Chem 103 Summer 2022
Professor Goldsmith

Key Name

EXAM 2 – July 1, 2022

#1 (/20)_____

#2 (/15)_____

#3 (/15)_____

#4 (/15)_____

#5 (/20)_____

#6 (/15)_____

Bonus (/3)_____

Total (/100)_____

• PLEASE SHOW ALL YOUR WORK

1. (20 points)

a) Place these **ions** in order of **increasing** size (i.e. smallest to largest): Sr^{+2}, S^{-2}, Rb^{+1}, Mg^{+2}

Sr^{2+} Mg^{2+} Rb^{+1} S^{-2}

b) Write the electron configuration for the phosphorous cation (P^{+1}). Will this ion be affected by a magnetic field?

$1s^2 2s^2 2p^6 3s^2 3p^2$

↖ Yes paramag

c) Which has the greater first ionization energy, As or Se? Explain – not just in terms of left/right trends but really **why** your answer is what it is.

As : $[Ar] 4s^2 4p^3$ ← greater IE

Se : $[Ar] 4s^2 4p^4$ ↑↓ ↑ ↑

easier to remove b/c paired

d) Explain how the size of atoms depends on their position on the periodic table (i.e. explain the trends in atomic sizes)

small

b/c n increases going down and e⁻ farther from nucleus

large

large ← → small

in a row n is same increased nuclear charge pulls in e⁻ closer

e) Draw the radial distribution function for the 3s orbital and explain what it means. What other orbital or orbitals could have a radial distribution function that looks like this one?

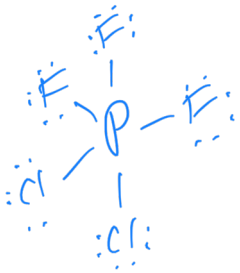
where prob is zero of finding electrons

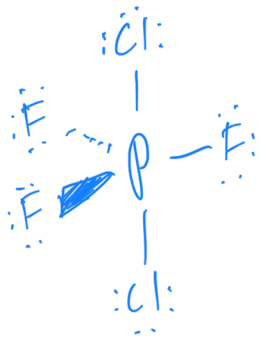
4p, 5d, 6f have same shape of radial distrib fxn

2. (15 points) 5 + 7x7 + 2x7 = 40 e⁻

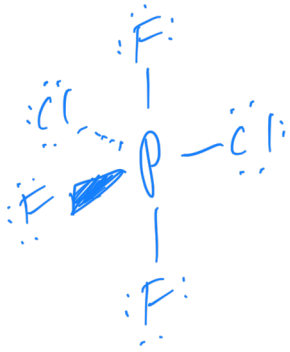
For the molecule PF_3Cl_2

- Draw the correct Lewis structure including all the lone pairs
- Name the electron pair geometry – trigonal bipyramid
- Name the molecular geometry – trigonal bipyramid
- There are **3** different 3-D molecular structures for this molecule – draw all 3 of them with appropriate three dimensionality
- Indicate which of your structures are polar and which are not polar – **and explain your reasoning.**

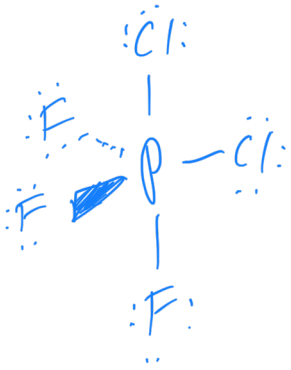




non polar



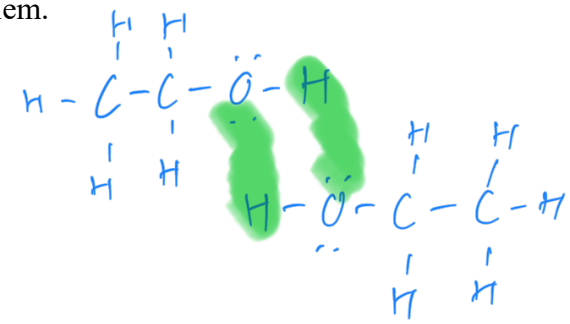
polar



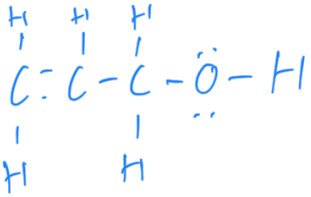
polar

3.(15 points)

