atom N are distributed over three energy levels
- The atomic radius of K is the largest of the group

V. Conclusion questions:

1) Examine your completed table. What general observations can be made of trends **within rows** and **within groups** for the following properties?
    - A) Density
    - B) Atomic radii
    - C) Melting point
2) Where are the heavy metals located? Give three examples.
3) List three properties which distinguish metals from nonmetals.
4) Give three reasons for sodium's location on the periodic table. Think of atomic structure and of physical properties.
5) Explain the relationship of oxidation numbers to electron configuration of groups 1A through VIIIA. How can an atom's electron configuration be predicted on the basis of its location in the periodic table?

Table

EXAMPLE:

Atomic #	Code letter	Symbol
Density		Phase**
	Oxidation #	
Atomic radii		Melting point, °C

0.0014 A gas 0.066 −218	0.0009 B gas 0.160 −249	1.82 C 0.115 44	5.90 D 0.122 29.8	0.0018 E gas 0.191 −189	0.00009 F gas 0.053 −259	5.32 G 0.123 937	1.85 H 0.111 1278
0.862 I 0.227 64	0.0037 J gas 0.198 −157	4.79 K 0.114 217	1.55 L 0.197 839	0.0013 M gas 0.070 −210	2.33 N 0.117 1410	0.003 O gas 0.099 −101	0.534 P 0.152 181
2.07 Q 0.104 113	2.70 R 0.143 660	0.971 S 0.192 98	1.74 T 0.160 649	2.27 U 0.077 3550	0.0016 V gas 0.072 −219	3.12 W liquid 0.111 −7	0.00018 X gas 0.122 −272
5.7 Y 0.125 817	2.34 Z 0.083 2079	1.53 * 1+ 0.248 39	7.31 * 2+, 4+ 0.141 232	6.69 * 3+, 5+ 0.136 631	0.0059 * gas 0 0.218 −112	* 1− 0.14 302	19.8 * 2+, 4+ 0.167 254
9.75 * 3+, 5+ 0.155 271	1.87 * 0.265 28	6.24 * 2−, 4+, 6+ 450	7.31 * 1+, 3+ 0.163 157	4.93 * 1− 0.128	11.85 * 1+, 3+ 0.170 304	0.0097 * gas 0 0.22 −71	3.5 * 2+ 725
11.3 * 2+, 4+ 0.175 328	2.54 * 2+ 0.215 769						

*No code letters **All are solids unless indicated

EXAMPLE:

Atomic #	Code letter	Symbol
Density		Phase
	Oxidation #	
Atomic radii		Melting point, °C

Row	IA (1)	IIA (2)	IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	VIIIA (18)
1								
2								
3								
4								
5								
6								

LAB 5: Molecular Smells 

Background:

How do we detect odors? Within the nose there are many nerve receptors that bind molecules in a very specific way. Odors are recognized because each odor molecule fits into its own nerve cell like a puzzle piece. The cells then send signals via the olfactory nerve to the olfactory bulb located in the front of the brain via the olfactory nerve. The brain interprets those molecules as the sweet flowers, or the curdling milk that you've held up to your nose. Humans can detect over 10,000 different smells. It has been shown that each olfactory receptor cell expresses a single odorant receptor protein, so there have to be as many types of olfactory receptor cells as there are odorant receptors. However, most odors are not produced by single molecules but by a combination of different chemicals, so that an "odorant pattern", a mosaic of smell rather than color, is sensed. One class of odor molecules commonly found in nature is *esters*. Esters are often responsible for “fruity’ smells, and a small change in the chemical shape of an ester molecule can dramatically affect the smell.

Fun Facts:

- Dogs have 1 million smell cells per nostril, and their cells are up to 100 times larger than those of humans
- Anosmia is the condition that makes people unable to smell.
- Your sense of smell directly affects your sense of taste.
- Smell can evoke emotions such as happiness, fear, even sexuality. The "smell-brain," the Rhinocephlon, is functionally associated with the entire emotional tone of a person.

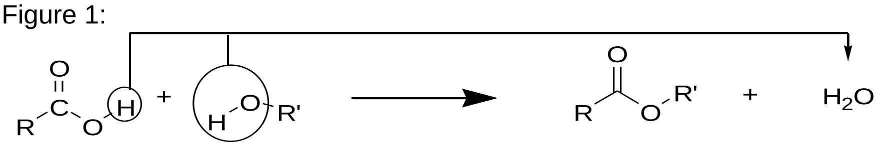
Purpose:

- To synthesize a compound and identify its aroma
- To learn common organic chemistry structural abbreviations

Introduction:

Esters are molecules that can be synthesized by the coupling of common alcohols to common carboxylic acids. An alcohol is any compound containing an OH group, and is generically written as R-OH where R represents any “random” other atoms. A carboxylic acid is any compound containing a COOH group, and is generically written as R-COOH. (Note: it is common organic chemistry practice to differentiate between R groups by using “primes.” For example, R is not the same as R’ which is not the same as R’’ etc.) This coupling of alcohols to carboxylic acids is known as an esterification reaction, is commonly acid catalyzed, is reversible and produces one molecule of water. The term esterification is used because the type of compound formed is known as an ester. Esters can be generically written as R-COOR’ where R and R’ may or may not be the same. See Figure 1 for an example of an esterification reaction.

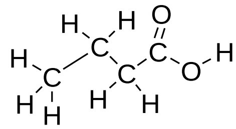
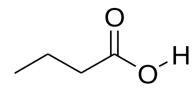
Figure 1:



Carboxylic acid   alcohol   ester

In this lab, you will choose an alcohol and a carboxylic acid, and couple the two in an esterification reaction. You will then try and identify the aroma of the ester you have formed.

Because of the complexity of the molecules involved, this is a good opportunity to learn some common organic structure abbreviations. Organic chemistry is mainly concerned with compounds containing many carbons. Organic chemists therefore draw structures in which each vertex or “corner” of the drawing represents a Carbon atom saturated with Hydrogen atoms. Any other atoms are then drawn in, and the common periodic table abbreviations used. Bonds are represented as lines, and double bonds double lines, triple bonds…well you get the idea. Take for example butyric acid, $C_4H_8O_2$, which can be represented in the following ways:

$C_4H_8O_2$ = $CH_3CH_2CH_2COOH$ =  = 

abbreviated organic structure

Materials:

250mL beaker with ice and water
Five test tubes
Test tube rack
250mL beaker with 100mL tap water heated to 60-65°C.

Safety:

Concentrated H_2SO_4 is highly corrosive. Wash for 15 minutes with water if it gets on you.
Use the wafting technique to smell the compounds.

Prelab:

Using the tables provided, complete the chart on page 58; an example is given.
Then choose five compounds to synthesize.

Procedure:

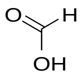
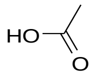
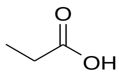
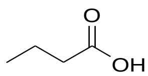
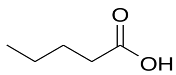
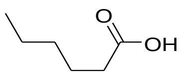
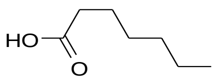
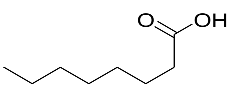
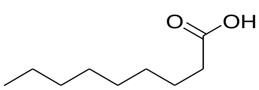
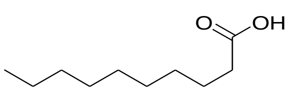
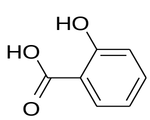
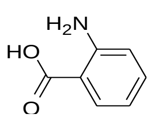
1. After completing the Pre-Lab, choose five odors you would like to synthesize. Take note of which carboxylic acid and alcohol are required to synthesize each ester. Construct a data table with a column for acid, alcohol and expected product.
2. Check to see that there is a 250mL beaker filled to the 100mL mark with tap water on a hot plate.
3. A thermometer should be in the water bath but not touching the bottom of the beaker or sides.
4. Obtain 5 clean test tubes and to each add the correct carboxylic acid and alcohol to make the desired ester. The quantities are listed below:
   - 1mL of your specific carboxylic acid
   - 1mL of your specific alcohol
   - 4 drops of concentrated H_2SO_4
5. Place all 5 test tubes in the hot water bath for 10 minutes.
6. Remove test tubes form hot water bath and place in an ice bath.
7. Add 5mL of distilled water to each test tube
8. Any ester formed will float on the water in the test tube
9. Note: the odor of the ester by wafting the fumes toward your nose with your hand.
10. Dispose of the esters in the beaker labeled “ester waste” located at the front of the class.

Conclusion:

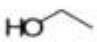
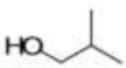
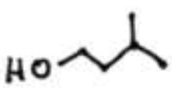
Answer the following questions in paragraph form.

1. How are esters recognized? (i.e. what is the main chemical group in the formula?)
2. How are esters synthesized?
3. In the synthesis of esters, what is used to catalyze the reaction?

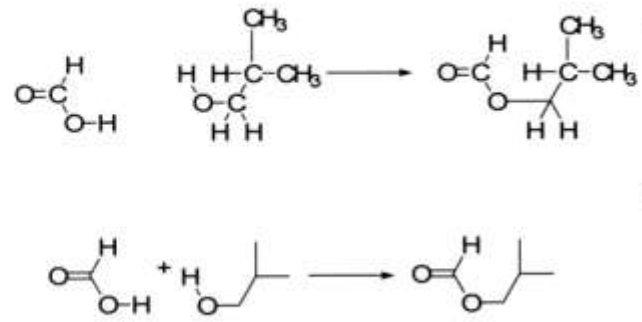
Carboxylic Acids

Structure	Scientific Name	Common Name	Expanded Chemical Formula
	formic acid	formic acid	$HCOOH$
	acetic acid	acetic acid	CH_3COOH
	propionic acid	propionic acid	CH_3CH_2COOH
	butyric acid	butyric acid	$CH_3(CH_2)_2COOH$
	Pentanoic acid	valeric acid	$CH_3(CH_2)_3COOH$
	Hexanoic acid	caproic acid	$CH_3(CH_2)_4COOH$
	Heptanoic acid	enanthic acid	$CH_3(CH_2)_5COOH$
	Octanoic acid	caprylic acid	$CH_3(CH_2)_6COOH$
	Nonanoic acid	pelargonic acid	$CH_3(CH_2)_7COOH$
	Decanoic acid	capric acid	$CH_3(CH_2)_8COOH$
	2-Hydroxy-benzoic acid	salycylic acid	$C_6H_4(OH)COOH$
	2-Amino-benzoic acid	anthranilic acid	$C_6H_4(NH_2)COOH$

Alcohols

Structure	Scientific Name	Common Name	Expanded Chemical Formula
—OH	methanol	Wood Alcohol	CH_3OH
	ethanol	Grain Alcohol	CH_3CH_2OH
	propanol	propyl alcohol	$CH_3(CH_2)_2OH$
	2-methyl-1-propanol	isobutyl alcohol	$CH_3CHCH_3CH_2OH$
	butanol	butyl alcohol	$CH_3(CH_2)_3OH$
	pentanol	pentyl alcohol	$CH_3(CH_2)_4OH$
	octanol	octyl alcohol	$CH_3(CH_2)_7OH$
	2-methyl-1-butanol	isoamyl alcohol	$CH_3CHCH_3(CH_2)_2OH$

Example:



Formic Acid isobutyl alcohol **Raspberry**

Structural Formula

Organic Structure

+ → Structural Formula

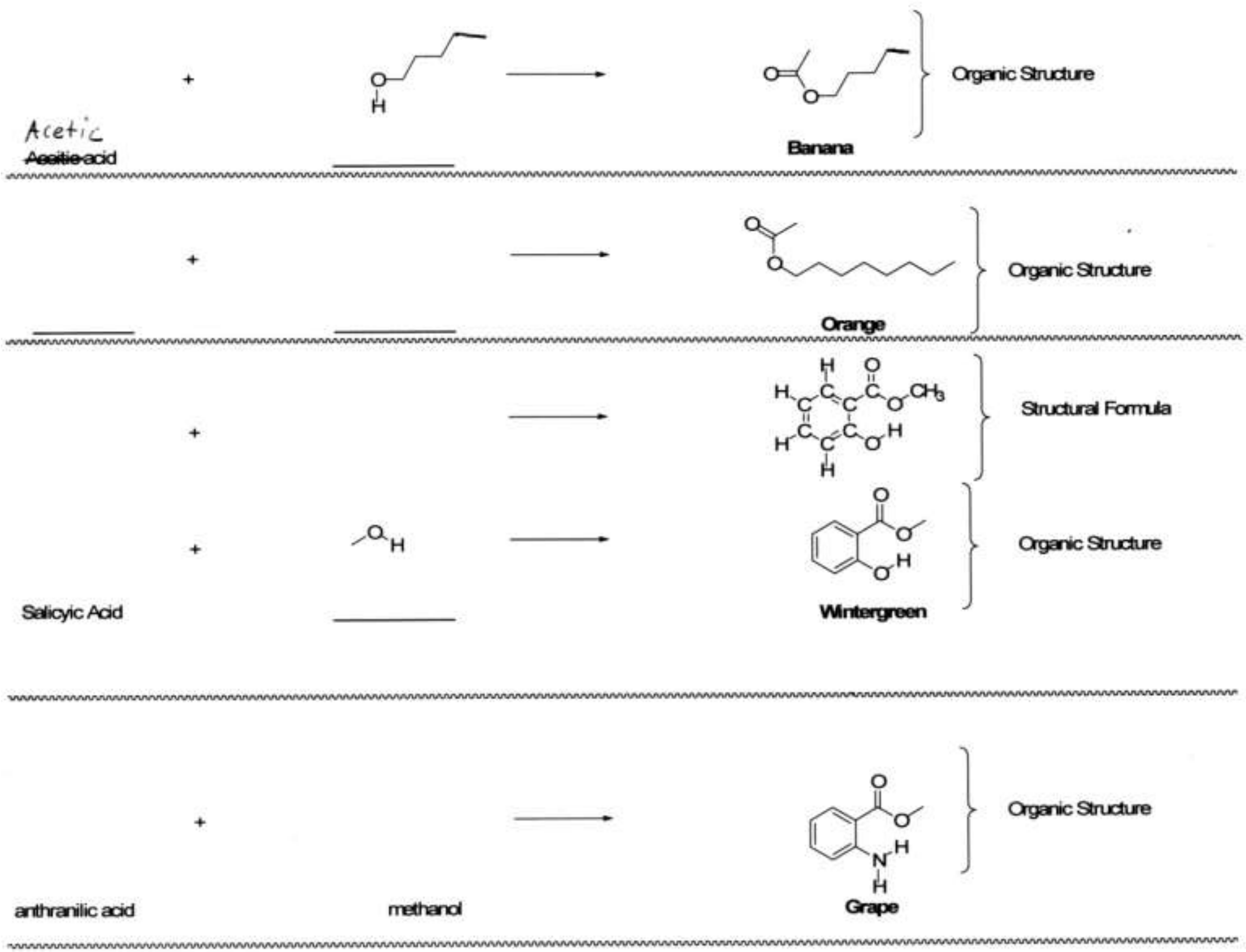
Organic Structure

______ isoamyl alcohol ~~butyl alcohol~~ **Pear**

+ → Structural Formula

Organic Structure

propionic acid butyl alcohol **Rum**

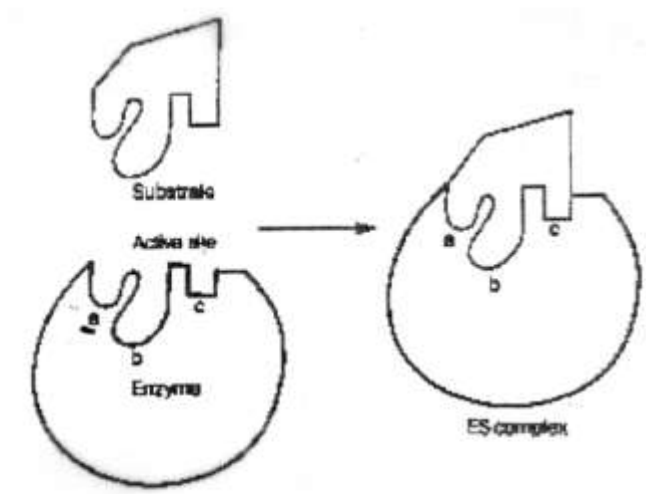

Acetic
Acetic acid
+
Organic Structure
Banana
+
Organic Structure
Orange
+
Structural Formula
+
Organic Structure
Salicyic Acid
Wintergreen
+
Organic Structure
anthranilic acid
methanol
Grape

