Chemistry 121 Practice Exam Package

1. This package was put together by students with knowledge of course content in Chem 121.
2. We are not guaranteeing that the answers are 100% correct. Please consult the UCS, should any questions regarding the content of this packet arise.
3. We apologize in advance for errors.
4. NO REFUNDS.

A lamp emits light at a wavelength of 550 nm.

a. What is the frequency of this light?

b. What is the colour of this light?

c. What is the energy of one photon of this light?

How many photons of light with a frequency of 3.75 GHz are required to produce 2 J of energy?

The binding energy of a particular metal is 373 kJ/mol.

a. What is the lowest frequency of light that will remove electrons from this metal?

b. If the metal is irradiated with light of wavelength 170 nm, what is the kinetic energy of the resulting ionized electrons?

c. If the wavelength is increased to 250 nm, what happens to the kinetic energy of the resulting ionized electrons?

As the wavelength is increased, energy is decreased based on the above equation, as they are inversely proportional.

Rank the following in order of increasing boiling point and explain the reasoning behind your ranking scheme.

CH_4, NaF, CH_3OH, CH_3F

Krypton freezes to form crystalline solid with a face-centered cubic lattice. The length of the unit cell edge is 4.73 Å.

a. Determine the coordination number of each krypton atom

b. Determine the shortest Kr-Kr distance.

c. Determine the density of solid krypton.

Identify the following orbitals by name and draw the orbital.

a. 1 radial node, 1 angular node

b. 0 radial nodes, 2 angular nodes

c. 2 radial nodes, no angular nodes

For a hydrogen atom the wave function for the state n = 2, l = 0, m = m_l = 0 is:

$$\psi_{200} = \frac{1}{4\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{3/2}(2-\sigma)e^{-\sigma/2}$$

where $\sigma = r/a_0$ and a_0 is the Bohr radius (5.29×10^{-11} m).

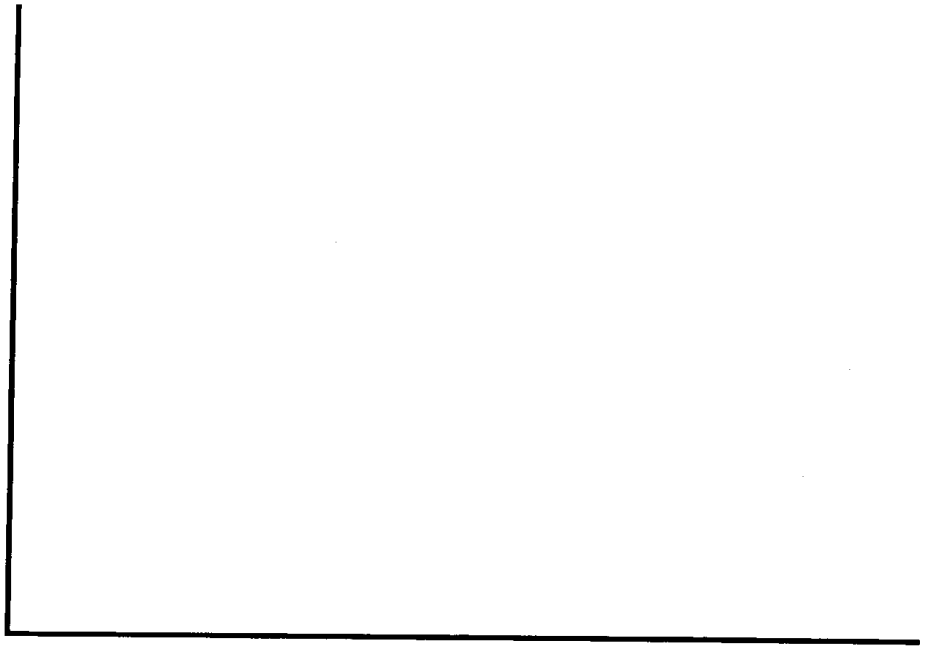
a. What orbital does this wave function describe?

b. Give the definition of a node in a wavefunction in one sentence.

c. How many nodes does this wave function have?

d. Calculate the position, in m, of the nodes for this wavefunction.

e. Using the axes drawn below, sketch the radial probability distribution for this wavefunction. Label the axes and indicate the point that corresponds to the most probable distance of the electron from the nucleus.



