Chem 103 Summer 2024
Professor Goldsmith

Key ____________________ Name

EXAM 2 – June 28, 2024

#1 (/20)____________

#2 (/10)____________

#3 (/20)____________

#4 (/20)____________

#5 (/15)___________

#6 (/15)____________

Bonus (/3)____________

Total (/100)____________

• SHOW ALL YOUR WORK

1. (20 points)

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

Mg^{2+} Sr^{+2} Rb^{+1} Se^{2+}

small ⟶ large

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

16-1 e = 15e

$1s^2 2s^2 2p^6 3s^2 3p^3$ ⟶ ↑↓ (3s) ↑ ↑ ↑ (3p)

paramagnetic - (yes) affected by magnet

c) Which has the greater electron affinity: P or Si? **EXPLAIN.**

Si: valence $3s^2 3p^2$ ↑↓ ↑ ↑ _ ← empty spot

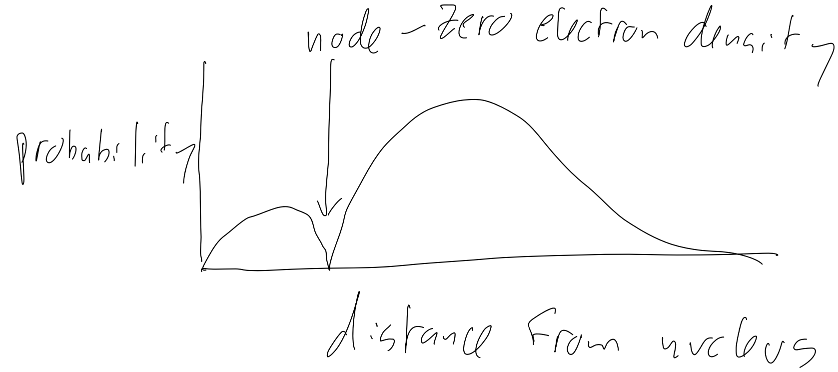
P valence $3s^2 3p^3$ ↑↓ ↑ ↑ ↑ - adding e- to P causes pairing + more repulsion

Si has greater EA

d) Which has the greater 2nd ionization energy Na or Si? **EXPLAIN.**

Na → 2nd electron removed is a core electron

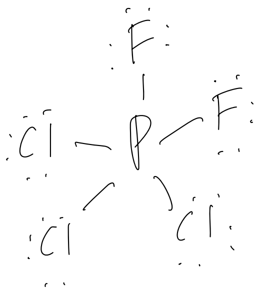
e) Draw the radial distribution function for the 3p orbital and explain its features. What other orbital(s) could have a radial distribution function that looks like this one?

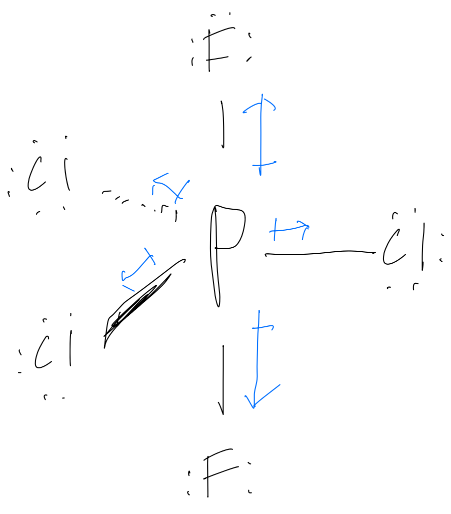


2s, 4d, 5f look similar

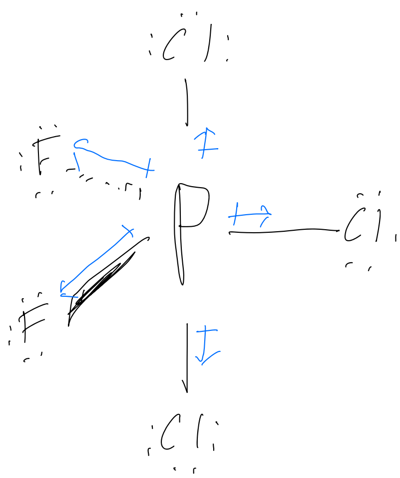
2. (10 points)
For the molecule PF_2Cl_3 – $40 e^-$

- Draw the correct Lewis structure including all the lone pairs
- Name the electron pair geometry – trigonal bipyrimidal
- Name the molecular geometry – trigonal bipyrimidal
- 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.**

