Problem Set 3 (**Due March 22nd by 7:00 PM**)

Answers to the problems in **RED** need to be submitted through the course website.

Review Questions (Bonus: 3/1)

1. What is the electron configuration of bromine?

2. What is the electron configuration of the first excited state of bromine?

3. The emission spectrum of bromine has a spectral line at 650 nm. What is the frequency and energy of this photon in SI units?

4. How many of each type of bond are present between carbon and nitrogen in CH_2NH?
   a. Sigma
   b. Pi
5. Clearly justify this trend in IE_1 values: Li < Be > B

Draw BrF_5 and answer questions 6-11.

6. What is the hybridization on bromine?

7. What is the hybridization of fluorine?

8. What is the electronic geometry of bromine?

9. What is the molecular geometry of bromine?

10. Is this molecule polar?

11. What intermolecular force(s) will stabilize BrF_5 in the liquid phase?

Chemical Calculations (Bonus: 3/1)

12. Convert each of the following to moles.
    a. 17.82 grams of carbon
    b. 4.569×10^{28} carbon atoms
    c. **86.3 kg of iron.**
    d. **3.892×10^{17} iron atoms.**

13. Calculate the Molecular weight of each of the following:
    a. Sodium hypochlorite
    b. **Lead (IV) perbromate**

14. How many moles are found in 10 grams of:
    a. Sodium perbromate
    b. **Lead (IV) hypochlorite**

15. Calculate the mass percent of **carbon** in each of the following:
    a. Sodium carbonate
    b. **Lead (II) acetate**

16. Elemental analysis has determined the following mass % values. Using the provided information, determine the empirical and molecular formulas.

	A	B	C
% Carbon	14.70	34.07	22.04
% Chlorine	65.09	51.28	65.16
% Oxygen	19.59	11.34	7.34
% Hydrogen	0.62	4.30	5.56
Molecular Weight	163.4 g mol^{-1}	846.02 g mol^{-1}	1089.8 g mol^{-1}

17. Determine the type of reaction:
    a. CH_4 (g) + 2 O_2 (g) → CO_2 (g) + H_2O (g)
    b. 2 NaCl (aq) + Fe (s) → $FeCl_2$ (aq) + 2 Na(s)
    c. **$NaMnO_4$ (aq) → Na (s) + Mn (s) + 2 O_2 (g)**
    d. **$MnCl_2$ (s) + FeS (s)+ → MnS (s) + $FeCl_2$ (aq)**

18. Balance the following reactions:
    a. PCl_5 (s) + H_2O (l) → H_3PO_4 (l) + HCl (g)
    b. **Li (s) + CO_2 (g) + H_2O (l) → $LiHCO_3$ (s) + H_2 (g)**
    c. C_3H_7 (g) + O_2 (g) → CO_2 (g) + H_2O (l)
    d. **N_2H_4 (g) → NH_3 (g) + N_2 (g)**

19. In each reaction, you start with 17 gram of the FIRST compound listed. Predict how much of EACH product you can form (in grams). Assume that there is excess of all other reactants. Note these are not balanced.
    a. C_3H_7 (g) + O_2 (g) → CO_2 (g) + H_2O (g)
    b. PCl_5 (s) + H_2O (l) → **H_3PO_4 (l) + HCl (g)**

20. For each of the following chemical reactions, 1.8 grams of **each** reactant is mixed together. Predict the mass of the bold-faced product that is formed.
    a. H_2 (g) + N_2 (g) → **NH_3 (g)**
    b. MgO (s) + $FeCl_3$ (s) → $MgCl_2$ (s) + **Fe_2O_3 (s)**

21. For each of the reactions in problem 20, determine the mass of any reactants left over.

22. Each of the reaction below occur in water. Determine the net ionic equation for each.
    a. Lead (II) acetate is mixed together with a solution of ammonium bromide.
    b. Barium nitrate is mixed with ammonium sulfate.
    c. **Sodium sulfide is added to a solution of magnesium chloride.**
    d. **Calcium nitrate and sodium phosphate are combined.**

23. 3.5 grams of each of the following hydrocarbons is combusted in **excess** oxygen. If 1.02 grams of water is produced, determine the **% yield** of the reaction.
    a. C_2H_6
    b. C_6H_6
    c. **C_3H_5**

Solutions (Bonus: 3/6)

24. Consider each of the following:
    a. 26 mg of aluminum chloride is added to 1.2 L of 526 μM silver (I) acetate. Determine the mass of any solids that form.
    b. 4.28 g of manganese (II) bromide is added to 526 mL of 1.2 M lead (II) nitrate. Determine the mass of any solid product that forms.

