Demonstrations and laboratory experiments of chemical reactions and chemical changes in Chemistry 111 are meant to illustrate the important concepts of chemistry. This exam focuses on the demonstrations and experiments you have seen this semester.

1. (26 points) One of the reactions you have seen in lecture and in the lab is

_____ $BaCl_2$(____) + _____ Na_2SO_4(_____) → _____$BaSO_4$(_____) + ____NaCl(_____)

(a) Balance the equation by placing the correct stoichiometric coefficients into the equation above.

(b) Insert into the (_____) above the state of each reactant and product (i.e., s, , liq, g, aq)

(c) Name the compounds

Compound	**Name**
$BaCl_2$	_____
Na_2SO_4	_____
$BaSO_4$	_____
NaCl	_____

(d) The reaction is a (*precipitation*)(*acid-base reaction*)(*gas-forming reaction*)(*redox reaction*)

_____

(e) Write the *net ionic equation* for this reaction.

(f) If you add 15 g of $BaCl_2$ (M = 208 g/mol) to excess Na_2SO_4 (M = 142 g/mol) what is the maximum number of grams of $BaSO_4$ (M = 233 g/mol) you can obtain?

i. 10.2 g $BaSO_4$

ii. 13.4 g $BaSO_4$

iii. 15.0 g $BaSO_4$

iv. 16.8 g $BaSO_4$

(g) Write the electron configuration for the Ba. Use the *spectroscopic notation* and the *noble gas abbreviation* for the core electrons.

(h) Consider the SO_4^{2-} ion. The number of *valence electrons* in the ion is _____. Draw the *Lewis electron dot structure* for the ion.

2. (14 points) Methanol, CH_3OH, was used as a fuel in the "potato" gun in class. The alcohol burns in air to give carbon dioxide and water.

   $2\ CH_3OH(liq)\ +\ 3\ O_2(g)\ \rightarrow\ 2\ CO_2(g)\ +\ 4\ H_2O(g)$

   (a) The reaction is a (*precipitation reaction*)(*acid-base reaction*)(*redox reaction*)

   _____

   (b) If you combine 15 g of CH_3OH and 25 g of O_2, what is the theoretical yield of H_2O?

   i. 4.22 g

   ii. 8.44 g

   iii. 16.9 g

   iv. 28.1 g

   (c) The enthalpy change for this reaction, ΔH°_{rxn}, is

   i. -357.6 kJ

   ii. -1198.8 kJ

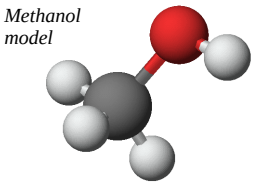
   iii. +1198.8 kJ

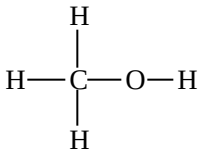
   iv. -1352.9 kJ

   v. +1352.9 kJ

   vi. None of the above.

   (d) The CH_3OH molecule has a total of _____ valence electrons. To show how they are distributed, place any additional bond pairs or lone pairs onto the framework (at the right) as appropriate.





   (e) Consider the molecule CO_2. The central atom is the molecule is _____, and it has _____ valence electrons. The Lewis electron structure for the molecule is (draw the structure below):

3. (24 points) Mr. Gummi Bear, composed of sugar, met an untimely end in a bath of molten $KClO_3$. The reaction occurring here can be written, for the sake of simplicity, as two reactions.

$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$ $\Delta H^\circ_{rxn} = ?$

$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(g)$ $\Delta H^\circ_{rxn} = -2538.5$ kJ

(a) If 3.00 g of sugar, $C_6H_{12}O_6$ (M = 180.6 g/mol) is decomposed, how much CO_2 can be produced?

i. 0.733 g

ii. 1.80 g

iii. 4.40 g

iv. 73.7 g

(b) If you wish to completely consume 3.00 g of sugar, $C_6H_{12}O_6$, how many grams of $KClO_3$ (M = 122.6 g/mol) must be used?

i. 2.04 g

ii. 8.15 g

iii. 12.2 g

iv. 18.4 g

(c) The name of $KClO_3$ is _____ .

(d) The oxidation number of Cl in KCl is _____ and it is _____ in $KClO_3$.

(e) The enthalpy change for the reaction $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$ is

i. +39.0 kJ

ii. -39.0 kJ

iii. +78.0 kJ

iv. -78.0 kJ

v. None of the above

and the reaction is (*endothermic*)(*exothermic*). _____

(f) The reaction of sugar ($C_6H_{12}O_6$) with O_2, as written above, has ΔH°_{rxn} = -2538.5 kJ. Is the reaction *endothermic* or *exothermic*? _____ What is the standard molar enthalpy of formation of sugar, ΔH°_f?

i. +1273 kJ/mol

ii. -1273 kJ/mol

iii. +1532 kJ/mol

iv. -1532 kJ/mol

v. +1904 kJ/mol

vi -1904 kJ/mol

Poor Mr. Gummi!