How many radial nodes are there in a 8s orbital?

a. 6 b. 9 c. 7 d. 0 e. 8

How many radial nodes are there in a 4d orbital?

a. 3 b. 4 c. 2 d. 1 e. 0

How many angular nodes are there in a 5p orbital?

a. 0 b. 1 c. 2 d. 3 e. 4

What is the ground state electronic configuration of tin?

a. [Kr] $5s^2 4d^{10} 5p^2$
b. [Kr] $5s^2 5d^{10} 5p^2$
c. [Kr] $5s^2 5p^2$
d. [Xe] $5s^2 5d^{10} 5p^2$
e. [Ar] $4s^2 3d^2$

Calculate the frequency of light, in Hz, emitted when gaseous Li^{2+} ions move from the n = 3 to the n = 2 state.

Give quantum numbers that describe:

a. an electron in a 4d orbital

b. a 5f orbital

c. a 5d orbital

Consider the following species: Na, Mg, O, Ar, and F

a. Which releases the greatest amount of energy when an electron is adsorbed (ie. which has the largest electron affinity)?

b. Which has the greatest first ionization?

c. Which has the smallest first ionization energy?

d. Which has the greatest second ionization energy?

State whether the following transitions are caused by absorption or emission of light.

a. N atom $1s^2 2s^2 2p^3 \rightarrow$ N atom $1s^2 2s^2 2p^3$

b. Mn atom [Ar] $4s^2 3d^5 \rightarrow$ Mn atom [Ar] $4s^1 3d^6$

c. Ni^{2+} ion [Ar] $4s^2 3d^8 \rightarrow Ni^{2+}$ ion [Ar] $3d^{10}$

Give the electron configurations for the following species:

a. Fe

b. Fe^{2+}

c. Fe^{3+}

What wavelength of light is needed to excite an electron in a hydrogen atom from the 2s to the 4p orbital?

Identify the geometry and hybridization of the central atom for each of the following species. Also state whether the molecule is polar or non-polar.

Species	Geometry	Hybridization	Polar or Non-Polar?
PCl_3			
NH_4^+			
SF_4			
SF_6			

For the cyanate anion NCO^-:

a. Draw the possible resonance structures.

b. Rank the resonance structure in order of increasing importance and explain your choices.

Draw the most favoured Lewis structure for the following molecules.

a. NH_4^+

b. ClNO

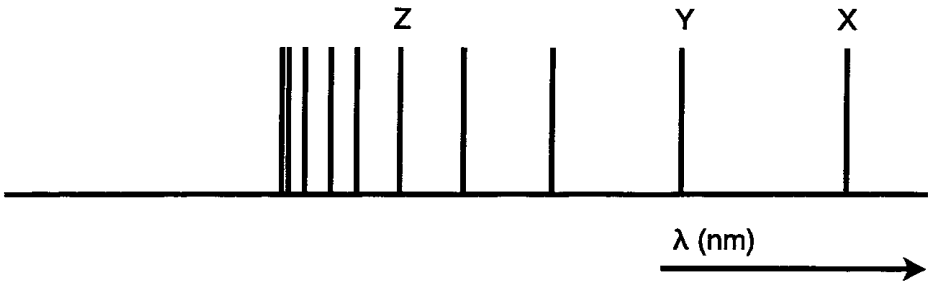
c. H_2SO_4

d. CH_2O

e. H_2CO_3

f. HNO_3

An emission spectrum for a one-electron species is shown below. The spectrum shows all lines resulting from a transition to the second excited state from higher energy states. The wavelength of light associated with transition Y is 142 nm.



a. Complete the following table by giving the initial and final states (quantum numbers) for each of the labelled transitions.

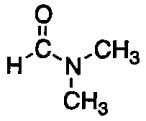
	Initial State	Final State
Line X		
Line Y		
Line Z		

b. Identify the species that exhibits the spectrum above.

Draw all the resonance structures of NO_3^-

How will the bond lengths in NO_3^- compare to those in BF_3? Explain.