25. What mass of solute is necessary to make:
    a. 1.8 L of 252 mM aluminum hypochlorite.
    b. 2.52 L of 1.86 M of bismuth (II) sulfate.

26. Many ionic compounds are available as 'hydrates'. This means that the solid form of the salt readily adsorbs water. These are named by adding 'hydrate' to the end of the name with a prefix suggesting how many waters (for example sodium chloride dihydrate has a formula of $NaCl \bullet (H_2O)_2$ and a MW of 94.5 g mol^{-1}). To make solutions from these compounds, the adsorbed water needs to be accounted for. Predict how much of the solid is needed to make the following solutions:
    a. 1.4 L of 462 mM nitrate from magnesium nitrate heptahydrate.
    b. 2.4 L of 250 μM perchlorate from a titanium (IV) perchlorate tetrahydrate.

27. Determine the resulting concentration of **chloride** when:
    a. 1 L of water is added to 3.2 L of 1.02 M $MgCl_2$
    b. 512 mL of water is added to 288 mL of 500 mM iron (III) chloride.

28. For each of the following reactions, calculate the mass of any solid that forms and the concentration of all Fe^{3+} and OH^- ions left in solution.
    a. 2.13 L of 0.868 M NaOH is mixed with 3.41 L of 562 mM $Fe(NO_3)_3$.
    b. 5.86 μL of 7.31 M $Ca(OH)_2$ is mixed with 1.00 L of 12 μM $FeCl_3$.

29. Determine if each of the following compounds will be soluble in water.
    a. Na_2S
    b. Fe_2S_3
    c. $Ca(OH)_2$
    d. $Mo_3(PO_4)_4$

30. What is the name of each ionic compound in problem 29?

31. For each pair, determine which would be more soluble in water.
    a. NH_3 or PH_3
    b. NaCl or AgCl
    c. **CH_3OH or CH_3SH**
    d. **CH_3OH or CH_3OCH_3**

Gases (Bonus 3/9)

32. Determine the volume of the product formed if the temperature and pressure remain constant.
    a. 2.8 L of N_2 (g) is added to 4.4 L of H_2 gas. NH_3 gas is formed.
    b. 2.8 L of N_2 (g) is added to 4.4 L of O_2 gas. N_2O_5 gas is formed.

33. Identify the diatomic gas.
    a. A 500 mL flask contains 12 grams of a gas at 490 K and pressurized to 385.27 kPa.
    b. A 250 mL flask contains 2.5 grams of a gas at 26.85 °C and pressurized to 779.51 kPa.

34. Determine the mass of the solid formed and the final pressure in the flask when:
    a. 5 grams of solid phosphorus is added to 4 L of Cl_2 gas at 1.4 atm and 212 °C. During the reaction, which produces PCl_5 (s), the volume remains the constant but the temperature increases by 15 °C.
    b. **12 grams solid I_2 is added to a 1.8 L flask containing F_2 gas at 5 atm and 100 °C. The reaction produces solid IF_5. During the reaction, the temperature increased by 25 °C and the volume doubled.**

35. Calculate the partial pressure of H_2O (in atm) when:
    a. The total pressure is 680 torr and the mole fraction of H_2O is 52%.
    b. **The total pressure is 107 kPa and the mole fraction of H_2O is 14%.**