LAB 6: Molecular Geometry

I. Purpose: In this lab, you will construct molecular models to understand their 3-D structures, and learn to visualize the shapes of molecules. You will examine the usefulness of VSEPR (valence shell electron pair repulsion) theory in predicting molecular geometries and bond angles. You will learn to draw simple projection formulas to depict the 3-D structures of molecules in 2 dimensions, and learn about structural and geometrical isomers.

Read the background and procedure IN ADVANCE so you will not be clueless when you come to class. I will not answer questions whose answers are in the text of this document!

II. Background: The shape of a molecule (molecular geometry) affects its physical properties and chemical behavior. For example, the 3-D structure of biomolecules affects their biological function: the specificity of enzyme-catalyzed reactions is due to the binding of only the particular substrate (a reactant) whose molecular geometry matches that of the active site on the enzyme.



Molecular architecture is fascinating. Some molecules are spiral, some have sheet-like structures, some are ring-shaped, and others are globular. Some structures are simple, while others are complicated. Methane, the main component of natural gas, is tetrahedral; the water molecule is V-shaped, or bent; ammonia is pyramidal. Proteins, which are macromolecules, consist of long chains of amino acids arranged in sheets and folded further into tertiary, and sometimes, quaternary structures. Regardless of the simplicity or complexity of the molecule, it is possible to deduce the <u>ideal</u> arrangement of covalent bonds around a central atom using simple guidelines provided in the VSEPR model.

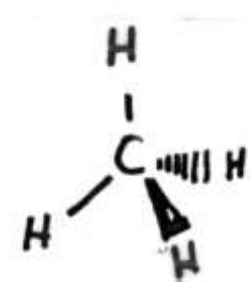
The VSEPR model is useful in predicting electronic and molecular geometries. In this model, electron pairs in a valence shell repel each other and adopt a geometry which keeps them as far apart as possible. Consequently, the geometry will depend on the number of electron pairs around the central atom. The Lewis structure for methane has four electron pairs around the central carbon atom; all are <u>bonding</u> pairs, bonded to the four hydrogen atoms. The most favorable arrangement, the one that minimizes electron-electron repulsion, is a tetrahedral one, with bond angles of 109.5˚ between the atoms.

The VSEPR model also allows one to predict the actual bond angles in a molecule or ion. The Lewis structure for water has four electron pairs around the central oxygen atom, consistent with a tetrahedral structure. However, two are <u>bonding</u> pairs (bonded to the two hydrogen atoms) and two are <u>nonbonding</u> pairs. The larger volume requirements of the nonbonding pairs force the bonding pairs closer together and cause the angle between the bonding pairs to be less than the <u>predicted</u> 109.5˚. The resulting geometry is called "V-shaped".

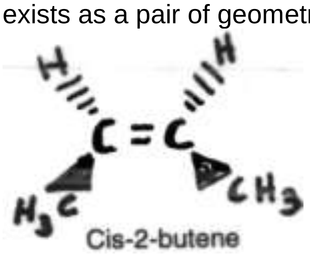
The table on the next page lists electron group arrangements and anticipated shapes of the molecules.

Total # of electron groups at central atom	# of non-bonding electron pairs	Predicted shape	Bond angles
2	0	Linear	180˚
3	0	Trigonal planar	120˚
3	1	Bent	120˚
4	0	Tetrahedral	109.5˚
4	1	Pyramidal	<109.5˚
4	2	Bent	<109.5˚
5	0	Trigonal bipyramidal	90˚ and 120˚
5	1	Sawhorse/Seesaw	90˚ and 120˚
5	2	T-shaped	90˚
5	3	Linear	180˚
6	0	Octahedral	90˚
6	1	Square pyramidal	90˚
6	2	Square planar	90˚

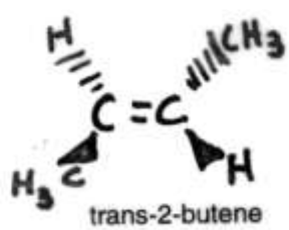
Molecular architecture can be depicted using space-filling models, ball-and-stick models, and skeletal models. In this experiment, you will work with ball-and-stick models. As you construct these models, pay close attention so that you can learn to visualize the shapes of molecules. You can also use simple projection formulas to represent on paper the 3-D structures of molecules. The methane molecule is depicted using a projection formula. The tetrahedral molecule is rotated until two of the C-H bonds are in the plane of the paper. The C-H bond pointing in front of the plane is represented using a solid wedged line, while a dashed wedged line represents the C-H bond behind the plane.



You will also construct **isomers**—compounds having the same molecular formula but different properties. *Structural isomers* differ in the sequence in which the atoms are bonded; for example, ethanol, CH_3CH_2OH, and dimethyl ether, CH_3OCH_3, are structural isomers. *Geometric isomers (cis-trans isomers)* have exactly the same sequence of bonded atoms, but differ in their spatial arrangement due to restricted rotation about a double bond (or similar structural feature). 2-Butene exists as a pair of geometric isomers.



Cis-2-butene



trans-2-butene

III.Procedure:
A significant portion of this lab will be completed as a whole-class activity during the “lecture” on molecular structure. You will work in groups of two or three, using clay and toothpicks to construct models of the various shapes. Use one color of clay to represent the central atom and another color to represent electron groups and/or substituents.
Use the table in this manual to draw the Lewis structures and to record the molecular geometry and central atom hybridization for the molecules. The background information, as tedious as it appears, will help you complete the task.

1) Create clay models of and draw the Lewis structures for the following cases:
   a) 2 electron groups around central atom
   b) 3 electron groups around central atom
   c) 4 electron groups around central atom

   Note that for these models ONLY, you do not need to record the hybridization.
2) Draw the Lewis structures and then construct models of beryllium fluoride and carbon dioxide. Use double bonds where necessary. Complete the table for each.
3) Draw the Lewis structures and then construct models of boron trifluoride and of the nitrate ion. Complete the table for each.
4) Draw the Lewis structure and then construct a model of CH_4 (methane). Complete the table.
5) In the five previous molecules, each electron pair is associated with a bond. Lone pairs affect the molecular shape but not the electron configuration. Draw the Lewis structure and construct a model of NH_3. Lone pairs are less restrained in space than bonding pairs so the bond angles will be greater between the lone pairs than between the bonded atoms. Complete the table, estimating the bond angle between the H atoms.
6) Draw the Lewis structure and then construct a model of H_2O. Complete the table, estimating the bond angle between the H atoms.
7) Create a clay model for the case of 5 electron groups around a central atom. Remember that the electron pairs should be as far as possible from each other. Given that five orbitals are required for the five electron pairs, what is the hybridization on the central atom?
8) Draw the Lewis structure and then construct a model of phosphorus pentafluoride. Complete the table; note that there are two different bond angles.
9) Replace one F atom in PF_5 to make PF_4Cl. How many isomers of PF_4Cl are possible? Draw each in the table.
10) Draw the Lewis structure and then construct a model of bromine trifluoride. Considering that the lone pairs will want to be as far from each other as possible, what is a good description of the molecular shape? Complete the table, estimating the bond angles between the fluoride atoms.
11) Draw the Lewis structure and then construct a model of I_3^-. Again considering that the lone pairs will want to be as far from each other as possible, what is a good description of the molecular shape? Complete the table, estimating the bond angles between the atoms.
12) Create a clay model for the case of 6 electron groups around a central atom. Remember that the electron pairs should be as far as possible from each other. Given that six orbitals are required for the six electron pairs, what is the hybridization on the central atom? Complete the rest of the table.
13) Draw the Lewis structure and then construct a model of sulfur hexafluoride. Complete the table.
14) Draw the Lewis structure and then construct a model of bromine pentafluoride. Where is the lone pair most likely to be- in the equatorial or the axial position? Complete the table, estimating the bond angles between the fluoride atoms.
15) Draw the Lewis structure and then construct a model of xenon tetrafluoride. Where are the lone pairs most likely to be- in the equatorial or the axial position? Complete the table, estimating the bond angles between the fluoride atoms.
16) Draw the Lewis structure and then construct a model of SF_4Cl_2, with S as the central atom. How many isomers are possible? Draw each in the table.
17) The geometry of more complex molecules may not be described by a single word (e.g. linear, bent, etc.). But it is still possible to talk about *local* geometry around a particular central atom. Draw the Lewis structure and then construct a model of the methanol molecule, CH_3OH (the formula written this way indicates that three H atoms and the O atom are bonded to the C, and the last H is bonded to the O). Clearly, the shape of this entire molecule is not accurately described by any of the words in the geometry table. Examine the model and answer the following questions:
   a) What does the Lewis structure suggest should be the H-C-H bond angle and the C-O-H bond angle?
   b) How do these compare to the H-C-H bond angle in methane and the H-O-H bond angle in water?
   c) What word best describes the arrangement of atoms around just the central carbon atom?
   d) What word describes the arrangement of atoms around the oxygen atom?
18) Draw the Lewis structure and build a model for hydrogen cyanide, HCN. What are the bond angles?
19) Draw the Lewis structure and construct a model of 1,2-dichloroethane, $ClCH_2CH_2Cl$. As you may notice, you can rotate freely about the C-C bond. The different arrangements that arise as a result of rotation about the C-C single bond DO NOT represent isomers.

a) Draw a projection formula where the C-C bond, the C-H bond on one carbon, and the C-Cl bond on the other carbon lie in the plane of the paper. Represent the other C-H and C-Cl bonds using dotted and solid wedged lines.
b) Construct a *structural isomer* of the above molecule. Draw its Lewis structure and a projection formula where the C-C bond, the C-H bond on one carbon, and the C-Cl bond on the other carbon lie in the plane of the paper. Represent the other C-H and C-Cl bonds using dotted and solid wedged lines.

20) Draw the Lewis structure(s) for $C_2H_2Cl_2$. Construct model(s). Explain why isomerism is or is not possible.

VSEPR THEORY LAB **NAME:**

Step 1. Draw the clay models of 2, 3 and 4 electron groups around the central atom:

2 electron groups:

3 electron groups:

4 electron groups:

BeF_2 **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

CO_2 **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

BF_3 **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

NO_3^- **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

CH_4 **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

NH_3 **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

H_2O **Example.**
Lewis Structure:

Hybridization:

Bond Angle Geometry:

$5\ e^-$ ***groups***
Lewis Structure:

Hybridization:

Bond Angle Geometry:

PF_5 **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

PF_4Cl **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

How many isomers can PF_4Cl have? Draw each one below:

BrF_3 **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

I_3^- **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

$6\ e^-\ groups$ Lewis Structure:	Hybridization:
Bond Angle Geometry:	

SF_6 **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

BrF_5 **Example.** Lqewis Structure:	Hybridization:
Bond Angle Geometry:	

XeF_4 **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

Where are the lone pair of electrons for BrF_5? Axial/Equitorial Positions (circle one) and explain below:

SF_4Cl_2 **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

How many isomers of SF_4Cl_2 are possible?

Methanol, CH_3OH Lewis Structure:	A. What does the Lewis Structure suggest should be the H-C-H bond angle And the C-O-H bond angle? B. How do these angles in a compare to the H-O-H bond angle in water? C. What word describes the arrangement of atoms around the central C? D. What word describes the arrangement of atoms around the oxygen?

HCN **Example.** Lewis Structure:	Hybridization:
Bond Angle Geometry:	

$ClCH_2CH_2Cl$ Work:

Prelab 7: Evaporation and Intermolecular Attractions

1. Prior to doing the experiment, complete the Pre-Lab table, found on page 69 of this manual. The name and formula are given for each compound. Draw a structural formula for a molecule of each compound. Then determine the molecular weight of each of the molecules. Dispersion forces exist between any two molecules, and generally increase as the molecular weight of the molecule increases. Next, examine each molecule for the presence of hydrogen bonding. Before hydrogen bonding can occur, a hydrogen atom must be bonded directly to an N, O, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability.

2. Answer the following questions, using complete sentences (of course!)

   a. What is the function of sweating?

   b. Where does the liquid water go when you sweat?

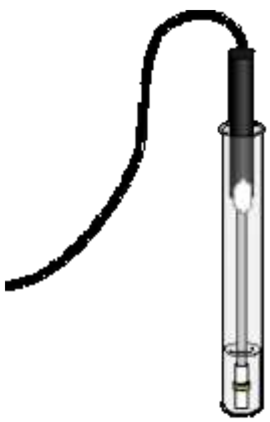
   c. What happens to the temperature of your skin when you sweat?

   d. Based on your personal experience of sweating, is evaporation endothermic (removes heat from a system)or exothermic (adds heat to a system)?