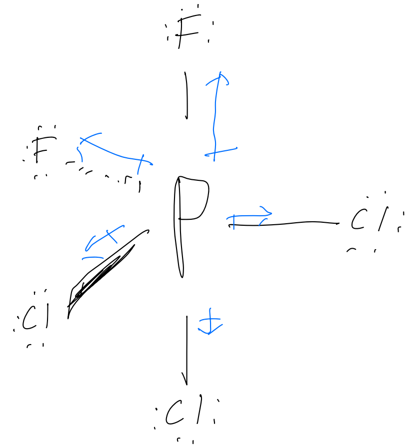




nonpolar
vectors cancel



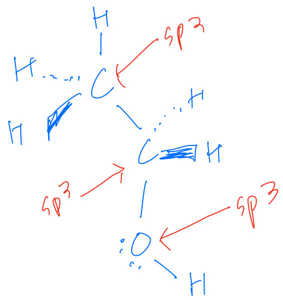
polar
vectors don't cancel

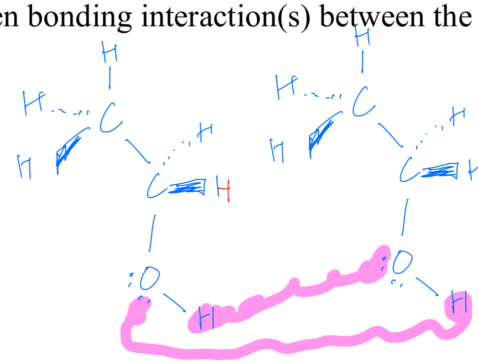


polar
vectors don't cancel

3.(20 points)

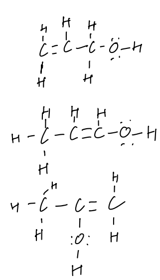
a) Draw the 3D structures of two ethanol molecules (CH_3CH_2OH), indicate the hybridization of all non-hydrogen atoms and show the hydrogen bonding interaction(s) between the molecules.



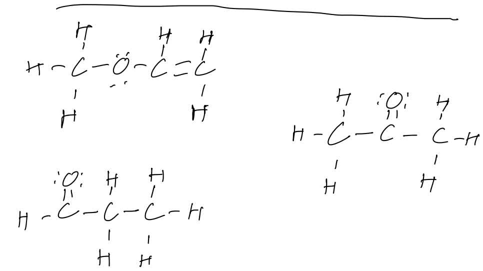


b) There are at least 9 different Lewis structures for C_3H_6O. Draw **2** of them that you are **sure** have **different** boiling points. Identify the one (of the two you drew) that has the **lower** boiling point and explain why that is.

structures w/ hydrogen bonding



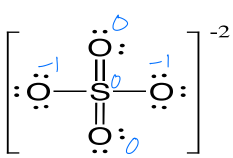
structures w/out hydrogen bonding



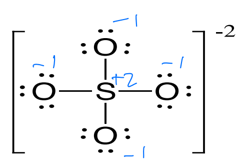
any of structures w/out hydrogen bonding will have lower bp than any of structure with hydrogen bonding

c) For each of the structures below, determine the formal charge on each atom. Explain which of the structures is a better representation of the true nature of the SO_4^{2-} anion

A



B



better b/c fewer non-zero formal charges

d) Hexanoic acid ($CH_3CH_2CH_2CH_2CH_2COOH$) and hexane ($CH_3CH_2CH_2CH_2CH_2CH_3$) mix well with one another. Explain why this is **and** describe **all** of the intermolecular interactions that are taking place in this hexanoic acid/hexane mixture.

HA/HA – dipole/dipole, hydrogen bonding, dipole/induced dipole, induced dipole/induced dipole

Hex/Hex – induced dipole/induced dipole

HA/Hex – dipole/induced dipole, induced dipole/induced dipole ← interactions allow for mixing

4. (20 points)

The Badwater ultramarathon starts in Death Valley and finishes (135 miles later) on Mount Whitney at an elevation of 8350 feet. At your beach house (assume sea level) where the temperature is a toasty 31.0 °C you put 0.65 grams of helium into a balloon to take with you on the race.

↳ 304.15 K

a) What is the volume of the balloon at your house?

$$0.65\,g\ He \times \frac{1\ mol}{4.00\,g} = 0.1625\ mol\ He$$

$$V = \frac{nRT}{P} = \frac{(0.1625\ mol)(0.08206\ \frac{L\,atm}{mol\,K})(304.15\,K)}{1.0\ atm}$$

$$V = 4.06\ L$$

b) You've have camped on Mount Whitney before and you know that at the finish line of the race it takes a long time to cook pasta because the boiling temperature of water is only 91.3°C there. When you finally get to the finish line (in the middle of the night) the temperature is 21.1°C. What is the volume of your balloon at the finish line?