36. For each of the following combustion reactions, determine the total pressure in the flask after each reaction has completed. Remember that ALL gases that are produced or remain (i.e. unconsumed reactants), contribute to the total pressure in the reaction flask. Assume that both products are gases and the reactions proceed with 100% yield.
    a. 1.82 atm of O_2 is added to a 2.00 L flask containing 250 mL of liquid octane (C_8H_{18}), which has a density of 703.00 kg m^{-3}. The temperature remains at 100 °C throughout the reaction.
    b. **0.56 atm of O_2 is added to a 1.00 L flask containing 12.5 mL of ethanol (CH_3CH_2OH), which has a density of 789.00 kg m^{-3}. The temperature remains at 100 °C throughout the reaction.**

Kinetics (Bonus: 3/20)

37. Given the following data, use the method of initial rates to determine the rate law – make sure to include values for the order with respect to each reactant and the value of the rate constant with the correct units.

    a.

Experiment	$[Cu^{2+}]$ (mM)	$[OH^-]$ (mM)	Rate (mM min^{-1})
1	0.468	0.147333	2.04×10^{-3}
2	0.468	0.884	0.0123
3	1.404	0.884	0.1101

b.

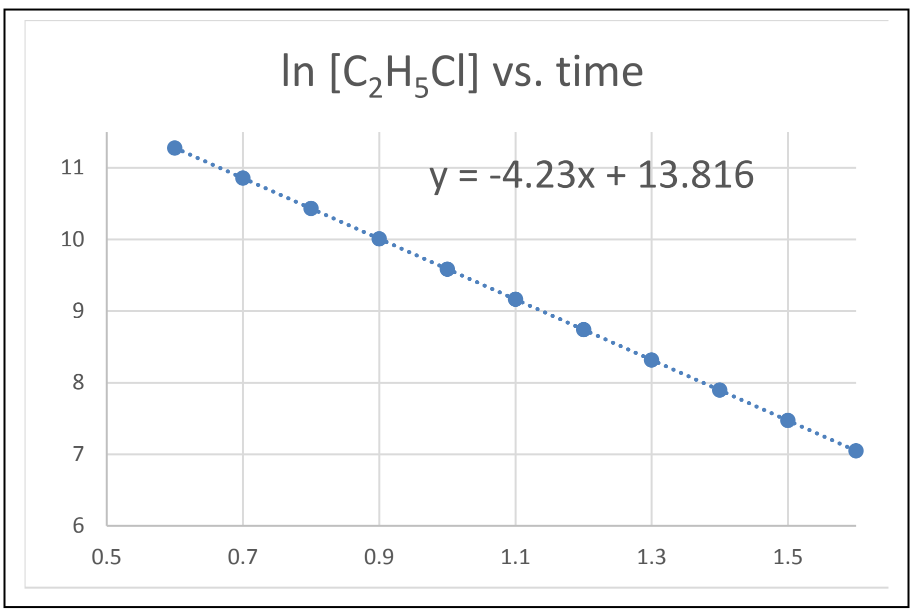
Experiment	$[NH_3]$ (mM)	$[H_2]$ (mM)	Rate (mM sec^{-1})
1	1.866	0.15	0.420
2	1.866	0.26	1.26
3	1.52	0.26	1.03

38. For each of the reactions in problem 37, determine the rate of the reaction when the concentration of each reactant is 0.5 M

39. For each of the data sets on the following page, determine:
    a. The order of the reaction (You'll need to have 3 graphs to determine this for certain!).
    b. Determine the rate constant with the correct units.
    c. The rate law
    d. The initial concentration of the reactant.
    e. The initial rate.

Example: $C_2H_5Cl\ (g) \rightarrow C_2H_5\ (g) + HCl\ (g)$

Time (min)	$[C_2H_5Cl]$ (μM)
0.6	79024.29
0.7	51767.12
0.8	33911.54
0.9	22214.72
1	14552.39
1.1	9532.96
1.2	6244.838
1.3	4090.86
1.4	2679.835
1.5	1755.503
1.6	1149.992



Your turn: $2\ HCl\ (g) \rightarrow H_2\ (g) + Cl_2\ (g)$

Time (sec)	[HCl] (M)
39	0.398883
42	0.392773
45	0.386847
48	0.381098
51	0.375516
54	0.370096
57	0.36483
60	0.359712
63	0.354736
66	0.349895
69	0.345185

Challenge Questions: Submit your answers directly to the professor for bonus points. You are strongly encouraged to stop by if you are stuck.