Lab 7: Evaporation and Intermolecular Attractions

In this experiment, temperature probes are placed in various liquids. Evaporation occurs when the probe is removed from the liquid's container. This evaporation is an endothermic process that results in a temperature decrease. The magnitude of a temperature decrease is, like viscosity and boiling temperature, related to the strength of intermolecular forces of attraction. In this experiment, you will study temperature changes caused by the evaporation of several liquids and relate the temperature changes to the strength of intermolecular forces of attraction. You will use the results to predict, and then measure, the temperature change for several other liquids.

You will encounter two types of organic compounds in this experiment—alkanes and alcohols. The alkane is xylene, C_8H_{10}. In addition to carbon and hydrogen atoms, alcohols also contain the -OH functional group. Methanol, CH_3OH, and ethanol, C_2H_5OH, are two of the alcohols that we will use in this experiment. You will examine the molecular structure of alkanes and alcohols for the presence and relative strength of two intermolecular forces—hydrogen bonding and dispersion forces.



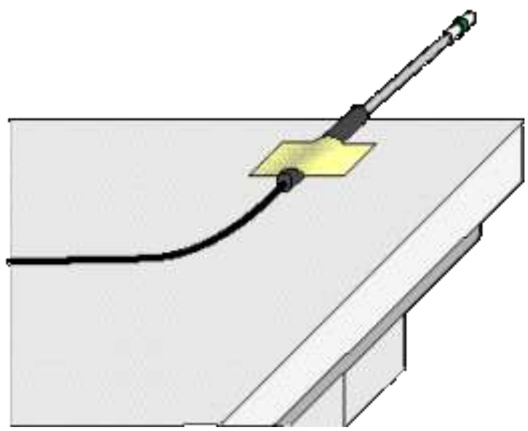


Figure 1

MATERIALS

LabPro or CBL 2 interface	methanol (methyl alcohol)
TI Graphing Calculator	ethanol (ethyl alcohol)
DataMate program	1-propanol
2 Temperature Probes	1-butanol
6 pieces of filter paper (2.5 cm X 2.5 cm)	xylene
2 small rubber bands	
masking tape	

PROCEDURE

1. **CAUTION:** *The compounds used in this experiment are flammable and poisonous. Because we are using small quantities, you do not need to wear goggles. However, avoid inhaling their vapors. Avoid contacting them with your skin or clothing. Be sure there are no open flames in the lab during this experiment. Notify your teacher immediately if an accident occurs.*

2. If necessary, plug Temperature Probe 1 into Channel 1 and Temperature Probe 2 into Channel 2 of the LabQuest.

3. Set up the LabQuest in TIME GRAPH mode to collect 80 data points, one every 3 seconds--each experiment will last 4 minutes.

4. Wrap the probes with square pieces of filter paper secured by small rubber bands or with tape as shown in Figure 1. Roll the filter paper around the probe tip in the shape of a cylinder. Hint: First slip the rubber band up on the probe, wrap the paper around the probe, and then finally slip the rubber band over the wrapped paper. The paper should be even with the probe end.

5. Set the probes with the filter paper ends over the sink. Tape in place if necessary. Simultaneously (that's why you have a lab partner) use the dropper bottles to soak the filter paper on probe 1 with ethanol and the filter paper on probe 2 with 1-propanol. The filter papers should appear to be saturated.

6. *Immediately* after soaking the filter papers, select START to begin collecting temperature data. A live graph of temperature *vs.* time for both Probe 1 and Probe 2 will be plotted on the LabQuest screen. The live readings are displayed in the upper-right corner of the graph, Probe 1 first, Probe 2 below.

7. Data collection will stop after 4 minutes. On the displayed graph of temperature *vs.* time, each point for Probe 1 is plotted with a dot, and each point for Probe 2 with a box. As you move the cursor right or left, the time (X) and temperature (Y) values of each Probe 1 data point are displayed below the graph. Based on your data, determine the maximum temperature, t_1, and minimum temperature, t_2. Record t_1 and t_2 for Probe 1.

   Switch the cursor to the curve of temperature *vs.* time for Probe 2. Examine the data points along the curve. Record t_1 and t_2 for Probe 2.

8. For each liquid, subtract the minimum temperature from the maximum temperature to determine Δt, the temperature change during evaporation.

9. Based on the Δt values you obtained for these two substances, plus information in the Pre-Lab exercise, *predict* the size of the Δt value for 1-butanol. Compare its hydrogen-bonding capability and molecular weight to those of ethanol and 1-propanol. Record your predicted Δt, then explain how you arrived at this answer in the space provided. Do the same for xylene. It is not important that you predict the exact Δt value; simply estimate a logical value that is higher, lower, or between the previous Δt values.

10. Test your prediction in Step 9 by repeating Steps 6-8 using 1-butanol with Probe 1 and xylene with Probe 2. You can reuse the filter paper if the probe temperature has returned to its initial temperature, meaning that the liquid has evaporated completely.

11. Based on the Δt values you have obtained for all four substances, plus information in the Pre-Lab exercise, predict the Δt value for methanol. Compare the hydrogen-bonding capability and molecular weight of methanol and xylene to those of the previous four liquids. Record your predicted Δt, then explain how you arrived at this answer in the space provided.

12. Test your prediction in Step 11 by repeating Steps 6-8, using methanol with Probe 1 and xylene with Probe 2.

PRE-LAB TABLE

Substance	Formula	Structural Formulas	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C_2H_5OH			
1-propanol	C_3H_7OH			
1-butanol	C_4H_9OH			
methanol	CH_3OH			
Xylene	C_8H_{10}			

DATA TABLE

Substance	t_1 (°C)	t_2 (°C)	Δt ($t_1 - t_2$) (°C)
ethanol			
1-propanol			
1-butanol			
methanol			
xylene			

Predicted Δt (°C)	Explanation

PROCESSING THE DATA

1. Which of the *alcohols* studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain using the results of this experiment.

2. Which of the alcohols studied had the closest Δt to that of xylene? Explain, based on your understanding of intermolecular forces and using the results of this experiment.

3. Plot a graph of Δt values of the four alcohols versus their respective molecular weights. Plot molecular weight on the horizontal axis and Δt on the vertical axis. What trend do you observe?

PRELAB 9: Alchemy--Can You Turn Copper to Gold?

1. What is an alloy?
2. Which two metals comprise the alloy you are making?
3. In this lab, are you making an interstitial or a substitutional alloy?

LAB 9: Alchemy--Can You Turn Copper to Gold?

I. Purpose: In this lab you will make an alloy, but it will look as if you have turned copper into gold.

II. Materials

Hot plate	Forceps
Evaporating dish	Steel wool
~ 1 gram NaOH (9 pellets)	0.2 g zinc dust
Penny (US currency, 1982 or earlier)	Bunsen burner

III. Safety: Wear safety goggles at all times. Sodium hydroxide is caustic and corrosive. Avoid contact and rinse spills immediately with copious amounts of water.
It is not necessary to perform this experiment under a hood because solutions should not be heated to the boiling point.

IV. Procedure

1. Dissolve the NaOH in 5 mL of water, and pour the solution into an evaporating dish.
2. Add 0.2 g of zinc dust to the NaOH solution.
3. Heat the mixture on a hot plate to just below the boiling point.
4. Meanwhile, clean a penny with steel wool (removes surface oxides).
5. Keep the evaporating dish on the hot plate, and use forceps to immerse the penny into the solution for about 1 minute, or until the penny turns silver on BOTH sides.
6. Again using forceps, remove the penny from the bath, rinse with water and pat dry with a paper towel.
7. Light the Bunsen burner. Grab the penny with the forceps and pass it briefly over the outer cone of the flame. The zinc metal coating on the penny will diffuse into the copper when you apply heat, and the coating will turn brassy yellow. Remove from the heat as soon as you see this happen—do not overheat! Cool the penny in water immediately and dry it.

WASTE DISPOSAL: Dilute the liquid remaining in the evaporating dish. Pour the solution AND the zinc into the container (funnel, filter paper and beaker) on the front desk; use additional water if necessary. The solution will be neutralized for final disposal. If anything catches on fire, you lose 10 points!

V. Conclusion/Analysis: In a coherent paragraph, provide a summary of the chemical operations you performed. Was the silver color an alloy formation or a plating process? What was the purpose of heating the penny in the Bunsen burner?

Break up to Make up….BONDS  

(AKA: the energy change in making H_2O)

I. Purpose: to observe what happens when making and breaking bonds

II. Materials:

a. 2 test tubes, 15 x 125 ml
b. 2 rubber stoppers, one-holed
c. Mossy Zinc, yeast, 3M HCl, 3% H_2O_2
d. 1 rocket (plastic pipette bulb)
e. launch pad and Tesla coil

III. Safety: Wear safety glasses because you're handing acid, and in case of misfires

IV. Calculations, part 1

a. Write a balanced equation for the formation of 1 mole water from hydrogen and oxygen.
b. Calculate the ΔH (enthalpy) of the reaction using the bond energy method and the bond energies in your lab manual. Indicate whether the reaction will be endothermic or exothermic.
c. The volume of the rocket is 5 ml. Recall that 1 mole of gas occupies 22.4 L, and calculate the total number of moles of gas the rocket can hold.
d. Determine how many moles of H_2 you will need, and how many moles of O_2 you will need, to react completely to form water.

V. Procedure

a. Fill the rocket with water.
b. Partner one: Add a pinch of yeast to a test tube, then half-fill the tube with H_2O_2 and stopper immediately. Place the rocket into the stopper hole and collect as much O_2 as you believe you need, based on calculation (d) above. The gas will displace the water in the rocket.
c. Partner two: Add a piece of mossy Zn to a test tube. When partner one has completed collecting O_2, half-fill the tube with HCl and stopper immediately. Place the rocket into the stopper hole and collect as much H_2 as you believe you need, based on calculation (d) above.
d. QUICKLY take your rocket to the front table and place on the launching pad. Initiate liftoff with the Tesla coil.
e. Collect your rocket and clean up all materials. The O_2 generation materials can go into the sink; put the mossy zinc into the solid waste beaker at the lecture table.

VI. Calculations, part 2

a. How many moles of H_2O did you make?
b. What was the enthalpy for this reaction?
c. How much is this energy in calories?
d. How many food calories is this?
e. Hand in!

Aladdin's Lamp
(decomposing H_2O_2 to H_2O and O_2)

50 ml of 30% H_2O_2(l) (the rest is water) is placed into the flask along with a catalyst. First the H_2O_2 decomposes into H_2O(l) and O_2(g). At this point, the mixture contains the water initially present PLUS water produced by the decomposition reaction. Then some of the water is converted to steam (H_2O(g)).
Useful data:

ΔHf	**Kcal/mole**
H_2O_2	-45.69
H_2O(l)	-65.32

1. Find the ΔH for the decomposition of H_2O_2(l).

2. Calculate the initial mass of pure H_2O_2(l) in the flask. Assume its density is the same as water's.

3. Calculate the amount of energy released by the decomposition of H_2O_2(l).

4. How many moles of water are made in the reaction? How many grams of water?

5. How much energy is needed to take ALL the water to its boiling point? (recall that the specific heat of liquid water is 1.00 cal/g-C)

6. How much energy is then left over to convert the liquid water to steam?

7. Since ΔHv of water is 585 cal/g, how much steam can you make?

8. What is the volume of steam produced? (PV=nRT, R = 0.08206 L-atm/mol-K) Is it greater than the volume of the flask?

PRELAB 10: Thermochemistry Calculations

Consult your notes to complete these calculations!! Show your work, with all units included, for full credit.

To determine the enthalpy of formation of CaO(s), ΔH°_f, one step in the procedure involves the reaction of CaO(s) with water to form slaked lime, $Ca(OH)_2$:

$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$ $\Delta H = ?$

A 1.00 g sample of CaO(s) was dissolved in 100. ml of water to give a solution with a density of 1.00 g/ml. A temperature rise of 3.70°C was measured. The specific heat of the solution was 4.00 J/g•deg.

1. Is heat absorbed or given off in this reaction?

2. Using the temperature change information given above, calculate the quantity of heat (in joules) absorbed or given off when 1.00 g of CaO is dissolved in water.

   Q = ___________________________J (what is the algebraic sign of "q"?)

3. Based on the result of step (2), what quantity of heat (in kJ) will be absorbed or released if 1.00 mol of CaO is dissolved in water?

   Q = ___________________________kJ/mole (what is the algebraic sign of "q"?)

4. Based on your answer in step (3), give the molar enthalpy, ΔH, for the reaction of CaO(s) with water.

LAB 10: Heat of Combustion: Magnesium  

I. Introduction: In this experiment, you will use Hess' law as you determine a heat of reaction that would be difficult to obtain by direct measurement—the heat of combustion of magnesium ribbon. The reaction is represented by the equation

(4) $Mg(s) + 1/2\ O_2(g) \longrightarrow MgO(s)$

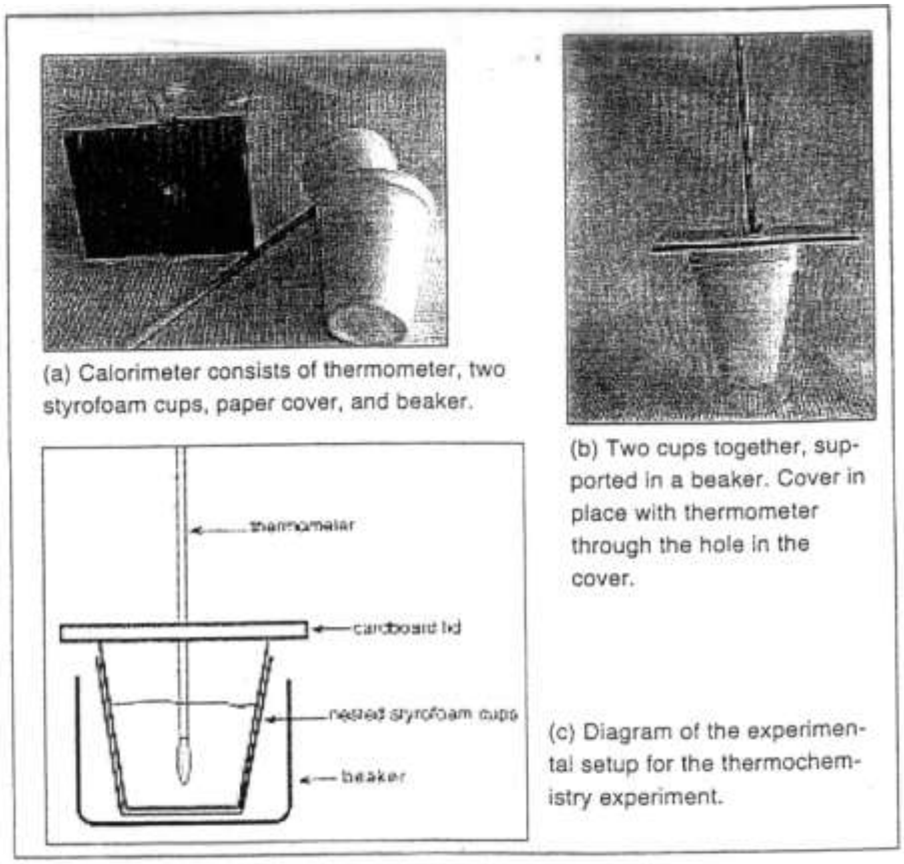
This equation can be obtained by combining equations (1), (2), and (3):

(1) $MgO(s) + 2\ HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$

(2) $Mg(s) + 2\ HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

(3) $H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l)$

Before you begin the experiment, combine equations (1), (2), and (3) to obtain equation (4). This should be in the data table. Heats of reaction for equations (1) and (2) will be determined in this experiment. ΔH for reaction (3) is -285.8 kJ.