4. (20 points) The thermite reaction produces molten iron in an oxidation-reduction reaction.

$$2\ Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2\ Fe(s) \qquad \Delta H^\circ_{rxn} = -851.5\ kJ$$

(a) The name of Al_2O_3 is _____ and of Fe_2O_3 is _____

The thermite reaction. See Figure 4.20.

(b) _____ is the reducing agent, and _____ has been reduced.

(c) The enthalpy change for the reaction, ΔH°_{rxn}, is -851.5 kJ. If 39.9 g of Fe_2O_3 (M = 159.7 g/mol) is used with excess Al, what quantity of heat is evolved?

i. q = -213 kJ

ii. q = -1260 kJ

iii. q = -3410 kJ

(d) What is the maximum possible yield of iron, Fe, if you begin with exactly 100 g of Al and 200 g of Fe_2O_3 (M = 159.7 g/mol)?

i. 69.8 g Fe

ii. 140 g Fe

iii. 206 g Fe

iv. 300 g Fe

(e) Write the electron configuration for Al using the *spectroscopic notation* (and *noble gas abbrevia - tion* if you wish).

(f) Iron is an ion in Fe_2O_3. This ion is Fe^{n+} (give charge)._____ Write the electron configuration for this ion using the *orbital box notation* (and *noble gas abbreviation* if you wish).

Is Fe_2O_3 a paramagnetic or diamagnetic compound? _____

5. (8 points) A favorite demonstration is the reaction of O_2 with the hydrogen gas in a balloon.

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$$

(a) If you fill a balloon with 0.523 g of H_2, what mass of water is theoretically possible from the reaction?

i. 1.05 g

ii. 2.33 g

iii. 4.67 g

iv. 9.33 g

(b) Hydrogen atoms have been the focus of much of our discussion of atomic structure. Consider *only* the following energy levels for the H atom. *(The diagram below does not attempt to show the correct energy level spacings.)*

---------- n = 5
---------- n = 4

---------- n = 3

---------- n = 2

---------- n = 1

Assume the emission spectrum of an excited H atom consists of transitions between these levels.

a) How many emission lines are possible, considering only the five quantum levels?
_____

b) The emission line having the longest wavelength corresponds to a transition from the level with *n* = _____ to the level with *n* = _____.

c) The emission line having the highest energy corresponds to a transition from the level with *n* = _____ to the level with *n* = _____.

6. (16 points) Acid-base reactions have played a prominent role in the course. The reaction of oxalic acid with a base was demonstrated in class, and you used it in lab.

$$H_2C_2O_4(aq) + 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(liq)$$

(a) What is the name of NaOH? _____

(b) Before beginning the lab, you got 100 mL of 2.0 M NaOH solution from the reagent shelf and added 250 mL of water. The concentration of the diluted NaOH solution is

i. 0.250 M

ii. 0.571 M

iii. 0.666 M

iv. 0.800 M

(c) Suppose you weigh out 0.836 g of oxalic acid, $H_2C_2O_4$ (M = 90.0 g/mol). You titrate this with 36.45 mL of NaOH. What is the concentration of the NaOH solution?

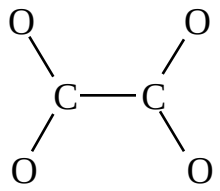
i. 0.255 M

ii. 0.510 M

iii. 0.666 M

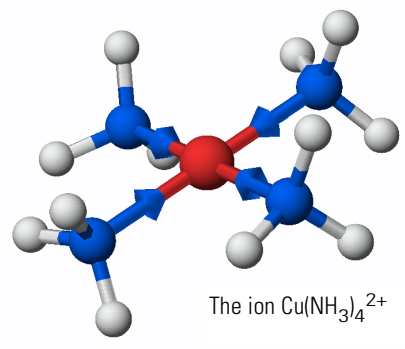
iv. 1.032 M

(d) The product of the reaction is $Na_2C_2O_4$, sodium oxalate. How many valence electrons does the oxalate ion, $C_2O_4^{2-}$, have? _____ The atoms of the oxalate ion are positioned in space as shown below, and single bonds have been put in place. Add any remaining bonds and lone pairs of electrons as needed.



(e) Hydrogen gas and NaOH are products of the reaction of sodium metal with water (a reaction you did in the lab). Write a balanced equation of this reaction, and then calculate the quantity of hydrogen gas that can be obtained from the reaction of 1.5 g of Na with excess water. ***(Show your work here!)***

7. (20 points) The copper complex laboratory involved several types of reactions. One of those was the titration of the ammonia attached to a Cu^{2+} ion with aqueous HCl.



$$Cu(NH_3)_4SO_4(aq) + 4\ HCl(aq) \rightarrow CuSO_4(aq) + 4\ NH_4Cl(aq)$$

(a) Suppose you titrate 1.25 g of a sample containing $Cu(NH_3)_4SO_4$ (M = 227.5 g/mol) and some impurities such as unreacted $CuSO_4$. You use 25.67 mL of 0.750 M HCl. What is the weight percent of $Cu(NH_3)_4SO_4$ in the sample?

i. 43.8%

ii. 64.2%

iii. 80.0%

iv. 87.6%

(b) What is the electron configuration of the Cu^{2+} ion? Give this configuration using the *orbital box notation* and the *noble gas abbreviation*.