40. The Haber-Bosch process changed the world - it is a chemical means to convert nitrogen gas into forms of nitrogen that can be used by plants (so, it's a way to make chemical fertilizer). The first step in this chemical process is the synthesis of ammonia gas from hydrogen and nitrogen gasses. If done under aerobic conditions (with O_2 around), the ammonia can react with gaseous oxygen to yield liquid water and aqueous nitric acid. If oxygen is the limiting reactant in the 2nd reaction, ammonium nitrate will be synthesized from the nitric acid when it reacts with the excess ammonia.
    a. Write three balanced reactions that represent the chemistry described above.
    b. 10.8 L of H_2 at 900. °C and 390.01 kPa is combined with 8.23×10^{-3} cubic meters of N_2 at 665 K pressurized to 1.5 atm. After the synthesis reaction completes, the temperature has changed to 1000 °C. Determine the total pressure in the flask after the reaction completes. Assume 100% yield and a total volume that is the sum of the two reaction flasks.
    c. Starting with the amount of NH_3 that you found in part b, determine the volume of O_2 at STP that is needed to completely convert the ammonia to ammonium nitrate.

41. 14g of dry ice (CO_2 (s)) is put into a 4.2 L chamber that has some amount of N_2 in it. This chamber is held at a constant temperature of 212 K as all of the CO_2 sublimates (s$\rightarrow$g). After this process has finished, it is determined that CO_2 accounts for 87% of the total pressure.
    a. What is the pressure of CO_2?
    b. What is the pressure in the chamber after the sublimation finishes?
    c. How many moles of N_2 is present in the chamber?
    d. What was the total pressure in the chamber prior to the sublimation?

Answers to black problems:

12a. 1.48 moles C 12b. 7.59×10^4 moles 14a. 0.06 mol 16a. $C_2Cl_3O_2H$ 16a. $C_{24}Cl_{12}O_6H_{36}$ 18a. PCl_5 (s) + 4 H_2O (l) → H_3PO_4 (l) + 5 HCl (g) 18c. 4 C_3H7 (g) +19 O_2 (g) →12 CO_2 (g) +14 H_2O (g) 20a. 2.19 g NH_3 22. a. Pb^{2+} + 2 Br^- → $PbBr_2$(s) b. Ba^{2+} + SO_4^{2-} → $BaSO_4$(s) 24a. 0.084 g AgCl (s)	13.a 74.44 g/mol 15a. 11.3% 17a. combustion 17b. single displacement 19a. 52.1 g CO_2 and 24.88 g H_2O 21. 1.41 g H_2 left no N_2 left 23. a. 16.2% b. 42.1% 25a. 82.3 g $Al(OCl)_3$
26a. 88.75 g $Mg(NO_3)_2$●$7H_2O$ (remember we're looking for 462 mM nitrate) and you need to consider the molar mass of the whole complex.	27a. 1.55 M Cl^-
28a. 65.84 g $Fe(OH)_3$ formed 0.234 M $Fe(NO_3)_3$ left 30a. sodium sulfide b. Iron (III) sulfide	29a. yes b. no 31a. NH_3 (polar and H-bonds) b. NaCl (AgCl is not soluble)
32a. 2.93 L NH_3	33. I_2
34a. 11.71 g PCl_5. P = 0 because all gas is consumed and none is produced	35. 353.6 torr H_2O
36a. 2.474 atm.	37a. Rate = 0.06323 $mM^{-2}min^{-1}[Cu^{2+}]^2[OH^-]$
38a. rate = 7.9×10^{-3} mM min^{-1}	39a.1st order b. k = 4.23 min^{-1} c. Rate = 4.23 $min^{-1}[C_2H_5Cl]$ d. $[C_2H_5Cl]_0$ = 1e6 μM e. Initial rate = 4.23×10^6 μM min^{-1}