(a) Calorimeter consists of thermometer, two styrofoam cups, paper cover, and beaker.

(b) Two cups together, supported in a beaker. Cover in place with thermometer through the hole in the cover.

(c) Diagram of the experimental setup for the thermochemistry experiment.

Figure Equipment and setup for the thermochemistry experiment.

II. MATERIALS:

250-mL beaker	
magnesium oxide, MgO	100-mL graduated cylinder
magnesium ribbon, Mg	Two Styrofoam cups
balance	
timer or watch with a second hand	Thermometer OR LabQuest with temperature probes
1.00 M HCl	

III. PROCEDURE

1. Obtain and wear safety glasses and an apron. Set up a data table for each reaction to measure temperature versus time.

Reaction 1

2. Set up a coffee cup calorimeter as shown in figure 1.
3. Measure out 100.0 mL of 1.00 M HCl into the Styrofoam cup. Lower the thermometer into the solution, making sure that you can read the scale from room temperature up. **CAUTION:** *Handle the HCl solution with care. It can cause painful burns if it comes in contact with the skin.*
4. Weigh out about 1.00 g of magnesium oxide, MgO, on a piece of weighing paper. Record the exact mass used in your data table. **CAUTION:** *Avoid inhaling magnesium oxide dust.*
5. Record the initial temperature in your data table. Add the white magnesium oxide powder to the solution and swirl the container gently. Record the temperature every 30 seconds, until the temperature has held constant or decreased for three consecutive readings.

6. Pour any liquid down the drain with lots of water, and discard any remaining solids in the trash.

Reaction 2

7. Follow the same procedure outlined in steps 2-6, using about 0.50 g of magnesium ribbon rather than magnesium oxide powder. The magnesium ribbon has been pre-cut to the proper length by your teacher. Be sure to record the measured mass of the magnesium. **CAUTION:** *Do not breathe the vapors produced in the reaction!*

☞ IF YOU GET THE SAME ΔT FOR BOTH REACTIONS, RUN ONE OF THEM AGAIN!

IV. PROCESSING THE DATA: SHOW YOUR WORK FOR CREDIT

1. Prepare a plot of temperature versus time for both reactions. Calculate the change in temperature, ΔT, for both.

2. Calculate the heat released by each reaction, q, using the formula

$$q = C_p \cdot m \cdot \Delta T$$

   C_p = 4.18 J/g°C, and m = 100.0 g of HCl solution. Convert joules to kJ in your final answer.

3. Determine ΔH. (ΔH = -q)

4. Determine the moles of MgO and Mg used.

5. Use your Step 3 and Step 4 results to calculate H/mol for MgO and Mg.

6. Determine ΔH/mol Mg for Reaction 4. (Use your Step 5 results, your pre-lab work, and ΔH = -285.8 kJ for Reaction 3).

7. Determine the percent error for the answer you obtained in Step 6. The accepted value for this reaction can be found in a table of standard heats of formation.

V. DATA AND CALCULATIONS

	Reaction 1 (MgO)	Reaction 2 (Mg)
1. Volume of 1.00 M HCl	ml	ml
2. Final temperature, T_2	°C	°C
3. Initial temperature, T_1	°C	°C
4. Change in temperature, ΔT	°C	°C
5. Mass of solid	g	g
6. Heat, q	kJ	kJ
7. ΔH	kJ	kJ
8. Moles	mol MgO	mol Mg
9. ΔH/mol	kJ/mol	kJ/mol

10. Determine ΔH/mol Mg for reaction (4)*.

(1) ____ __________

(2) ____ __________

(3) ____ __________

(4)* ____ __________

11. Percent error kJ/mol

LAB 11: Serial Dilution

I. Purpose: This exercise is to familiarize you with the process of serial dilution to make solutions of known concentration, and with using scientific notation to express large and small concentrations.

II. Materials

FD&C Red Dye #40 (Allura Red, 496.2 g/mol)
small test tubes and rack OR transparency sheet OR well plate

Dropper pipette	Water
Crucible	Ring stand and Bunsen burner OR hot plate

III. Safety: Don't drink the solutions. The dye may stain your skin, so if you get any on you, wash off immediately.

IV. Procedure

1. Set up a table with a space for recording dilution number, color intensity, and concentration. Put 10 drops of the dye into the first location (test tube, spot on transparency sheet, well). The concentration of this 100% solution can be designated as "1X."
2. Take one drop of 1X and add it to the well next to the first one. Add 9 drops of water to this single drop.
3. This second well now contains 10 drops of liquid (one of dye, 9 of water). This is the "0.1X" solution.
4. Repeat the dilutions until you can barely see the red dye in the wells. Record the concentrations (as 1X, 0.1X, 0.001X, etc.) of each dilution you make and note the color intensity.
5. Mass the crucible and record. Now make one more dilution into the crucible so that you can no longer see any dye color. Since you can't see the dye, does that mean there IS NO dye in the dilution? The following steps will help you decide.
6. Mass the crucible and the diluted dye solution and record.
7. Using the hot plate or Bunsen burner, heat the crucible until all the water evaporates, leaving behind any dissolved substances. Remove from the heat and let cool. Check mass until two consecutive readings are within ± 0.005 g.

V. Calculations:

1. Calculate the mass % of dye in the final dilution.
2. Calculate the theoretical number of molecules in the final dilution, making the following assumptions:
    - 10 drops of the 100% solution has a mass of 0.35 gram.
    - 1 gram of dye contains approximately 1.2×10^{21} molecules.

   HINT: your first dilution has 1/10 the number of molecules as in the original, 100% solution.
3. Calculate the actual number of molecules in the final dilution, using the weight of residue from procedure step (7), above.
4. How different is the actual number of molecules from the theoretical (what is your % error?)?

LAB 12: The Concentration of Acetic Acid in Vinegar

I. Purpose. Commercially available white vinegar is actually a solution of acetic acid, diluted with water to an agreed-upon volume percent. In this lab, you will determine the concentration and weight percent of acetic acid in vinegar.

Read the procedure IN ADVANCE and prepare a data table (straight lines drawn with a ruler) to record the data you will be collecting. You will be graded on how close your result is to the manufacturer's label, so proceed carefully!

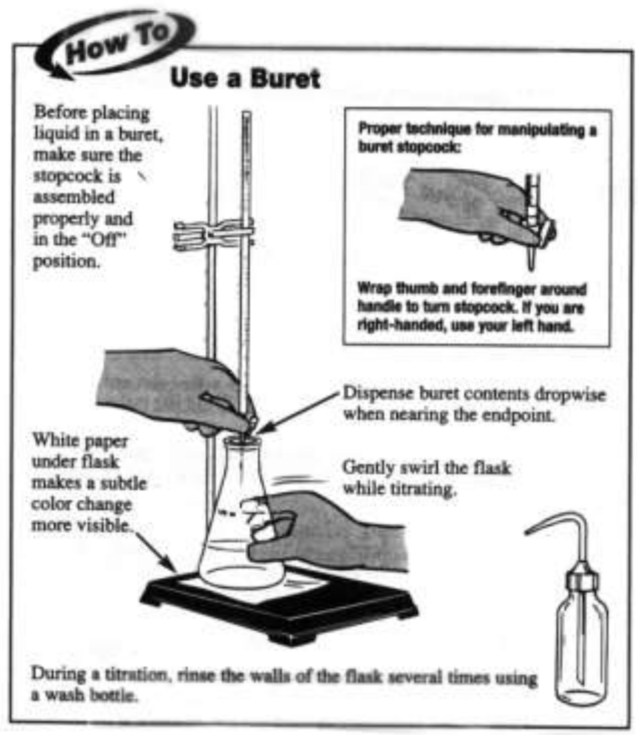
II. Safety. Vinegar is not a hazardous substance but avoid contact with your eyes. Sodium hydroxide solution is corrosive; if you get any on your skin, wash with lots of water until your skin no longer feels slippery. If you get any in your eyes, proceed directly to the eyewash. Phenolphthalein indicator has a laxative effect; don't drink it.

III. Equipment.

50-mL burette and stand	100-mL graduated cylinder
250-mL Erlenmeyer flask	150-mL or 250-mL beakers
burette funnel	wash bottle

IV. Procedure.

1. Using a clean 250-mL Erlenmeyer flask, obtain about 10 mL of vinegar from the buret at the lecture table. You do not have to use exactly 10.00 mL, but you must record the amount of vinegar you DO use to the 0.01 mL place. Add about 50 mL of deionized water and 3 drops of indicator solution, and swirl to mix.
2. Obtain about 100 mL of the standard sodium hydroxide solution in a clean, dry beaker. Record the molarity of the solution. Rinse a clean burette with a small portion of the standard NaOH solution, then use the funnel to fill the burette to a point near the zero mark. Remove the funnel before going any further. Slowly drain enough of the NaOH solution into a waste beaker to ensure that the tip of the burette is filled and that no air bubbles are present in the tip.
3. Record the initial volume reading to the nearest 0.01 mL. Titrate the acid sample, swirling constantly, to the indicator endpoint. The color change should persist for 30 seconds (it will eventually fade). Record the final burette reading to the nearest 0.01 mL.
4. Repeat with a second sample of vinegar. Refill the burette only as necessary, because unused NaOH solution must be discarded-it cannot be returned to the reagent bottle.
5. All solutions can be washed down the sink.



V. Calculations

- Write the *molecular* and *net ionic* equations for the reaction of acetic acid and NaOH to determine the mole ratio
- Find the molarity of each vinegar solution you titrated
- Find the average molarity

- Calculate the grams of acetic acid present in 100 mL of the original solution; this is the % concentration of the vinegar reported on the side of the vinegar bottle.

VI. Conclusion. State your results in one sentence. You will lose points if you ramble.

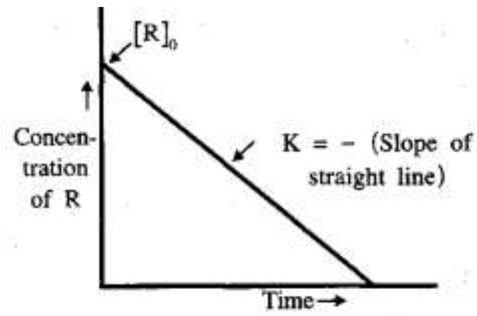
VII. Analysis. Explain how the calculated molarity of acetic acid would be affected by each of the following mishaps; be as specific as possible in explaining your answer (ie, use math).

1. If the tip of the burette was not filled with sodium hydroxide before the initial volume reading was recorded.
2. If a few drops of solution splashed out of the Erlenmeyer flask during the titration.
3. If the wet burette was not rinsed with sodium hydroxide before filling.
4. If the volume of water added to the Erlenmeyer flask was slightly larger than 50 mL.

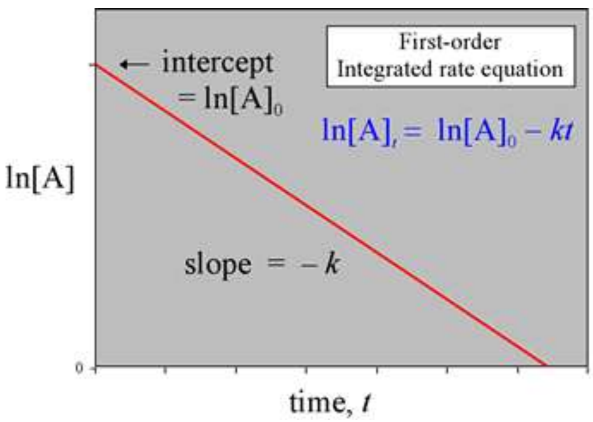
Prelab 13: Rates of Chemical Reactions

Consider the reaction A+B → C. Use this generic reaction to answer the following questions.

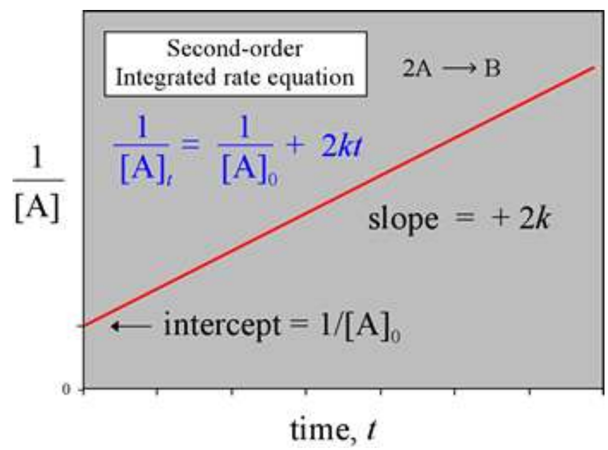
1. If a rate is NOT DEPENDENT on the concentration of a reactant, a plot of initial reactant concentration versus reaction time is a straight line with a negative slope. What you will observe experimentally is that increasing the concentration of reactants does not affect the rate of reaction. Write the rate law for such a reaction.



6.3 The change in concentration of reactant with time for zero order reaction.



2. If a rate is dependent on the concentration of one reactant to the **first** power, a plot of ln[reactant] vs reaction time will be a straight line with a negative slope, as illustrated to the left. Write one possible rate law for such a reaction.



3. If a rate is dependent on the concentration of one reactant to the **second** power, a plot of 1/[reactant] vs reaction time will be a straight line with a positive slope, as illustrated to the right. Write **two** possible rate laws for such a reaction.