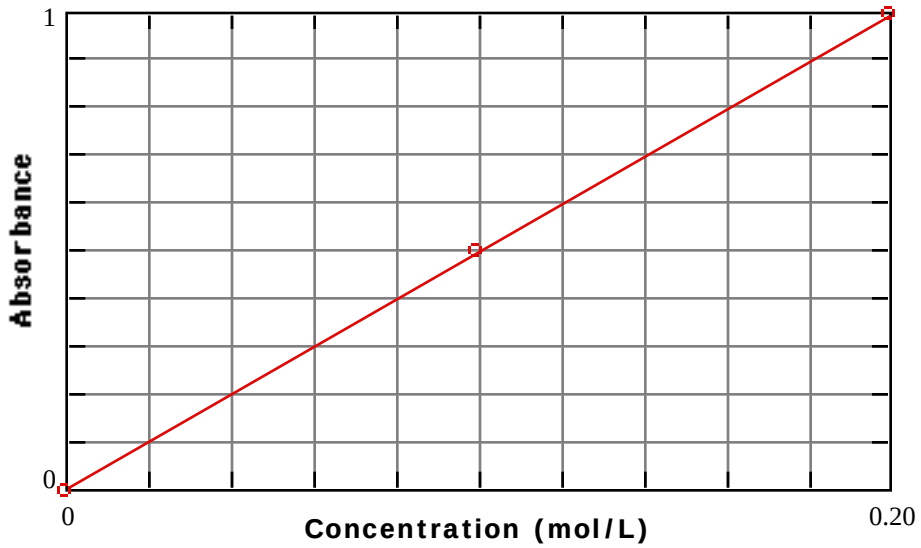
(c) Copper has only two stable (nonradioactive) isotopes, ^{63}Cu and ^{65}Cu. The latter, ^{65}Cu, has _____ neutrons in its nucleus. Which is the more abundant of the two? _____

(d) A product of the reaction above is the NH_4^+ ion. The name of this ion is _____ and its Lewis electron dot structure is

(e) The copper(II) ion can form complexes such as $[Cu(SCN)_4]^{2-}$ with the thiocyanate ion, SCN^-. Draw the Lewis electron dot structure for SCN^-, including *all possible resonance structures*. (C is the central atom in this case.)

7. (continued)

(f) Part of the copper complex lab involved analyzing the sample using spectroscopy. A sample calibration graph for the analysis of copper(II) ion in solution is given here. The absorbance of the solution is plotted on the vertical axis, and the concentration of Cu^{2+} ion is plotted on the horizontal axis.



Suppose you dissolve 0.20 g of a sample of a copper-containing sample in 10. mL of water and find that the absorbance of the solution is 0.68. The concentration of copper(II) in your solution is _____ mol/L, and the weight percent of copper in the sample is

i. 4.32%

ii. 8.64%

iii.21.6%

iv. 43.2%

8. (points) **PERIODIC PROPERTIES.** Throughout the semester, and in the laboratory, you learned about the chemistry of many different elements.

(a) As you descend Group 1A, the sizes of the elements (*increases*) (*decreases*) _____ and they react with water (*more rapidly*) (*less rapidly*). _____(Recall the video you have seen several times.) Which fundamental atomic property — *size, ionization energy, elec - tron affinity* — can be used most readily to explain this trend? Explain briefly.

(b) You looked at a number of elements in the lab. Considering Al, C, Ca, Li, Mg, Na, and K,

i) Which has the lowest ionization energy? _____

ii) Which has the greatest affinity for an electron? _____

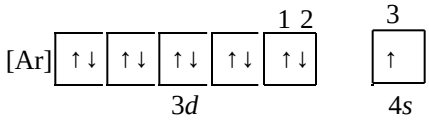
iii) Which has the largest radius? _____

iv) Which element has the smallest radius? _____

iv) Which elements are in the alkaline earth group? _____

v) Which element has the greatest difference between the first and second ionization energies? _____

(c) Write a complete set of quantum numbers (n, ℓ, m_ℓ, m_s) for electrons 1, 2, and 3 for copper,



Electron	**n**	ℓ	$\mathbf{m_\ell}$	$\mathbf{m_s}$
1	____	____	____	____
2	____	____	____	____
3	____	____	____	____

(d) Copper uses *d* orbitals for its valence electrons. Sketch a picture of a *d* orbital. How does it differ from a p orbital?

9. (1 point) Are you looking forward to the vacation? _____