Problem Set 2 (**Due February 20th by 7:00 PM**)

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

Challenging Review Questions. (Bonus: Due 2/6)

The first 8 ionization energies of element "X" are shown below (in aJ). Use this information to answer 1-4.

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7	IE_8
1.68	3.17	4.84	8.24	10.42	35.32	42.23	49.60

1. How many valence electrons does X have?

2. What group does X belong to?

3. Which element would be most similar to X? Zinc, Iron, Calcium, Tin, Bismuth, or Bromine?

4. Clearly explain why the difference between IE_3 and IE_4 is greater than the difference between IE_2 and IE_3.

5. Determine the wavelength of the photon needed to move an electron from the ground state of a hydrogen atom to the 7^{th} energy level. Report your answer in nm.

6. The ionic radius of $^{58}Ni^{2+}$ is 63 pm. Calculate its density in g mL^{-1}. Hint: a similar problem is on the 1^{st} exam.

7. Using your understanding of periodic trends, order these elements by increasing density (least dense to most dense). **O, N. B, F**

Ions and Ionic Compounds (Bonus: 2/6)

8. Predict common charge on each of the following. If more than one exist, write them all. If a common charge does not exist, select 0.

   Hydrogen Strontium **Lead** **Aluminum** Fluorine Selenium **Argon**

9. Classify each of the following as covalent or ionic bonds:

N and N N and Na Ca and H **Sc and Cl** **Cl and F** **Na and H**

10. Predict the ionic compound that will form between the following:
    a. Nitrogen and sodium
    b. Magnesium and Nitrogen
    c. Aluminum and Phosphorus
    d. Selenium and Potassium

11. For each of the following lists, identify all variable charge metals.
    a. Na, Zn, Bi, Re, Mn, In
    b. Ru, Cd, Sn, Zr, K, Al

12. Determine the electron configuration for each of the following. You may use shorthand notation.

Fe^{+3} **Fe^{+2}** In^{+1} **In^{+3}** **Cu^{+1}** Cu^{+2} Mn^{+2} **Mn^{+7}**

13. Name each of the following:

NaH BeF_2 **$(NH_4)_2O$** Na_2CO_3 $CrCl_6$ **Fe_2S_3**

14. Determine the molecular formula:

Zinc Chloride **Thallium (I) Phosphate** Thallium (III) Phosphide **Tin (IV) Oxide**

Sodium nitride Sodium nitrite Sodium nitrate Iron (III) Selenide

Molecular Compounds (Bonus: 2/13)

You will need to draw the Lewis Structure for each compound to answer most of these questions

Answer problem 15-19 for each of these compounds.

ClO_2^- ClO_3^- **CO_2** CO_3^{2-} PCl_3 **NO_2^-** O_3 **S_3** NO_3^- **I_2F^-**

15. What is the central atom of the compound?
16. How many double bonds are present in the compound?
17. How many lone pairs are on each atom?
18. What is the formal charge on each atom?
19. Does this molecule have resonance forms? If yes, how many resonance forms exist?

20. For each pair, determine which molecule is the most stable. Give a brief explanation why you made your selection.
    a. BrO_3^- vs. FO_3^-
    b. NO_4^{-3} vs. PO_4^{-3}
    c. I_3^- vs. F_3^-

21. For each of the following situations, determine the molecular formula for a neutral molecule **made from only nitrogen and chlorine** that contains:
    a. A single bond between the nitrogen atoms.
    b. A double bond between the nitrogen atoms.

22. Name each of the following compounds.

N_2O_2 N_2O_4 **C_2H_6** **SF_6**

23. For each pair, pick the molecule that has the **strongest** bond between the indicated atoms.
    a. O_2 vs H_2O_2 Compare O-O bonds
    b. N_2 vs. N_2H_2 Compare N-N bonds
    c. C_2H_6 vs. C_2H_4 Compare C-C bonds

