Chem 103 Summer 2023
Professor Goldsmith

Key Name

EXAM 2 – June 30, 2023

#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 (i.e. smallest to largest): Sr^{+2}, Se^{-2}, Rb^{+1}, Mg^{+2}

$Sr^{2+} > Mg^{2+}$ Se^{-2} bigger than everything else

$Rb^{+} > Sr^{2+}$

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

small → large

b) Write the electron configuration for the sulfur monocation (S^{+1}). Will this ion be affected by a magnetic field? 15e-

$1s^2 2s^2 2p^6 3s^2 3p^3$ ← 3 unpaired e- so paramagnetic

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

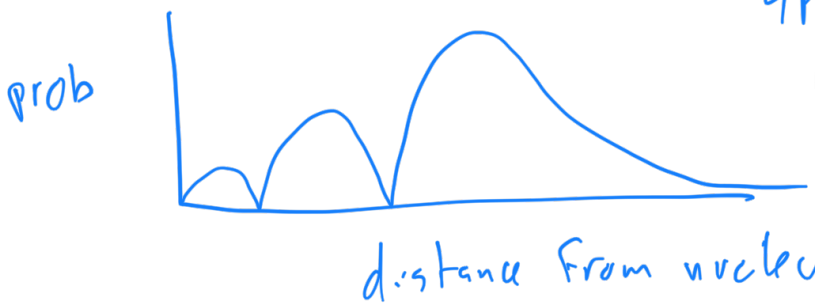
Si: ↑↓ ↑ ↑ □ ← greater EA b/c empty p

P ↑↓ ↑ ↑ ↑ ← have an additional e- would require pairing

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

Na - b/c 2nd IE is of core e-

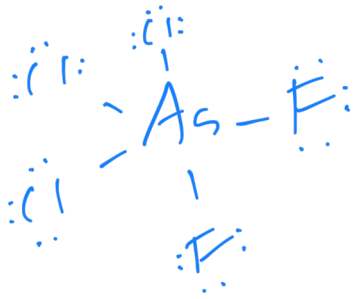
e) Draw the radial distribution function for the 3s orbital and explain its features. What other orbital(s) could have a radial distribution function that looks like this one?



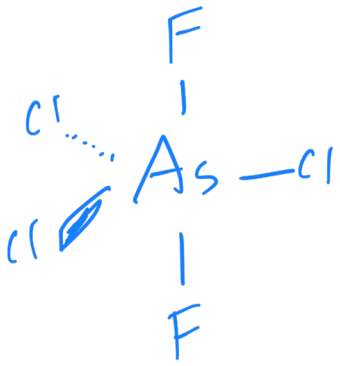
4p, 5d, 6f would look similar

2. (10 points)
For the molecule AsF_2Cl_3

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

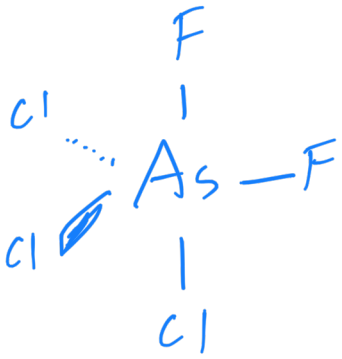


electron pair and molec geom both trigonal bipyramid

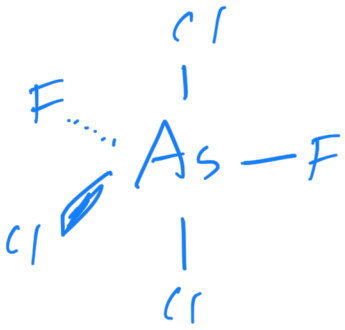


nonpolar

all vectors cancel



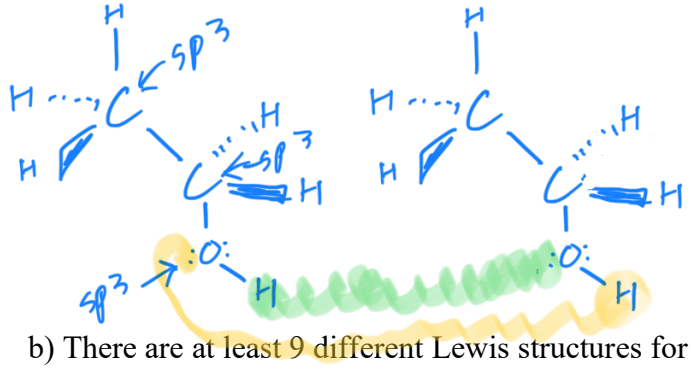
polar



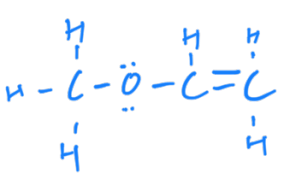
Polar

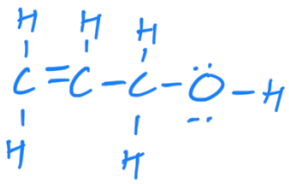
3.(20 points)

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.