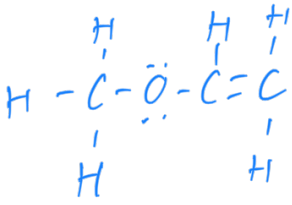
a) Draw the Lewis structures of two ethanol molecules (CH_3CH_2OH) and show the hydrogen bonding interaction(s) between them.



b) There are at least 9 different Lewis structures for C_3H_6O. Draw **2** of them that you are **sure** have **different** boiling points. Identify the one (of the two you drew) that has the **lower** boiling point and explain why that is.



higher bp
can do hydrogen bonding



lower bp
cannot do hydrogen bonding

c) Identify which molecule has the higher boiling point and **explain** why: C_8H_{18} and C_3H_8.

Both non polar
Large mass → more e⁻ → more polarizable
stronger ID/ID interactions

d) Butanol ($CH_3CH_2CH_2CH_2OH$) and pentane (C_5H_{12}) mix well with one another. Explain why this is **and** describe **all** of the intermolecular interactions that are taking place in this butanol/pentane mixture.

Butanol has large non polar portion of structure

B/B - dipole/dipole, hydrogen bonding, Induced dipole/Induced dipole
P/P - ID/ID
P/B - D/ID, ID/ID

4. (15 points)

a) You have a flask with a volume of 4.75 L that says on it "Danger, this flask will explode if the pressure inside is greater than 15.0 atm". One of your colleagues just put 90.0 grams of oxygen gas inside the flask. All of a sudden the heating system in your lab goes haywire and the lab starts to get hotter and hotter. At what temperature will the flask explode?

$90.0\text{ g } O_2 \times \frac{1\text{ mol}}{32\text{ g}} = 2.81\text{ mol } O_2$

$PV = nRT \qquad T = \frac{PV}{nR} = \frac{(15.0\text{ atm})(4.75\text{ L})}{(2.81\text{ mol})(0.08206\ \frac{\text{L atm}}{\text{mol K}})} = 309\text{ K}$

above 309 K flask will explode

b) They fix the heat in your lab and it is now a comfy 24°C. Into flask described above (4.75 L, containing 90.0 grams of oxygen, will explode if pressure >15.0 atm) you add 25.5 grams of xenon gas. Was this a bad idea? (i.e. did the flask explode?) You must show all work for full credit.

$75.5\text{ g Xe} \times \frac{1\text{ mol}}{131\text{ g}} = 0.195\text{ mol Xe}$

$0.195\text{ mol Xe} + 2.81\text{ mol } O_2 = 3.01\text{ mol gas}$

$P = \frac{nRT}{V} = \frac{(3.01\text{ mol})(0.08206\ \frac{\text{L atm}}{\text{mol K}})(273.15+24\text{ K})}{4.75\text{ L}}$

$P = 15.44\text{ atm} \rightarrow \text{BOOM}$

5. (20 points)

a) Explain, according to valence bond theory what orbitals are involved in the 3 N-H bonds of NH_3.