4. Is it possible to write a rate law just by looking at the equation of the reaction? Why or why not?

5. What does it mean when a reaction order is negative?

Lab 13: Rate of Chemical Reactions  

I. Purpose: In this lab you will observe the effect of varying the temperature of a reaction and the concentrations of a reactant on the rate (speed) of the reaction. You will derive an equation that allows you to predict the effect of changing reactant concentration on the reaction rate, the rate law.

II. Materials:

Part A:

Equipment	Chemicals in burette
2-10mL graduated cylinder	Distilled water
2 large test tubes, 1 test tube rack	0.02 M KIO_3 (potassium iodate)
Stop watch	0.02 M $NaHSO_3$ (sodium hydrogen sulfite) + 4% starch, 2.5 ml conc. H_2SO_4/liter

Part B:

250 ml beaker   ice or hot plate   thermometer

III. Safety: Rinse off any chemicals immediately, or you will turn into a frog. Wear safety goggles at all times!

IV. Procedure

Part A: The effect of varying concentration on reaction rate

8. Examine data table A carefully. You will perform a total of 4 experiments. You will vary the amounts of reactants as indicated in the table. *It is vital that you clean the test tubes (tt) well between experiments, or your results will be bizarre.*
9. Using a clean tt, add from the burette the amount of KIO_3 solution indicated for the experiment number (1-4, from 4 ml to 10 ml).
10. Add from a burette the amount of distilled water indicated for the experiment number (1-4, from 6 ml to 0 ml). Add to the tt containing KIO_3 and set aside.
11. Using a second clean tt, add from the burette 10 ml of $NaHSO_3$ solution.
12. Using a stop watch or a watch with a second hand, start timing as soon as you add the $NaHSO_3$ to the KIO_3. Pour back and forth between the tts three times to obtain uniform mixing.
13. Place the tt containing the mixed solutions into the tt rack and watch carefully. Stop the timer at the first sign of a reaction. In data table A, record the time elapsed for each experiment.

	ml KIO_3	ml H_2O	ml $NaHSO_3$	Time to rxn (sec)	Initial [KIO_3]	Initial [$NaHSO_3$]
1	4	6	10		0.004	0.010
2	6	4	10		0.006	0.010
3	8	2	10		0.008	0.010
4	10	0	10		0.010	0.010

Part B: The effect of varying temperature on reaction rate

1. Examine data table B carefully. Each group will perform the reaction at an assigned temperature. You will run your reaction TWICE. Your group letter designation will determine the temperature you use. You will obtain data for the other temperatures from your classmates. All initial concentrations will be the same for the temperature tests.
2. In one tt place 4 ml of the KIO_3 solution and 6 ml of H_20.
3. In the second tt, place 10 ml of the $NaHSO_3$ solution.
4. Fill a 250 ml beaker two-thirds of water and bring the water to your assigned temperature, using ice or a hot plate as necessary.

5. When the water bath is at the correct temperature, place the tts in the bath and allow to stand for 10 minutes, until the tts are also at the correct temperature.
6. Mix the solutions and note the time to observe a change as with part A. Keep the mixed solution in the bath during the reaction.
7. Repeat the experiment to confirm your results.
8. Record your results on the whiteboard. Make sure to record results from other groups in your lab book!

Group	Temp., ˚C	ml KIO_3	ml H_2O	ml $NaHSO_3$	Time to rxn (sec)	Initial $[KIO_3]$	Initial $[NaHSO_3]$
A	5	4	6	10		0.004	0.010
B	15	4	6	10		0.004	0.010
C	25	4	6	10		0.004	0.010
D	35	4	6	10		0.004	0.010

V. Calculations

Part A:

1. Following the procedure you learned in class, calculate the rate of each reaction, assuming that when the reaction is complete, all the KIO_3 is used up { $[KIO_3]$ = 0.0M.}
2. Make THREE plots:
   a. $[KIO_3]$ vs reaction time
   b. $\ln[KIO_3]$ vs reaction time
   b. $1/[KIO_3]$ vs reaction time

Which plot gives the best fit to a straight line? Refer to the prelab information to determine the order of the reaction with respect to $[KIO_3]$—zero, first or second.

3. Find k, the rate constant, from the slope of the plot with the best fit to a straight line. Include appropriate units.

SHOW ALLYOUR WORK!

Part B:

1. Plot the rate (M-sec^{-1}) versus temperature. Draw the best-fit straight line between the points.
2. Pick a temperature and find the corresponding rate from the line.
3. Pick a temperature 10˚C higher than the temperature you chose in (2) and find the corresponding rate from the line.
4. Divide: $\frac{\text{Rate at (T + 10˚C)}}{\text{Rate at T}}$ What is the ratio?

VI. Conclusion: Use the following paragraph as a guide for what information must be included.

Based on our data from part A, the rate law for the reaction is ___________________and the k is ______________. The variable(s) that were held constant for this part of the work were _____ _____. Changing temperature also affected the rate of reaction. Increasing the temperature 10˚C ___________ the reaction rate.

LAB 14: Equilibrium and LeChatelier's Principle

I. Introduction/Purpose: LeChatelier's Principle is as follows: If an equilibrium system is subjected to a stress, the system will react to remove the stress. To remove a stress, a system will form more products, using up reactants; or reverse the reaction and form more reactants, using up products. In this experiment you will form several equilibrium systems. Then, by putting different stresses on the systems, you will observe how equilibrium systems react to a stress.

II. Data Table: Start out by preparing a full-page, five column data table with nice straight lines. In the first column, write the equation for the equilibrium system to be observed. In the second, write a synopsis of the stress you will put on the system. You want to prepare an equilibrium system and then shift it both right and left (extra points for coming up with more ways to shift the system, given the material list). In the third, predict what you will observe when you stress the system in the indicated manner and **why**. During the lab, you will record what you observe when you actually stress the system. In the "conclusion" column, note if your prediction was confirmed. If it was not, explain why. **This table will be all that is graded for the lab.** An example (not from this lab, sorry!) is shown below:

Reaction	Stress	Prediction	Observation	Conclusion
1. $MgCl_2(s) \leftrightarrow Mg^{+2}(aq) + Cl^-(aq)$	a. Add HCl (Cl^- ions) b. Add MgO	a. Shift left because product added; $MgCl_2$ ppt out b. Shift left because product added; $MgCl_2$ ppt out	a. Solid formed ($MgCl_2$) b. no effect	a. Prediction correct b. Prediction incorrect; MgO not soluble

III. Materials: This lab is set up with a station for each system to be observed. You will move from station to station to test the various systems. The chemicals and equipment at each station are:

Station	Chemicals	Equipment
1	Saturated solution of sodium chloride, NaCl(s) Hydrochloric acid, HCl, 12 M Distilled water Baking soda (for acid spills)	13 x 100-mm test tube funnel rubber stopper
2	Bromthymol blue indicator solution (HIn) Hydrochloric acid, HCl, 0.1 M Sodium hydroxide, NaOH, 0.1 M Distilled water Baking soda (for acid spills) Vinegar (for base spills)	Test tube Rubber stopper
3	Potassium thiocyanate, KSCN, 0.002 M Iron(II) nitrate, $Fe(NO_3)_3$, 0.2 M Potassium thiocyanate, KSCN(s) Disodium hydrogen phosphate Distilled water	4 test tubes spatula rubber stopper
4	Cobalt(II) chloride, $CoCl_2 \bullet 6H_2O(s)$ Ethanol, $C_2H_5OH(l)$ Hydrochloric acid, HCl, 12 M Silver nitrate, $AgNO_3$, 0.1M Baking soda (for acid spills)	10- or 25-ml graduated cylinder 50-ml beaker 3 test tubes rubber stopper spatula stirring rod
5	Sealed pipet containing ethanolic cobalt(II) chloride solution	Hot plate Thermometer 250-ml beaker w/ 60°C water Ice bath in 250-ml beaker

IV. Safety: Concentrated HCl is hazardous. Its vapors are irritating and it can cause chemical burns upon contact with skin. Wash spills off yourself with lots of water, and neutralized spills on the lab bench with baking soda. Neutralize spills of 0.1 M NaOH with vinegar.
Ethanol is flammable and must not be used around open flames.
Wear safety glasses over your eyes (i.e., not around your neck or on top of your head) when handling chemicals.

V. Procedure

1. **Equilibrium in a Saturated Solution.**
   You will investigate the equilibrium in saturated sodium chloride solution:

   $NaCl(s) \leftrightarrow Na^{+}(aq) + Cl^{-}(aq)$

   You have before you a saturated solution of NaCl. Fill a test tube about ½ full with the solution. Add some Cl^{-} ions in the form of concentrated HCl. How can you shift the equilibrium right? Write your idea down and try it. Record your observations and conclusions as described in "data table," above.

2. **An Acid-Base Indicator Equilibrium.**
   Acid-base indicators are large organic molecules that can gain and lose hydrogen ions to form substances that have different colors. The reaction of the indicator bromthymol blue can be illustrated as follows:

   $HIn(aq) \leftrightarrow H^{+}(aq) + In^{-}(aq)$
   Yellow Blue

   In this reaction, HIn is the neutral indicator molecule, and In^{-} is the indicator ion after the molecule has lost a hydrogen ion. Equilibrium reactions can easily be forced to go in either direction. Reactions like this are said to be reversible.

   Fill a small test tube about half-full of distilled water. Add several drops of bromthymol blue indicator solution. Add 5 drops of 0.1 M HCl and mix. Note the color of the indicator.

   Next add 0.1 M NaOH drop by drop with stirring until no further color change occurs. Again, note the color. See if you can add the right amount of acid to this test tube to cause the solution to be green in color after it is stirred-at this point in the system, half of the indicator is blue and half is yellow.

3. **A Complex Ion Equilibrium.**
   An equilibrium system can be formed in solution with the following ions:

   $Fe^{+3}(aq) + SCN^{-}(aq) \leftrightarrow FeSCN^{+2}(aq)$
   Colorless colorless red-brown

   The iron ion (Fe^{+3}) and the thiocyanate ion (SCN^{-}) are both colorless; however, the ion that forms from their combination, the $FeSCN^{+2}$ ion, is colored a dark red-brown. It is the color of this ion that will indicate how the equilibrium system is being affected.

   Fill each of the 4 test tubes about half full with distilled water. Add 2 drops of the KSCN solution to each test tube. Then add 1 drop of the $Fe(NO_3)_3$ solution to each.

   The first test tube will be your control; the other three will be used to observe the effect of stressing the equilibrium system that you have prepared.has resulted in three ways.

   To the second test tube add 2-3 crystals of solid KSCN and record the results in your data table.

To the third test tube add 2 drops of $Fe(NO_3)_3$ solution. Stopper, shake, and record the results.

To the fourth test tube add several crystals of Na_2HPO_4, a few at a time. Stopper, shake, and record the results. What is being precipitated out of solution? Look to your solubility rules for an explanation.

4. **An Equilibrium with Cobalt Complex Ions (Concentration).**
In this section we will investigate the equilibrium between two different complex ions of cobalt. The reaction is endothermic:

$Co(H_2O)_6^{+2}(aq) + 4Cl^-(aq) \leftrightarrow CoCl_4^{-2} + 6H_2O(l)$ $\Delta H = +50$ kJ/mole
Pink blue

Measure about 10 ml of ethanol in a beaker.

Examine solid cobalt(II) chloride, noting both its color and the formula of the compound. Dissolve a small amount of cobalt(II) chloride (about half the size of a pea) in the beaker of ethanol. The solution will be blue. Add water, a few drops at a time, until the solution is purple. If you add too much water and the solution turns pink, add a little concentrated HCl until it is purple. This is your initial system. Equally divide the solution among three test tubes.

The first test tube will be the control. To the second test tube, add 5 drops of concentrated HCl, 12 M, one drop at a time with stirring. Note the results.

To the third test tube, add 5 drops of 0.1M $AgNO_3$ solution. A precipitate forms. What is its composition? Do you observe a color change?

5. **An Equilibrium with Cobalt Complex Ions (Temperature).**
Obtain a sealed pipet containing some of the alcoholic cobalt chloride-water system. Note its color. Immerse the large end of the pipet in some hot water (about 60˚C) and see if there is a color change.

Lastly, chill the pipet in an ice bath to see if the color change in the previous step is reversible.

POSTLAB 14: Equilibrium and LeChatelier's Principle

Use examples from the lab to answer the following questions:

1. What happens when you add product to a system at equilibrium?
2. Once a system is at equilibrium, what is one way to remove product?
3. What happen when you add reactant to a system at equilibrium?
4. Once a system is at equilibrium, what is one way to remove reactant?
5. At equilibrium, are there always more products than reactants?

Lab 15: The Effectiveness of Various Antacids

Purpose: To determine the effectiveness of various antacids.

Background: Commercial antacids work to relieve indigestion and heartburn by neutralizing stomach acid. These products can contain one or more of a variety of substances that react with the hydrochloric acid found in gastric juice, thereby relieving symptoms. Ingredients commonly found in these products include calcium carbonate, $CaCO_3$; magnesium hydroxide, $Mg(OH)_2$; and aluminum hydroxide, $Al(OH)_3$.
In this experiment, you will be given two or more antacid products and 0.10 M HCl (to simulate stomach acid). Design an experiment to determine which of the products is the most effective in neutralizing stomach acid.

Procedure: NOTE: Consult safety information and obtain teacher approval before beginning the experiment. Design an experiment to determine which of the antacid products is most effective in neutralizing stomach acid, noting the following:

- Record the active ingredients and recommended dosage for each antacid product.
- Solid tablets should be crushed in a mortar and pestle with 10 ml of water before beginning.

Safety:

1. Contact with hydrochloric acid can cause severe burns. If contact occurs, wash the area immediately with water for 15 minutes and notify the instructor. Contact with the eyes can cause permanent damage. If contact with the eyes occurs, use an eyewash for 15 minutes and call for an ambulance.
2. Always wear safety goggles when handling acid.
3. After reviewing your procedure, the teacher will discuss any safety precautions specific to your experiment.

Questions for further thought:

1. Write a balanced equation for the reaction of each active ingredient with HCl.
2. Why do some people who do not suffer from indigestion regularly take antacids?

Write up: A grading rubric is on the next page. Your write-up will need to include: your hypothesis as to which product will be more effective; your procedure and an explanation of any changes you made to your original; your data and/or observations; complete calculations; a conclusion stating your results; an analysis explaining whether your conclusion supported your hypothesis and any possible errors you may have experienced; and how you think you may be able to avoid them if you were to do the lab again. You must also answer the questions!