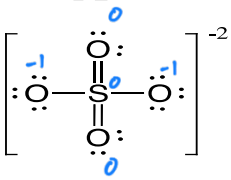




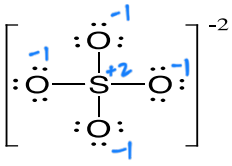
lower bp b/c no hydrogen bonding

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 less non-zero formal charges

d) Hexanoic acid ($CH_3CH_2CH_2CH_2CH_2COOH$) and hexane (C_6H_{14}) mix well with one another. Explain why this is **and** describe **all** of the intermolecular interactions that are taking place in this ~~butanol/pentane~~ hexanoic acid/hexane mixture. They can mix b/c hexanoic acid has a big non polar part

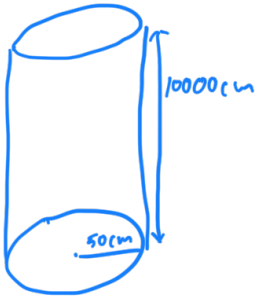
HA/HA – dipole/dipole, hydrogen bonding, London

Hex/Hex – London

HA/Hex – dipole/induced dipole, London

4. (20 points)

a) Assume air is 80% nitrogen and 20% oxygen (by moles). If you have a column of air whose base has a diameter of 1.00 m and whose height is 100.0 m, how many grams does the air in it weigh at 1.00 atm of pressure and 25 °C? (Note that the area of a circle is πr^2 where π=3.14 and r is the radius of the circle)



$V = (50\,cm)^2 \times 3.14 \times 10000\,cm = 7.85 \times 10^7\,cm^3 = 7.85 \times 10^4\,L$

$n = \frac{PV}{RT} = \frac{(1\,atm)(78500\,L)}{(0.08206\,\frac{L\,atm}{mol\,K})(298.15\,K)} = 3209\ moles \rightarrow 2567\ mol\ N_2$, $642\ mol\ O_2$

$2567\ mol\ N_2 \times \frac{28\,g}{mol} = 71876\,g$

$642\ mol\ O_2 \times \frac{32\,g}{mol} = 20544\,g$

$92420\,g$ or $92.42\,kg$

b) At sea level, the pressure is 1.00 atmospheres and that is the result of the mass of the air pushing down on things. If you consider a column of air with a diameter of 1.00 m that reaches all the way up to outer space, the mass of all of the air in that column will be 8130 kg. The deepest mine in the world is the Mponeng gold mine in South African whose maximum depth is 2.87 kilometers below sea level. What is the atmospheric pressure at the deepest part of this mine?

100 m column of air weighs 92.42 kg

$2.87\,km \times \frac{1000\,m}{1\,km} \times \frac{92.42\,kg}{100\,m} = 2652\,kg$ for below sea level air

10782 kg total mass of air

$\frac{1\ atm}{8130\,kg} = \frac{?\ atm}{10782\,kg} \rightarrow 1.326\ atm$ at bottom of mine

c) If you put a thermometer in a pot of boiling water at the bottom of the Mponeng gold mine what temperature will it read? (If you didn't get a reasonable answer for part b, use 1.5 atm for this part)

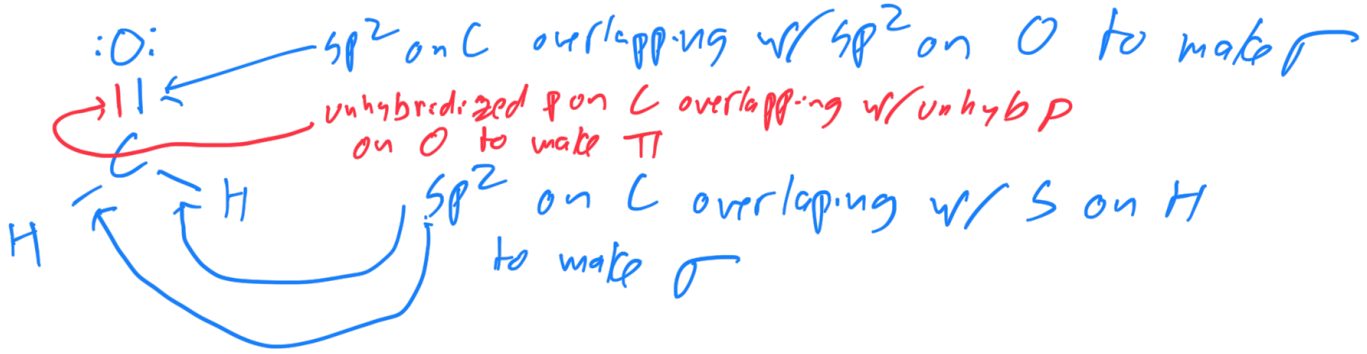
$\ln\left(\frac{1.326\ atm}{1\ atm}\right) = -\frac{(22565\,J/g \times 18.02\,g/mol)}{8.314\,J/mol\,K}\left(\frac{1}{T_2} - \frac{1}{373.15\,K}\right)$