24. For each pair, pick the molecule that has the **longest** bond between the indicated atoms.

a. O_2 vs H_2O_2 Compare O-O bonds

b. N_2 vs. N_2H_2 Compare N-N bonds

c. C_2H_6 vs. C_2H_4 Compare C-C bonds

25. Name each of the following:

a. HCl

b. H_2SO_4

c. HNO_3

d. $HBrO_2$

e. $HBrO_4$

f. HBrO

26. Write the chemical formula for each compound.

a. Nitrous acid

b. Sulfurous acid

c. Carbonic acid

d. Hydrobromic acid

e. Acetic acid

Molecular Geometry, Polarity, and Hybridization (Bonus: 2/16)

27. What is the hybridization of each **boldfaced atom** in:

CCl_3**F** **N**H_3 **Br_3^{-1}** **Xe**F_4 **S**F_4 **SeF_6** **S**O_3^{-2}

28. For each of the following pairs, determine which has smaller bond angles.

a. CH_2O vs. CH_4 compare H-C-H bond angles

b. NH_4^+ vs. NH_3 compare H-N-H bond angles

c. SO_3 vs. SO_2 compare O-S-O bond angles

d. SOF_4 vs. SF_4 compare F-S-F bond angles

29. Draw the Lewis structure for each molecule listed below and answer each of following questions about the **central atom**.

a. Determine the electron geometry.

b. Determine the molecular geometry.

c. Determine the hybridization.

BrF_3 **PH_3** Br_3^{-1} **XeF_4** SF_4 SeF_6 SO_3^{-2}

30. Determine how many sigma bonds and pi bonds are present between the indicated atoms.

a. CH_2O C and O

b. HCN C and N

31. Determine if each of the following molecules are polar:

CH_3OCH_3 (C-O-C connectivity) CBr_3F **XeF_2** **CH_2NH**

32. For each of the following molecules, identify ALL intermolecular forces that stabilize condensed phases.

H_2O $CH_3CH_2CH_2CH_3$ **PH_3** **HF** HCl NaCl

33. For each of the following pairs, determine which has the higher melting temperature.

CH_4 or CF_4 CF_4 or CBr_3F PH_3 or NH_3 **HF or HCl** **TeH_2 or SeH_2**

34. Use Molecular Orbital (MO) Theory to determine the **bond order and number of unpaired electrons** for each of the following diatomic atoms. Recall that the orbital order changes when Oxygen or Fluorine are involved:

MO order for just carbon and/or nitrogen: σ_{2s}, σ_{2s}*, $\pi_{2p,}$ σ_{2p}, π_{2p}*, σ_{2p}*
MO order when oxygen and/or fluorine are part of the molecule: σ_{2s}, σ_{2s}*, σ_{2p}, $\pi_{2p,}$ π_{2p}*, σ_{2p}*

C_2 **CO** CN^{-1} N_2 **O_2** NO F_2 **OF^{+1}** OF^{-1}

Challenge Questions

Submit your answers to this question **directly to me for bonus points**. You are strongly encouraged to stop by my office with questions.

35. It is possible to mathematically predict if a compound will be ionic or covalent using measurable values for several physical properties that we've discussed in class. To a first approximation, this can be accomplished by considering:

- the amount of energy needed to ionize the cation $X \rightarrow X^+ + e-$
- the amount of energy gained when the anion forms $X + e- \rightarrow X^-$
- the charge stabilization gained when the two ions interact $E_p = 231\ aJ \cdot pm \left(\frac{q_1 q_2}{r}\right)$

Using the data in the table below, determine which of the following ionic compounds forms most favorably. Clearly justify your answer.

NaF, NaCl, NaBr, KF, KCl, or KBr

Atom	Ionization Energy 1 (aJ)	Electron Affinity 1 (aJ)	Ionic Radius (pm)
Sodium	0.823		105
Potassium	0.695		138
Chlorine		0.5795	181
Fluorine		0.5449	113
Bromine		0.5688	196

36. The following are descriptions of two different compounds. Your task is to determine the Lewis structure of the compound.
    a. This monovalent anion (meaning a -1 charge) consists of a neutral central atom from the 4th shell with trigonal pyramidal geometry. It is bonded to two halogens from the 3rd shell and one shell 2 element that carries a -1 formal charge. The central atom has one pi bond.

    b. This monovalent anion consists of a neutral central atom from the 5th shell with square pyramidal geometry. It is covalently bonded to two different types of atoms from the 2nd shell, none of which carry a permanent formal charge of -1. One pi bond exists in this molecule and two resonance forms can be drawn.