Available Materials:

Antacids	0.1 M HCl	bromthymol blue indicator
Buret	ring stand	mortar and pestle
Distilled water	250-ml beaker	stirring rod

Lab 15 Report : The Effectiveness of Various Antacids

CATEGORY	4	3	2	1
Experimental Hypothesis	Hypothesis is an "if-then" statement relating strength of antacid to its chemical characteristics.	Hypothesis relates the strength of antacid to its chemical characteristics, but is not an "if-then" statement.	Hypothesis does not directly relate strength of antacid to its chemical characteristics.	The hypothesis appears to have been written 5 minutes before class started, with no basis.
Procedures	Procedure is listed in clear steps. Each step is numbered and is a complete sentence. Use of chemicals is minimized.	Procedure steps are listed in a logical order, but steps are not numbered and/or are not in complete sentences. Use of chemicals is minimized.	Procedure steps are listed but are not in a logical order or are difficult to follow. No attempt is made to use materials efficiently.	Procedure appears to have been scribbled on the back of a napkin during breakfast.
Cleanup	I can't tell you were here today.	I had to remind you to clean up.	I found trash in your sink.	I had to clean up your dishes (grr).
Calculations	All calculations are shown and labelled with units so work can be followed.	Calculations are shown with units but are set up incorrectly.	Calculations are shown without units.	Numbers appear as if by magic, without any work shown.
Conclusion	Conclusion is a one or two sentence statement describing the strength of the antacids tested.	Conclusion is not written in complete sentences but does describe the strength of the antacids tested.	Conclusion does not follow logically from data collected.	Conclusion is missing or included in analysis
Analysis	Analysis includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment. Whether the results are consistent with label claims are discussed. At least one change in the experiment that could improve precision is described.	Analysis includes whether the findings supported the hypothesis and what was learned from the experiment. Whether the results are consistent with label claims are discussed.	Analysis includes what was learned from the experiment. No patterns, trends or predictions are made based on the data.	No significant attempt is made to correlate data with hypothesis.
Data	Data are entered legibly in a table during real time. Graphs and tables are labeled and titled.	Data are transferred to a table after lab is complete. Graphs and tables are labeled and titled.	Data are accurately represented in written form, but no graphs or tables are presented.	Data are written in the margins of your lab instructions without any labels or identification.

Lab 16: Determining the pH of an Unknown Solution

Purpose: To determine the color of several indicators over a range of pH and design an experiment to determine the pH of an unknown solution.

Background: Indicators are substances that change color as the concentration of H+ changes (i.e., they change color with corresponding changes in pH).

Procedure: You will be given solutions of known pH and several indicators. Bring to lab a procedure to determine the color of the indicators at various values of pH. After executing your procedure, design an experiment to determine the pH of an unknown solution by performing a maximum of four tests.

Safety:

- Acids and bases are both strong irritants. Contact should be avoided. If contact occurs, wash the area for 15 minutes and notify the instructor.
- After reviewing your procedure, the instructor will discuss any safety precautions that are specific to your experiment.

Question for further thought:

1. How is the pH of a solution calculated?
2. What is the relationship between the pH and the pOH of a solution?
3. In a given solution, the [H+] = 0.01. What are the pH and the pOH of the solution?

Write up: A grading rubric is on the next page. Your write-up will need to include: your procedure for determining the color of the indicators at various values of pH and an explanation of any changes you made to your original; your procedure for determining the pH of the unknown (in the form of a flow diagram); your data and/or observations; a conclusion summarizing your results; a discussion explaining your results and your evidence for this and any possible errors you may have experienced; and how you think you may be able to avoid them if you were to do the lab again. You must also answer the questions!

List of chemicals
Solutions of pH 1,4,7,10, and 14
phenolphthalein
bromocresol purple
congo red
bromthymol blue
methyl red
alizarin yellow R
methyl orange
thymol blue
bromcresol green

List of equipment
graduated cylinder
well plate
small test tubes

Lab Report : pH Indicators

CATEGORY	4	3	2	1
Format	Report is legible and includes purpose, materials, synopsis of procedures, data tables, flow diagram, observations, conclusion and error analysis.	Report contains all required elements but is difficult to read.	Report is missing one of the required elements.	Report is missing two or more of the required elements.
Flow chart	Flow chart is neat, prepared with a straightedge, and follows a logical sequence of actions.	Flow chart follows a logical sequence of actions but is drawn in freehand.	The logic behind the flow chart is not clear.	Flow chart appears to have been scribbled on the back of a napkin during breakfast.
Cleanup	I can't tell you were here today.	I had to remind you to clean up.	I found trash in your sink.	I had to clean up your dishes (grr).
Error analysis	Two possible sources of error and their effect on results are suggested.	Two possible sources of error are included, but their effect on results is not discussed.	One possible source of error is included.	No error analysis included.
Data	Data and observations are entered legibly in a table during real time. Tables are labeled and titled.	Data are transferred to a table after lab is complete. Tables are labeled and titled.	Data are accurately represented in written form, but no tables are presented.	Data are written in the margins of your lab instructions without any labels or identification and no observations included.

PRELAB 17: Electrochemistry in Action!

1. Draw a diagram and label the following: the reactions happening at each coin, the anode and cathode, which electrode is negative and which is positive, and the flow of electrons.

2. Give two possible reasons why current won't flow, and how to remedy this.

LAB 17: Electrochemistry in Action!

I. Purpose: To correlate amount of plating with number of electrons transferred.

II. Safety: This lab uses strong acids. Wear safety goggles at ALL times. If any solutions touch your skin, wash off with plenty of soap and water.

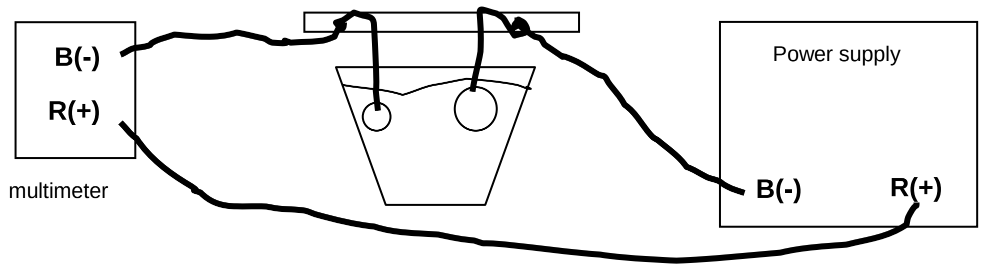
III. Materials:
SUPPLIED BY YOU: One penny (1982 or older), one quarter
SUPPLIED BY SCHOOL:

variable DC power supply	3 connecting wires
alligator clips	ammeter
glass rod	balance
dilute HNO_3	3 M NaOH
3 M H_2SO_4	plating solution ($CuSO_4/H_2SO_4$)
sandpaper	copper wire

IV. Procedure:

1. Clean a penny by dipping in dilute nitric acid (don't use your fingers!) and then washing it thoroughly. Clean a quarter by soaking for a few minutes in NaOH, rinsing, and then soaking it in 3 M H_2SO_4.
2. Use sandpaper to rub any plastic coating from the copper wire. Wrap the wire around each coin, leaving about 4" at the top. The main reason that plating doesn't work is lack of contact between wire and coin. Make sure the coin is tightly wrapped.
3. Accurately weigh each coin with its wire and record the weight.
4. Wrap each wire around the glass rod. The rod will be placed on top of the beaker in order to suspend the coins in the electroplating solution.
5. Add about 100 mL of the copper plating solution to a 250 ml beaker.
6. Place the glass rod on top of the beaker and suspend the coins in the solution. DO NOT ALLOW THE COINS OR WIRE TO TOUCH EACH OTHER.
7. Hook up the wires as shown in the diagram. The quarter should be wired directly to the negative (black terminal) electrode on the variable DC power supply. The positive (red terminal) should be connected to the "10 Amp" terminal on the multimeter. The penny should be connected to the "Com" terminal on the multimeter. Place the alligator clips on the copper wire under the glass rod. Have your teacher check the setup!
8. Set the multimeter to read 10 amps. Turn the power supply's variable control to its lowest setting, and turn on the power supply. If no current is observed, check the following:
    a. Disconnect the alligator clips attached to the coins and touch the clips together. If current does not flow, the multimeter and/or power supply are not working properly and need to be replaced. If current does flow, the problem is with the contact between coins and wires.
    b. If the problem is with the contact between coins and wires, resand the wire at contact points (to coin and to alligator clips). Make sure the wire is wrapped tightly around the coin and touches the coin at at least four points. Keep trying until current flows!
9. Adjust the current to about 1.00 amps and begin timing. Adjust as needed during electroplating to maintain a constant reading. After about 20 minutes, turn off the power supply.

10. Remove the coins, keeping the wires attached, rinse GENTLY and allow to dry.
11. Disconnect the wires. Leave the beaker and the plating solution at the lab station.
12. Dry well each coin with the wires still attached and weigh the assemblies.



V. Questions: Answer in COMPLETE SENTENCES. When calculations are required, SHOW YOUR WORK to get full credit.

1. What is oxidized and what is reduced in the reactions?
2. What are the sources of the copper plated on the quarter?
3. What are the sources of electrons?
4. What is the purpose of the power supply?
5. If you continued the electrolysis for a longer period of time, eventually no further plating will occur. Why not?
6. Name three other substances that can be electroplated. What metals can be used to electroplate?
7. Compare the change in mass of the negative electrode with the mass change of the positive. Explain any differences or similarities.
8. Determine the moles of copper plated (Cu = 63.5 g/mol) and the moles of electrons needed to plate the copper. Do two calculations: one using the weight LOST by the penny, and one using the weight GAINED by the quarter.

Quantum Mechanix

Fill in the table below!
Write the quantum numbers for ONE valence electron

				Quantum numbers			
Z	Element Symbol	Electron Configuration	"Condensed" Configuration	n	l	m_l	m_s
1	H	$1s^1$		1	0	0	+1/2
2	He						
3							
4							
5							
6							
7							
8							
9							
10							
11							
		$1s^2 2s^2 2p^6 3s^2 3p^4$					
25							
		$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$					
35							
	Pb						

Write the most likely (most stable) electronic configuration for the ION of the element with Z=:

a) 4

b) 8

c) 9

d) 11

Lewis Structures: The Next Level

1) Write the Lewis structures for each of the following formulas:

BeH_2 BH_3 BF_3 SCl_2

CH_4 H_2O NH_3 ClF HF

2) Write the Lewis structures for each of the following formulas (multiple bond):

H_2CO NO_2^+

C_2H_4 CO_2

3) Write the Lewis structures for each of the following formulas (multiple bond):

N_2 HCN

CO NO^+

4) Draw Lewis structures for each of the following molecules. These DO NOT follow the octet rule!

XeF_2

SF_4

ClF_3

PCl_5

5) For those who need additional challenges:

OCl^-

H_2S

SO_3^{-2}

PO_4^{-3}

BrF_3

BrF_5

IF_3

I_3^-

Thermochemistry: Bond Energies Name:______________________________

1. Using the table of bond energies, estimate the heat of combustion for one mole of acetylene:
   $C_2H_2(g) + (5/2)O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$
   a. 1220 kJ
   b. -1220 kJ
   c. -447 kJ
   d. 447 kJ
   e. 365 kJ

2. Using the table of bond energies, estimate the ΔH for the reaction:
   $H_2O_2 + CH_3OH \rightarrow H_2CO + 2H_2O$
   a. -345 kJ
   b. -199 kJ
   c. -105 kJ
   d. +199 kJ
   e. +345 kJ

Bond	Bond Energy (kJ/mol)
C−C	347
C=C	614
C≡C	839
C−O	358
C=O	799
C−H	413
O−H	463
O−O	146
O=O	495
H−H	432

3. A challenge! Calculate the N-F bond energy given the following information:
   N_2 bond energy = 941 kJ/mol
   F_2 bond energy = 154 kJ/mol

   $\frac{1}{2} N_2(g) + 3/2\ F_2(g) \rightarrow NF_3(g)$ ΔH = -103 kJ/mol

Thermochemistry: Heats of Formation Name:___________________________

The ΔHrxn for an equation can be calculated using ΔHf for the individual compounds.
Step 1: Make sure the equation is balanced.
Step 2: Assign ΔHf=0 for all **elements in their standard states** (25˚C, 1 atm.)
Step 3: For all other components, find the ΔHf from table, and remember to multiply the number times the coefficient from the balanced equation.
Step 4: Subtract the left side from the right side: ΔHrxn = ∑ ΔHfproducts - ∑ ΔHfreactants

1. $Mg(s) + O_2(g) \rightarrow MgO(s)$ ΔH = __________kJ exo or endo?

2. $KClO_3(s) \rightarrow KCl(s) + O_2(g)$ ΔH = __________kJ exo or endo?

3. $Zn(s) + HCl(aq) \rightarrow Zn^{+2}(aq) + Cl^{-}(aq) + H_2(g)$ ΔH = __________kJ exo or endo?

4. $OH^{-}(aq) + H_2SO_4(aq) \rightarrow SO_4^{-2}(aq) + H_2O(l)$ ΔH = __________kJ exo or endo?

5. $CO_2(g) \rightarrow C(s) + O_2(g)$ ΔH = __________kJ exo or endo?

6. $Al(s) + Fe_2O_3(s) \rightarrow Fe(s) + Al_2O_3(s)$ ΔH = __________kJ exo or endo?

7. $CaCO_3(s) + HCl(aq) \rightarrow CaCl_2(s) + H_2CO_3(aq)$ ΔH = __________kJ exo or endo?

8. $C(s) + Fe_2O_3(s) \rightarrow Fe(s) + CO_2(g)$ ΔH = __________kJ exo or endo?

9. $H_2SO_4(aq) \rightarrow SO_2(g) + H_2O(g) + O_2(g)$ ΔH = __________kJ exo or endo?

Thermochemistry: ΔHf and Hess's Law   Name:______________________________

1. Calculate the enthalpy change in the reaction below. Report results in kJ.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

2. Given the following data, calculate ΔH for the reaction **$2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$**

Reaction	ΔH, kJ
$2C_2H_6(g) + + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$	-3120
$C(s) + O_2(g) \rightarrow CO_2(g)$	-394
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$	-572

3.Find the standard enthalpy of formation for ethyne (C_2H_2), given the following standard enthalpies of combustion, in kJ/mole: $C_2H_2(g)$ = -1300; C(s) = -394; $H_2(g)$ = -286.