$-5.77 \times 10^{-5}\,K^{-1} = \frac{1}{T_2} - 2.6799 \times 10^{-3}\,K^{-1}$

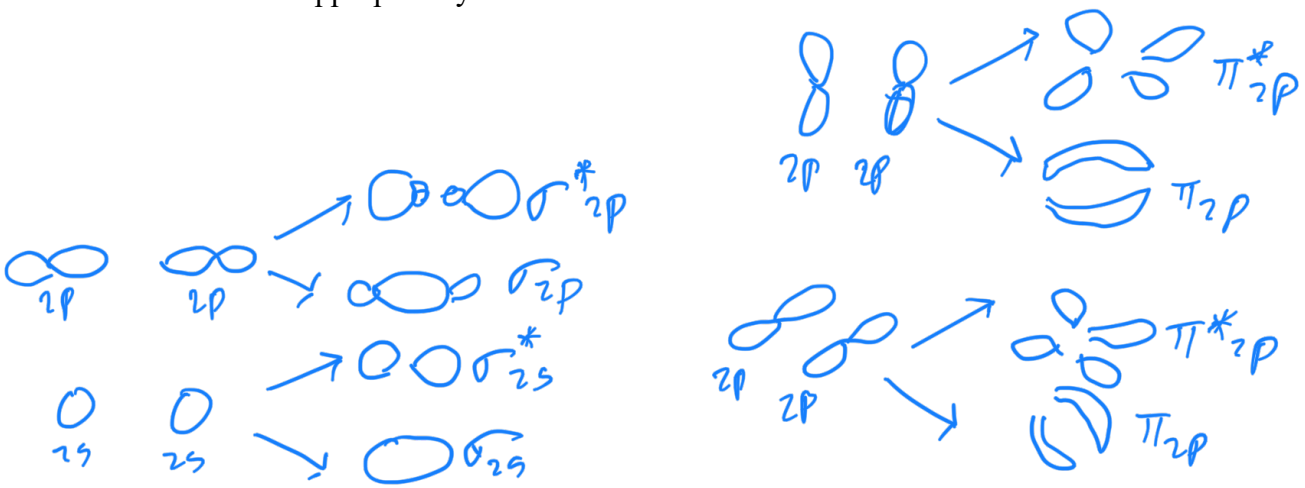
$T_2 = 381.36\,K$ or $108.2\,^{\circ}C$

5. (15 points)

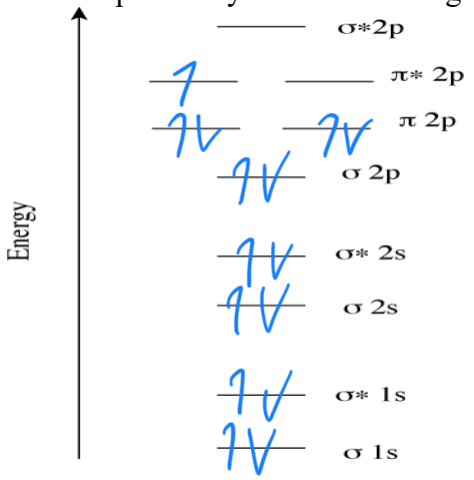
a) Explain, according to valence bond theory, what orbitals are involved all of the bonds of CH_2O. Draw a picture to further clarify your explanation.



b) Using molecular orbital theory, describe the bonding in O_2 (you can just 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 O_2^{+1} cation and give the bond order. Explain why is bond is stronger or weaker than the bond in O_2.



$BO = \frac{10-5}{2} = 2.5$

stronger than in O_2 b/c one less e^- in antibonding orbital

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?

$$E_2 = \frac{-2.75 \times 10^{-18}\ J}{8} = -3.44 \times 10^{-19}\ J$$

$$E_5 = \frac{-2.75 \times 10^{-18}\ J}{125} = -2.20 \times 10^{-20}\ J$$

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

$$E_{photon} = 3.22 \times 10^{-19}\ J$$

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

$$\lambda = 6.17 \times 10^{-7}\ m \text{ or } 617\ nm$$

Bonus (3 points) To what molecular geometry do you aspire? Why?

LAST NAME _____

FIRST NAME _____