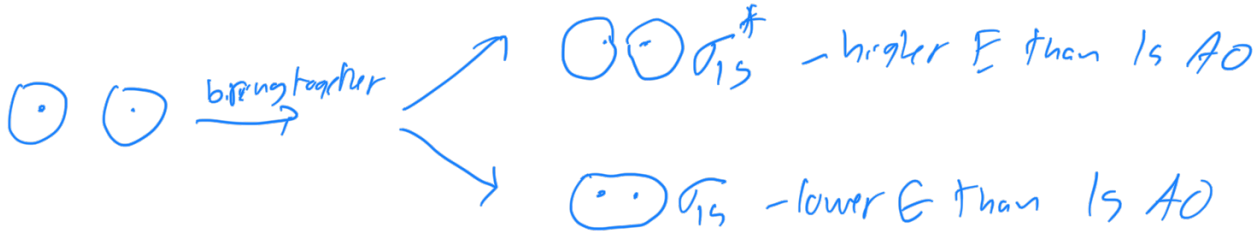
unhybridized 1s on H overlapping w/ sp^3 hybrid on N

b) Why is a consideration of just the simple, unhybridized, atomic orbitals of N and H insufficient to describe the bonding in NH_3?

tetrahedral e-pair/trigonal pyramid geometry requires overlapping orbitals at angles $\neq 90°$. And unhybridized AOs of N are all at 90°

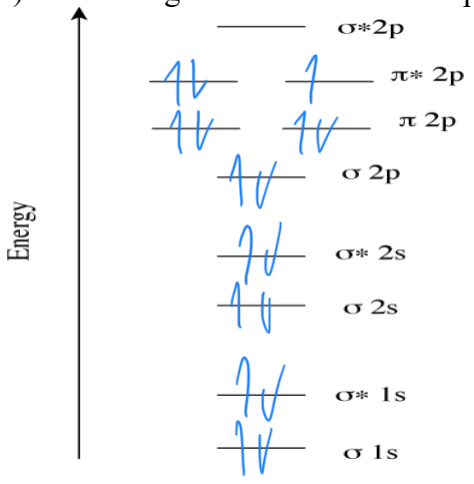
c) Using molecular orbital theory, describe the bonding in H_2. Start by drawing the relevant atomic orbitals on each atom and then show pictorially how those orbitals combine to make molecular orbitals- make sure to label the molecular orbitals appropriately.

1s AO + 1s AO → σ_{1s} and σ_{1s}^*



d) On the diagram below fill in the appropriate electrons for the F_2^{+1} cation.

Size (alle, not just valence)



e) What is the bond order of the fluorine-fluorine bond in F_2^{+1}? It is a stronger or a weaker bond than in F_2? Explain.

BO $F_2^+ = \frac{10-7}{2} = 1.5$ - stronger bond b/c fewer e⁻ in antibonding orbitals

BO $F_2 = \frac{10-8}{2} = 1$

6. (15 points) Imagine a model for the hydrogen atom that is different than the one that we talked about in class. In this alternative model, the energy of each energy level (E_n) is given by the following formula: $E_n = -3.25 \times 10^{-18}\ J\ (1/n^3)$ where n is the principal quantum number describing that energy level. If you want to cause an electron to be excited from the n=2 level to the n=5 level by shining light on the atom, what is the wavelength of light that is necessary to make this happen?

$E_5 = -3.25 \times 10^{-18}\ J \left(\frac{1}{5^3}\right) = -2.6 \times 10^{-20}\ J$

$E_2 = -3.25 \times 10^{-18}\ J \left(\frac{1}{2^3}\right) = -4.06 \times 10^{-19}\ J$

$\Delta E = -2.6 \times 10^{-20}\ J - -4.06 \times 10^{-19}\ J = 3.8 \times 10^{-19}\ J$

$E_{photon} = 3.8 \times 10^{-19}\ J = \frac{hc}{\lambda}$

$\lambda = \frac{(6.626 \times 10^{-34}\ J \cdot s)(3 \times 10^{8}\ m/sec)}{3.8 \times 10^{-19}\ J}$

$\lambda = 5.23 \times 10^{-7}\ m$ or $523\ nm$

Bonus (3 points) What is your electron pair geometry and what is your molecular geometry? Why?

LAST NAME _____

FIRST NAME _____