4. Calculate the standard enthalpy of formation of propan-1-ol (C_3H_7OH), given the standard enthalpies of combustion, in kJ/mole: $C_3H_7OH(l)$ = -2010; C(s) = -394; $H_2(g)$ = -286.

Use the following data to solve the next two problems.

Reaction	ΔH, kJ/mole
$C(s) + O_2(g) \rightarrow CO_2(g)$	-394
$H_2(g) + ½ O_2(g) \rightarrow H_2O(l)$	-286

5. The ΔHf for phenol (C_6H_5OH) = -209.3 kJ/mole. Calculate its standard enthalpy of combustion.

6. Calculate the standard enthalpy of formation of propane (C_3H_8). The standard enthalpy of combustion of propane is -2220 kJ/mole.

Thermochemistry Review

1) Write the equation for liquid water turning to ice, and indicate if the process is endothermic or exothermic.

2) Why is it a good idea to rinse your thermos bottle with hot water before filling it with hot coffee?

3) Plants use the following photosynthetic reaction to produce glucose and other nutrients from carbon dioxide and water:

   $6CO_2(g) + 6H_20(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

   Based on the above reaction, why would extensive deforestation exacerbate the greenhouse effect?

4) Which of the following processes are exothermic?
   a) $H_2(g) \rightarrow 2H(g)$
   b) $I_2(g) \rightarrow I_2(s)$
   c) $Br_2(l) \rightarrow Br_2(g)$
   d) $H_2O(l) \rightarrow H_2O(s)$

5) Consider the combustion of propane:

   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \quad \Delta H = -2221 \text{ kJ}$

   What mass of propane is needed to release 555 kJ of energy?

6) A 12-fluid ounce can of diet cola contains 360.1 g of soda (specific heat = 4.2 $J\cdot K^{-1}g^{-1}$) and the aluminum can (specific heat = 0.90 $J\cdot K^{-1}g^{-1}$) weighs 19.3 g.
   a) What amount of thermal energy must be removed to cool a six-pack of soda from 25°C to 0°C? Ice requires 334 J/g to melt.
   b) What mass of ice is needed to cool the six-pack of sodas?

7) The molar heat capacity of copper is 24.435 $J\cdot K^{-1}mol^{-1}$. What temperature change would take place if 260 J of thermal energy was removed from a 0.30 mol block of copper?

8) How much energy must be removed from 15.0 g of red phosphorus (look up its formula!) to cool it from 25°C to 23°C? The molar heat capacity of red phosphorus is 21.21 $J\cdot K^{-1}mol^{-1}$.

9) You have 1 mol of diamond (heat capacity = 6.11 $J\cdot K^{-1}mol^{-1}$) and 1 mol of graphite (heat capacity = 8.53 $J\cdot K^{-1}mol^{-1}$). Which substance must absorb the greater amount of heat for an increase in temperature from 298 K to 371 K? How much heat energy is required?

10) A student heated a 32.6 g sample of metal to 99.83°C and put it into a calorimeter containing 100.0 g of water initially at 23.62°C. The system's final temperature was 24.41°C.
   a) The specific heat of water is 4.184 $J\cdot K^{-1}g^{-1}$. What was the specific heat of the metal?
   b) Compare the specific heat you calculated in (a) to determine if the metal was Cr (specific heat = 0.460 $J\cdot K^{-1}g^{-1}$), Mo (specific heat = 0.250 $J\cdot K^{-1}g^{-1}$) or W (specific heat = 0.135 $J\cdot K^{-1}g^{-1}$).

11) The following reaction describes the formation of ozone:
   $3O_2(g) \rightarrow 2O_3(g) \quad \Delta H = 285.4 \text{ kJ}$

   Determine the enthalpy change in this reaction when:
   a) 1.00 mol O_2 reacts
   b) 1.00 mol O_3 is formed
   c) 1.00 g O_2 reacts

12) Use the following equations:

$N_2O_4(g) \rightarrow 2NO_2(g)$ $\Delta H = 57.20$ kJ
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = -114.14$ kJ

to find the heat of reaction for:
$2NO(g) + O_2(g) \rightarrow N_2O_4(g)$

13) Use the following equations to find ΔHf for $CuCl_2(s)$:

$2Cu(s) + Cl_2(g) \rightarrow 2CuCl(s)$ $\Delta H = -274.4$ kJ
$2CuCl(s) + Cl_2(g) \rightarrow 2CuCl_2(s)$ $\Delta H = -165.8$ kJ

14) Find the heat of formation of liquid hydrogen peroxide at 25°C from the following equations:
$H_2(g) + 1/2O_2(g) \rightarrow H_2O(g)$ $\Delta H = -241.818$ kJ
$2H(g) + O(g) \rightarrow H_2O(g)$ $\Delta H = -926.919$ kJ
$2H(g) + 2O(g) \rightarrow H_2O_2(g)$ $\Delta H = -1070.60$ kJ
$2O(g) \rightarrow O_2(g)$ $\Delta H = -498.340$ kJ
$H_2O_2(l) \rightarrow H_2O_2(g)$ $\Delta H = 51.46$ kJ

15) Use ΔHf data to find the enthalpy of reaction for the following:

a) $C(graphite) + CO_2(g) \rightarrow 2CO(g)$

b) $2HI(g) + F_2(g) \rightarrow 2HF(g) + I_2(s)$

c) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

16) First, write the chemical equation for the formation of one mole of methane, $CH_4(g)$, from elements in their standard states.

Now find ΔHf for $CH_4(g)$ at 20°C using the following data:

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H = -286.10$ kJ
$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -394.89$ kJ
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -882.0$ kJ

17) A person walking along a level sidewalk uses approximately 2.0 kJ of energy for each mile traveled per each pound the person weighs. How far should a 120-lb person walk to burn up the energy in a 1-lb box of candy? Assume that the candy is 100% sucrose, and that the reaction for metabolizing sucrose is 12% efficient:
$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$ $\Delta H = -2221.7$ kJ

18) Calculate the energy in a C − O bond using the values of the O − O, O − H, and C − H bond energies given in HWK #2 and the equation:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta H = -802.335$ kJ

Standard Thermodynamic Values for Selected Substances at 298 K (25°C)

SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$e^-(g)$	0	0	20.87
Aluminum			
$Al(s)$	0	0	28.3
$Al^{3+}(aq)$	−524.7	−481.2	−313
$AlCl_3(s)$	−704.2	−628.9	110.7
$Al_2O_3(s)$	−1676	−1582	50.94
Barium			
$Ba(s)$	0	0	62.5
$Ba(g)$	175.6	144.8	170.28
$Ba^{2+}(g)$	1649.9	—	—
$Ba^{2+}(aq)$	−538.36	−560.7	13
$BaCl_2(s)$	−806.06	−810.9	126
$BaCO_3(s)$	−1219	−1139	112
$BaO(s)$	−548.1	−520.4	72.07
$BaSO_4(s)$	−1465	−1353	132
Boron			
B(β-rhombohedral)	0	0	5.87
$BF_3(g)$	−1137.0	−1120.3	254.0
$BCl_3(g)$	−403.8	−388.7	290.0
$B_2H_6(g)$	35	86.6	232.0
$B_2O_3(s)$	−1272	−1193	53.8
$H_3BO_3(s)$	−1094.3	−969.01	88.83
Bromine			
$Br_2(l)$	0	0	152.23
$Br_2(g)$	30.91	3.13	245.38
$Br(g)$	111.9	82.40	174.90
$Br^-(g)$	−218.9	—	—
$Br^-(aq)$	−120.9	−102.82	80.71
$HBr(g)$	−36	−53.5	198.59

SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
Cadmium			
$Cd(s)$	0	0	51.[illegible]
$Cd(g)$	112.8	78.20	167.[illegible]
$Cd^{2+}(aq)$	−72.38	−77.74	−61.1
$CdS(s)$	−144	−141	71
Calcium			
$Ca(s)$	0	0	41.[illegible]
$Ca(g)$	192.6	158.9	154.7
$Ca^{2+}(g)$	1934.1	—	—
$Ca^{2+}(aq)$	−542.96	−553.04	−55.2
$CaF_2(s)$	−1215	−1162	68.8
$CaCl_2(s)$	−795.0	−750.2	114
$CaCO_3(s)$	−1206.9	−1128.8	92.9
$CaO(s)$	−635.1	−603.5	38.2
$Ca(OH)_2(s)$	−986.09	−898.56	83.3[illegible]
$Ca_3(PO_4)_2(s)$	−4138	−3899	263
$CaSO_4(s)$	−1432.7	−1320.3	107
Carbon			
C(graphite)	0	0	5.6[illegible]
C(diamond)	1.896	2.866	2.43
$C(g)$	715.0	669.6	158.0
$CO(g)$	−110.5	−137.2	197.5
$CO_2(g)$	−393.5	−394.4	213.7
$CO_2(aq)$	−412.9	−386.2	121
$CO_3^{2-}(aq)$	−676.26	−528.10	−53.1
$HCO_3^-(aq)$	−691.11	587.06	95.0
$H_2CO_3(aq)$	−698.7	−623.42	191
$CH_4(g)$	−74.87	−50.81	186.1
$C_2H_2(g)$	227	209	200.85
$C_2H_4(g)$	52.47	68.36	219.22
$C_2H_6(g)$	−84.667	−32.89	229.5
$C_3H_8(g)$	−105	−24.5	269.9
$C_4H_{10}(g)$	−126	−16.7	310
$C_6H_6(l)$	49.0	124.5	172.8
$CH_3OH(g)$	−201.2	−161.9	238
$CH_3OH(l)$	−238.6	−166.2	127
$HCHO(g)$	−116	−110	219
$HCOO^-(aq)$	−410	−335	91.6
$HCOOH(l)$	−409	−346	129.0
$HCOOH(aq)$	−410	−356	164
$C_2H_5OH(l)$	−277.63	−174.8	161
$C_2H_5OH(g)$	−235.1	−168.6	282.6
$CH_3CHO(g)$	−166	−133.7	266
$CH_3COOH(l)$	−487.0	−392	160
$C_6H_{12}O_6(s)$	−1274.5	−910.56	212.1
$CN^-(aq)$	151	166	118
$HCN(g)$	135	125	201.7
$HCN(l)$	105	121	112.8
$HCN(aq)$	105	112	129
$CS_2(g)$	117	66.9	237.79
$CS_2(l)$	87.9	63.6	151.0
$CH_3Cl(g)$	−83.7	−60.2	234
$CH_2Cl_2(l)$	−117	−63.2	179
$CHCl_3(l)$	−132	−71.5	203
$CCl_4(g)$	−96.0	−53.7	309.7

Standard Thermodynamic Values for Selected Substances at 298 K (25°C)

SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$CCl_4(l)$	−139	−68.6	214.4
$COCl_2(g)$	−220	−206	283.74
Cesium			
$Cs(s)$	0	0	85.15
$Cs(g)$	76.7	49.7	175.5
$Cs^+(g)$	458.5	427.1	169.72
$Cs^+(aq)$	−248	−282.0	133
$CsF(s)$	−554.7	−525.4	88
$CsCl(s)$	−442.8	−414	101.18
$CsBr(s)$	−395	−383	121
$CsI(s)$	−337	−333	130
Chlorine			
$Cl_2(g)$	0	0	223.0
$Cl(g)$	121.0	105.0	165.1
$Cl^-(g)$	−234	−240	153.25
$Cl^-(aq)$	−167.46	−131.17	55.10
$HCl(g)$	−92.31	−95.30	186.79
$HCl(aq)$	−167.46	−131.17	55.06
$ClO_2(g)$	102	120	256.7
$Cl_2O(g)$	80.3	97.9	266.1
Chromium			
$Cr(s)$	0	0	23.8
$Cr^{3+}(aq)$	−1971	—	—
$CrO_4^{2-}(aq)$	−863.2	−706.3	38
$Cr_2O_7^{2-}(aq)$	−1461	−1257	214
Copper			
$Cu(s)$	0	0	33.1
$Cu(g)$	341.1	301.4	166.29
$Cu^+(aq)$	51.9	50.2	−26
$Cu^{2+}(aq)$	64.39	64.98	−98.7
$Cu_2O(s)$	−168.6	−146.0	93.1
$CuO(s)$	−157.3	−130	42.63
Fluorine			
$F_2(g)$	0	0	202.7
$F(g)$	78.9	61.8	158.64
$F^-(g)$	−255.6	−262.5	145.47
$F^-(aq)$	−329.1	−276.5	−9.6
$HF(g)$	−273	−275	173.67
Hydrogen			
$H_2(g)$	0	0	130.6
$H(g)$	218.0	203.30	114.60
$H^+(aq)$	0	0	0
$H^+(g)$	1536.3	1517.1	108.83
Iodine			
$I_2(s)$	0	0	116.14
$I_2(g)$	62.442	19.38	260.58
$I(g)$	106.8	70.21	180.67
$I^-(g)$	−194.7	—	—
$I^-(aq)$	−55.94	−51.67	109.4
$HI(g)$	25.9	1.3	206.33
Iron			
$Fe(s)$	0	0	27.3
$Fe^{3+}(aq)$	−47.7	−10.5	−293
$Fe^{2+}(aq)$	−87.9	−84.94	113
$FeO(s)$	−272.0	−251.4	60.75

SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$Fe_2O_3(s)$	−825.5	−743.6	87.400
$Fe_3O_4(s)$	−1121	−1018	145.3
Lead			
$Pb(s)$	0	0	64.785
$Pb^{2+}(aq)$	1.6	−24.3	21
$PbCl_2(s)$	−359	−314	136
$PbO(s)$	−218	−198	68.70
$PbO_2(s)$	−276.6	−219.0	76.6
$PbS(s)$	−98.3	−96.7	91.3
$PbSO_4(s)$	−918.39	−811.24	147
Lithium			
$Li(s)$	0	0	29.10
$Li(g)$	161	128	138.67
$Li^+(g)$	687.163	649.989	132.91
$Li^+(aq)$	−278.46	−293.8	14
$LiF(s)$	−616.9	−588.7	35.66
$LiCl(s)$	−408	−384	59.30
$LiBr(s)$	−351	−342	74.1
$LiI(s)$	−270	−270	85.8
Magnesium			
$Mg(s)$	0	0	32.69
$Mg(g)$	150	115	148.55
$Mg^{2+}(g)$	2351	—	—
$Mg^{2+}(aq)$	−461.96	−456.01	118
$MgCl_2(s)$	−641.6	−592.1	89.630
$MgCO_3(s)$	−1112	−1028	65.86
$MgO(s)$	−601.2	−569.0	26.9
$Mg_3N_2(s)$	−461	−401	88
Manganese			
$Mn(s, \alpha)$	0	0	31.8
$Mn^{2+}(aq)$	−219	−223	−84
$MnO_2(s)$	−520.9	−466.1	53.1
$MnO_4^-(aq)$	−518.4	−425.1	190
Mercury			
$Hg(l)$	0	0	76.027
$Hg(g)$	61.30	31.8	174.87
$Hg^{2+}(aq)$	171	164.4	−32
$Hg_2^{2+}(aq)$	172	153.6	84.5
$HgCl_2(s)$	−230	−184	144
$Hg_2Cl_2(s)$	−264.9	−210.66	196
$HgO(s)$	−90.79	−58.50	70.27
Nitrogen			
$N_2(g)$	0	0	191.5
$N(g)$	473	456	153.2
$N_2O(g)$	82.05	104.2	219.7
$NO(g)$	90.29	86.60	210.65
$NO_2(g)$	33.2	51	239.9
$N_2O_4(g)$	9.16	97.7	304.3
$N_2O_5(g)$	11	118	346
$N_2O_5(s)$	−43.1	114	178
$NH_3(g)$	−45.9	−16	193
$NH_3(aq)$	−80.83	26.7	110
$N_2H_4(l)$	50.63	149.2	121.2
$NO_3^-(aq)$	−206.57	−110.5	146
$HNO_3(l)$	−173.23	−79.914	155.6
$HNO_3(aq)$	−206.57	−110.5	146

SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$NF_3(g)$	−125	−83.3	260.6
$NOCl(g)$	51.71	66.07	261.6
$NH_4Cl(s)$	−314.4	−203.0	94.6
Oxygen			
$O_2(g)$	0	0	205.0
$O(g)$	249.2	231.7	160.95
$O_3(g)$	143	163	238.82
$OH^-(aq)$	−229.94	−157.30	−10.54
$H_2O(g)$	−241.826	−228.60	188.72
$H_2O(l)$	−285.840	−237.192	69.940
$H_2O_2(l)$	−187.8	−120.4	110
$H_2O_2(aq)$	−191.2	−134.1	144
Phosphorus			
P_4(s, white)	0	0	41.1
$P(g)$	314.6	278.3	163.1
P(s, red)	−17.6	−12.1	22.8
$P_2(g)$	144	104	218
$P_4(g)$	58.9	24.5	280
$PCl_3(g)$	−287	−268	312
$PCl_3(l)$	−320	−272	217
$PCl_5(g)$	−402	−323	353
$PCl_5(s)$	−443.5	—	—
$P_4O_{10}(s)$	−2984	−2698	229
$PO_4^{3-}(aq)$	−1266	−1013	−218
$HPO_4^{2-}(aq)$	−1281	−1082	−36
$H_2PO_4^-(aq)$	−1285	−1135	89.1
$H_3PO_4(aq)$	−1277	−1019	228
Potassium			
$K(s)$	0	0	64.672
$K(g)$	89.2	60.7	160.23
$K^+(g)$	514.197	481.202	154.47
$K^+(aq)$	−251.2	−282.28	103
$KF(s)$	−568.6	−538.9	66.55
$KCl(s)$	−436.7	−409.2	82.59
$KBr(s)$	−394	−380	95.94
$KI(s)$	−328	−323	106.39
$KOH(s)$	−424.8	−379.1	78.87
$KClO_3(s)$	−397.7	−296.3	143.1
$KClO_4(s)$	−432.75	−303.2	151.0
Rubidium			
$Rb(s)$	0	0	69.5
$Rb(g)$	85.81	55.86	169.99
$Rb^+(g)$	495.04	—	—
$Rb^+(aq)$	−246	−282.2	124
$RbF(s)$	−549.28	—	—
$RbCl(s)$	−435.35	−407.8	95.90
$RbBr(s)$	−389.2	−378.1	108.3
$RbI(s)$	−328	−326	118.0
Silicon			
$Si(s)$	0	0	18.0
$SiF_4(g)$	−1614.9	−1572.7	282.4
$SiO_2(s)$	−910.9	−856.5	41.5
Silver			
$Ag(s)$	0	0	42.702
$Ag(g)$	289.2	250.4	172.892

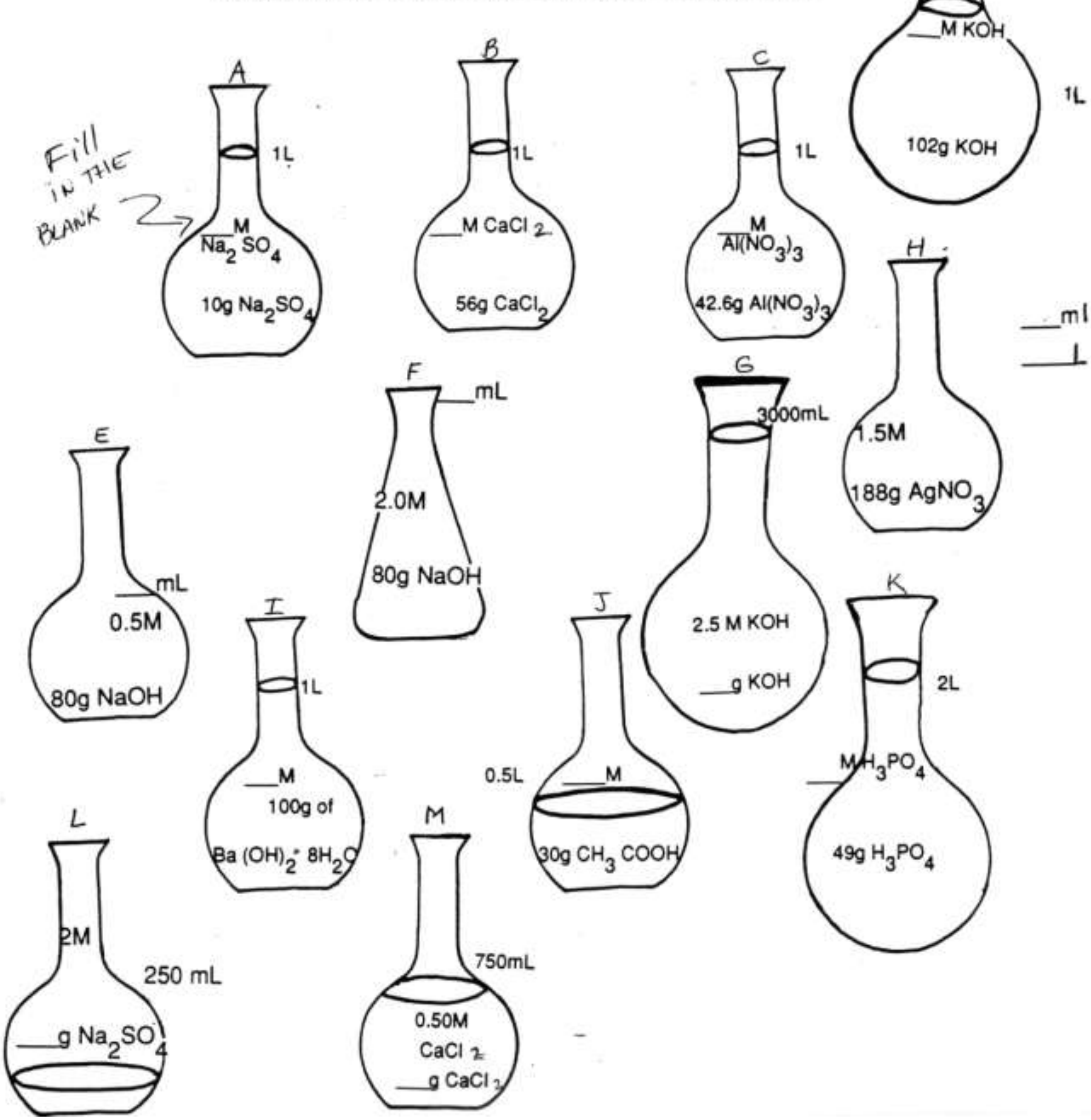
SUBSTANCE OR ION	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$Ag^+(aq)$	105.9	77.111	73.93
$AgF(s)$	−203	−185	84
$AgCl(s)$	−127.03	−109.72	96.11
$AgBr(s)$	−99.51	−95.939	107.1
$AgI(s)$	−62.38	−66.32	114
$AgNO_3(s)$	−45.06	19.1	128.2
$Ag_2S(s)$	−31.8	−40.3	146
Sodium			
$Na(s)$	0	0	51.44
$Na(g)$	107.76	77.299	153.61
$Na^+(g)$	609.839	574.877	147.85
$Na^+(aq)$	−239.66	−261.87	60.2
$NaF(s)$	−575.4	−545.1	51.21
$NaCl(s)$	−411.1	−384.0	72.12
$NaBr(s)$	−361	−349	86.82
$NaOH(s)$	−425.609	−379.53	64.45
$Na_2CO_3(s)$	−1130.8	−1048.1	139
$NaHCO_3(s)$	−947.7	−851.9	102
$NaI(s)$	−288	−285	98.5
Strontium			
$Sr(s)$	0	0	54.4
$Sr(g)$	164	110	164.54
$Sr^{2+}(g)$	1784	—	—
$Sr^{2+}(aq)$	−545.51	−557.3	−39
$SrCl_2(s)$	−828.4	−781.2	117
$SrCO_3(s)$	−1218	−1138	97.1
$SrO(s)$	−592.0	−562.4	55.5
$SrSO_4(s)$	−1445	−1334	122
Sulfur			
S(rhombic)	0	0	31.9
S(monoclinic)	0.30	0.096	32.6
$S(g)$	279	239	168
$S_2(g)$	129	80.1	228.1
$S_8(g)$	101	49.1	430.211
$S^{2-}(aq)$	41.8	83.7	22
$HS^-(aq)$	−17.7	12.6	61.1
$H_2S(g)$	−20.2	−33	205.6
$H_2S(aq)$	−39	−27.4	122
$SO_2(g)$	−296.8	−300.2	248.1
$SO_3(g)$	−396	−371	256.66
$SO_4^{2-}(aq)$	−907.51	−741.99	17
$HSO_4^-(aq)$	−885.75	−752.87	126.9
$H_2SO_4(l)$	−813.989	−690.059	156.90
$H_2SO_4(aq)$	−907.51	−741.99	17
Tin			
Sn(white)	0	0	51.5
Sn(gray)	3	4.6	44.8
$SnCl_4(l)$	−545.2	−474.0	259
$SnO_2(s)$	−580.7	−519.7	52.3
Zinc			
$Zn(s)$	0	0	41.6
$Zn(g)$	130.5	94.93	160.9
$Zn^{2+}(aq)$	−152.4	−147.21	−106.5
$ZnO(s)$	−348.0	−318.2	43.9
ZnS(s, zinc blende)	−203	−198	57.7

Name______________

MOLARITY PROBLEMS:

MAKE SOLUTIONS!!

1) Express the CONC. OF SOLNS' in Molarity (M), OR
2) calculate how many grams you need of a compound to make a specific CONC., or
3) determine the volume or a SOLN' given some specifics.



Kinetics Practice

1. The compound RX_3 decomposes according to the equation:

   $3RX_3 \rightarrow R + R_2X_3 + 3X_2$

In an experiment the following data were collected for the decomposition at 100˚C. What is the average rate of reaction for the *entire* experiment?

Time (sec)	$[RX_3]$ (mol L^{-1})
0	0.85
2	0.67
6	0.41
8	0.33
12	0.20
14	0.16

a. -.019 mol $L^{-1}s^{-1}$
b. -0.044 mol $L^{-1}s^{-1}$
c. -0.049 mol $L^{-1}s^{-1}$
d. -0.069 mol $L^{-1}s^{-1}$

2. For the reaction

   $3A(g) + 2B(g) \rightarrow 2C(g) + 2D(g)$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial rate (mol/(L-min))
1	0.200	0.100	6.00×10^{-2}
2	0.100	0.100	1.5×10^{-2}
3	0.200	0.200	1.20×10^{-1}
4	0.300	0.200	2.70×10^{-1}

a. Rate = $k[A][B]^2$
b. Rate = $k[A]^2[B]$
c. Rate = $k[A]^3[B]^2$
d. Rate = $k[A]^{1.5}[B]$

3. For the reaction

   $A(g) + 2B(g) \rightarrow 2E(g) + 2F(g)$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial rate (mol/(L-min))
1	0.125	0.200	7.25
2	0.375	0.200	21.75
3	0.250	0.400	14.50
4	0.375	0.400	21.75

a. Rate = $k[A][B]$
b. Rate = $k[A]^2[B]$
c. Rate = $k[A][B]^2$
d. Rate = $k[A]$

4. For the rection

$$2A + B + 2C \rightarrow D + E$$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial [C] (mol/L)	Initial rate (mol/(L-min))
1	0.225	0.150	0.350	0.0217
2	0.320	0.150	0.350	0.0439
3	0.225	`0.250	0.350	0.0362
4	0.225	0.150	0.600	0.01270

a. Rate = k[A][B][C]
b. Rate = $k[A]^2[B][C]$
c. Rate = $k[A]^2[B][C]^{-1}$
d. Rate = $k[A][B]^2[C]^{-1}$

5. The rate constant for a reaction is 4.65 L $mol^{-1}s^{-1}$. The overall order of the reaction is:

a. zero b. first c. second d. third

6. Sulfuryl chloride, $SO_2Cl_2(g)$, decomposes at high temperatures to form $SO_2(g)$ and $Cl_2(g)$. The rate constant at a certain temperature is 4.68×10^{-5} s^{-1}. The order of the reaction is:

a. zero b. first c. second d. third

7. Which of the following sets of units could be appropriate for a zero order reaction?

a. s^{-1}
b. mol L^{-1} s^{-1}
c. L mol^{-1} s^{-1}
d. L^2 mol^{-2} s^{-1}
e. L^3 mol^{-3} s^{-1}

8. Which of the following sets of units could be appropriate for a second order reaction?

a. s^{-1}
b. mol L^{-1} s^{-1}
c. L mol^{-1} s^{-1}
d. L^2 mol^{-2} s^{-1}
e. L^3 mol^{-3} s^{-1}

9. Which of the following sets of units could be appropriate for a third order reaction?

a. s^{-1}
b. mol L^{-1} s^{-1}
c. L mol^{-1} s^{-1}
d. L^2 mol^{-2} s^{-1}
e. L^3 mol^{-3} s^{-1}