Black Problems:

8. H^{+1} or H^{-1} Sr^{+2} F^{-1} Se^{-2}

9. N and N → covalent N and Na → ionic Ca and H → ionic

10. Na_3N Mg_3N_2

11. Bi, Re, Mn, In

12. Fe^{3+}: [Ar] $3d^5$ In^{+}: [Kr] $5s^2 4d^{10}$ Cu^{+2}: [Ar] $3d^9$ Mn^{+2}: [Ar] $3d^5$

13. Beryllium fluoride sodium carbonate chromium (VI) chloride

14. $ZnCl_2$ TlP $NaNO_2$ $NaNO_3$

15. ClO_3^- = Cl CO_2 = C CO_3^{2-} = C PCl_3 = P O_3 = O NO_3^- = N

16. ClO_3^- = 2 CO_2 = 2 CO_3^{2-} = 1 PCl_3 = 0 O_3 = 1 NO_3^- = 1

17. ClO_3^- → Cl = 1 1 oxygen has 3 and two oxygens have 2 CO_2 → C = 0 O = 2 CO_3^{2-} → C = 0 2 oxygens have 3 and one oxygen has 2 PCl_3 → P = 1 Cl = 3 O_3 → central O has 1, one outer O has 2 and the other has 3 NO_3^- → N = 0 two O have 3, one O has 1

18. ClO_3^- → Cl = 0 the oxygen double bond = 0, oxygen with single bond = -1 CO_2 → C = 0 O = 0
CO_3^{2-} → C = 0 the oxygen double bond = 0, oxygen with single bond = -1 PCl_3 → P = 0 Cl = 0
O_3 → central O = +1, the oxygen double bond = 0, oxygen with single bond = -1 NO_3^- → N = +1 the oxygen double bond = 0, oxygen with single bond = -1

19. ClO_3^- = 3 CO_2 = 1 CO_3^{2-} = 3 PCl_3 = 1 O_3 = 2 NO_3^- = 3

20. a. BrO_3^- because expanded the octet allow formal charge to be minimized. F cannot expand the octet.
b. PO_4^{-3} because expanded the octet allow formal charge to be minimized. N cannot expand the octet.

21. N_2Cl_4

22 dinitrogen dioxide dinitrogen tetraoxide

23. a. O_2 (double bonds are stronger than single bonds)
b. N_2 (triple bonds are stronger than double bonds)

24. H2O2 → single bonds are longer than double bonds
N2H2 → double bonds are longer than triple bonds

25. a. Hydrochloric acid
b. Sulfuric acid

26. a. HNO_2

27. **C**Cl_3**F** → C = sp^3, F = sp^3 **N**H_3 → sp^3
Br_3^{-1} → terminal bromines are sp^3, central is sp^3d
SF_4 → sp^3d **S**O_3^{-2} → sp^3

28. CH_4 Tetrahedral vs. trig. planar
NH_3 because of lone pair

29. BrF_3 a. Trig. Bipyramidal b. T-shaped c. sp^3d Br_3^{-1} a. Trig. Bipyramidal b. linear c. sp^3d
SF_4 a. Trig. Bipyramidal b. seesaw c. sp^3d
SeF_6 a. Octahedral b. Octahedral c. sp^3d^2
SO_3^{-2} a. Tetrahedral b. Trig. pyramidal c. sp^3

30. a. Double bond → one sigma and one pi

31. CH_3OCH_3 → yes CBr_3F → yes

32 H_2O (London Dispersion, dipole-dipole, H-bond)
$CH_3CH_2CH_2CH_3$ (London Dispersion)
HCl (London Dispersion, dipole-dipole)
NaCl (London Dispersion, Ion-Ion)

33. CF_4 because it's bigger = stronger LDF
CBr_3F because it's polar
NH_3 because it can H-bond

34. C_2 – BO=2, 0 unpaired; CN^- – BO=3, 0 unpaired
N_2 – BO=3, 0 unpaired; NO – BO=2.5, 1 unpaired
F_2 – BO=1, 0 unpaired; OF^{-1} – BO=1, 0 unpaired