Need to know atmospheric pressure

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$T_1 = 373.15\,K$, $P_1 = 1\ atm$ } boiling @ 1 atm

$T_2 = 364.45\,K$, $P_2 = ?$ } boiling at altitude

$$\Delta H_{vap} = 2256\ \frac{J}{g} \times \frac{18.02\,g}{1\ mol} = 40653\ \frac{J}{mol}$$

$$\ln\left(\frac{P_2}{1\,atm}\right) = \frac{-40653\ \frac{J}{mol}}{8.314\ \frac{J}{mol\,K}}\left(\frac{1}{364.45\,K} - \frac{1}{373.15\,K}\right)$$

$$\ln P_2 = -0.3128 \longrightarrow P_2 = 0.73\ atm$$

$$V = \frac{(0.1625\ mol)(0.08206\ \frac{L\,atm}{mol\,K})(294.25\,K)}{0.73\ atm} = 5.38\ L$$

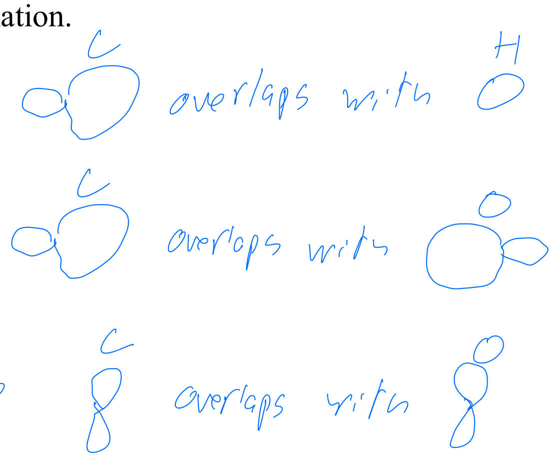
5. (15 points)

a) Explain, according to **valence bond theory**, what orbitals are involved <u>all</u> of the bonds of CH_2O. Draw a picture to further clarify your explanation.

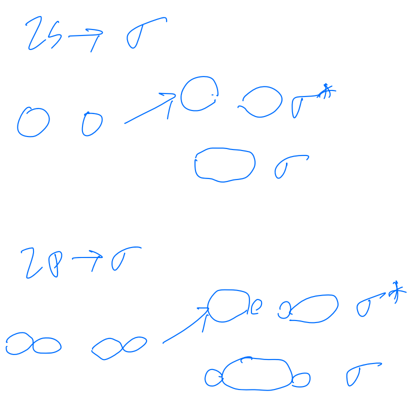
C H σ   C sp2 and H 1s

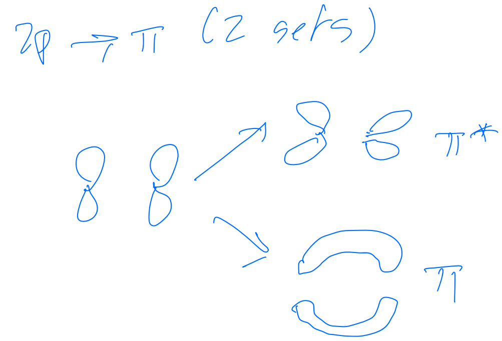
C O σ   C sp2 and O sp2

C O π   C unhyb p and O unhyb p

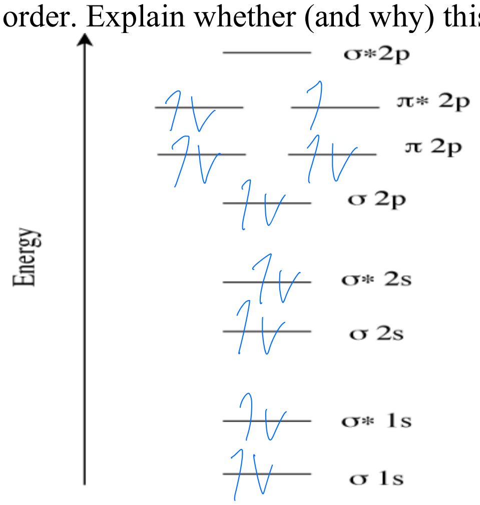


b) Using molecular orbital theory, describe the bonding in O_2 (**only consider the electrons in the valence shell**). Start by drawing the relevant atomic orbitals on each atom and then show **pictorially** how those orbitals combine to make molecular orbitals- make sure to label the molecular orbitals appropriately.





c) On the diagram below fill in the appropriate electrons for the F_2^{+1} cation and give the bond order. Explain whether (and why) this bond is stronger or weaker than the bond in F_2.



$BO = \frac{10-7}{2} = 1.5$

F_2^+ has stronger bond than F_2 b/c fewer e⁻ in antibonding

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: $E_n = -2.75 \times 10^{-18}\ J\ (1/n^3)$ 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?

$E_2 = -2.75 \times 10^{-18}\ J \left(\frac{1}{2^3}\right) = -3.44 \times 10^{-19}\ J$

$E_5 = -2.75 \times 10^{-18}\ J \left(\frac{1}{5^3}\right) = -2.20 \times 10^{-20}\ J$

$\Delta E = -2.20 \times 10^{-20}\ J - -3.44 \times 10^{-19}\ J = 3.22 \times 10^{-19}\ J$

↑ energy of photon

$\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34}\ J\ sec)(3 \times 10^{8}\ m/sec)}{3.22 \times 10^{-19}\ J} = 6.17 \times 10^{-7}\ m$

or 617 nm

Bonus (3 points) What is your electron configuration? Why?

LAST NAME ____________________

FIRST NAME ____________________