The Lewis structure for dimethylformamide is shown below:



In this molecule:

a. What is the hybridization of the carbon attached to the hydrogen?

b. What is the hybridization of the nitrogen atom?

c. What is the HCO bond angle?

d. What is the HCH bond angle?

e. What is the maximum number of atoms that can lie in the same plane?

For the following molecules, write the best Lewis structure, molecular shape as predicted by VSEPR, and whether the molecule is polar or nonpolar. The central atom is underlined.

Molecule	Lewis Structure	Molecular Shape	Polar or Non-Polar
O<u>C</u>S			
$[\underline{S}F_5]^-$			
$H_2\underline{C}O$			
$\underline{Xe}O_4$			
$\underline{N}H_3$			

Based on the description given below, write the names of the elements A, B, X, and Y in the appropriate spaces provided at the end of this question.

> Elements A and B are metals from the third period of the Periodic Table, and they react with the non-metal X_2 to form compounds with formulas such as AX, B_2X_2, and B_2X. At room temperature, Metal A reacts with $Y_{2(g)}$ violently to yield AY_2, whereas Metal B reacts with $Y_{2(g)}$ in a violent reaction to form BY. Elements X and Y can be found in various combinations, including the compound X_2Y_7 which is isoelectronic with pyrosilicate, pyrophosphate, and pyrosulphate anions.

A _____

B _____

X _____

Y _____

Tungsten has a body-centered cubic crystal structure with a metallic radius of 139 pm. Calculate the density in g/cm^3.

Using VSEPR theory, predict the molecular shape of $[P(CH_2OH)_4]^+$.

Specify the number of radial and angular nodes for each of the following.

a. $n = 15, l = 10, m_l = -5$

b. $n = 10, l = 8, m_l = -5$

c. $n = 7, l = 6, m_l = -2$

d. $n = 12, l = 1, m_l = 1$

List all the possible quantum number combinations for $n = 4$ orbitals.

Phosphorous has a higher ionization energy than sulfur. Why?

Order the following ions from smallest to largest:

K^+, Cl^-, S^{2-}, Ca^{2+}

Predict the molecular shape of $(SiF_6)^{2-}$

A colourless solid A has an elemental composition of 46.74% Si and 53.26% O. A is reacted with $C_{(s)}$ and heat to afford a solid B and a colourless gas X. Reaction of B with two equivalents of $Cl_{2(g)}$ and the addition of heat yields compound Y with no byproducts. It is a colourless volatile liquid that fumes in air. Reaction of Y with water yields A again and Z as a byproduct. Identify A, B, X, Y, Z.

Draw all the possible resonance structures for $[XeOF_3]^+$ and indicate the formal charge. Xe is the central atom. Indicate which is the most stable resonance structure and explain why.

Diethyl aminosulfur trifluoride (DAST) $(CH_3CH_2)_2NSi(CH_3)_3$ is used in organic synthesis as a source of fluoride. DAST can be synthesized form the following reaction:

$$(CH_3CH_2)_2NSi(CH_3)_3 + SF_4 \rightarrow (CH_3CH_2)_2NSF_3 + (CH_3)_3SiF$$

a. Draw the Lewis structure of DAST (S is the central atom).

b. Use VESPR theory to predict the molecular shape of DAST.

c. What is the hybridization of the sulfur atom?

A proton is accelerated to 1/10 of the velocity of light and velocity can be measured with a precision of 1%. What is the uncertainty in the position of this proton?

Silicon and silicates can be distinguished from each because:

a. Silicones form crystalline solids while silicates do not.
b. Silicates contain Si-O-Si units while silicones do not.
c. Silicates have lower melting points than silicones.
d. Silicones contain organic substituents while silicates do not.

The fact that molecular oxygen is paramagnetic can be explained by:

a. the Lewis structure of O_2
b. resonance structures
c. as a violation of the octet rule
d. the molecular orbital diagram
e. hybridization of atomic orbitals

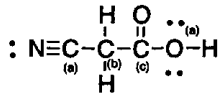
The hybridization of Xe in XeF_3^+ is:

a. sp
b. sp^2
c. sp^3
d. sp^3d
e. sp^3d^2

Beams of low energy helium atoms can diffract from a crystal surface and provide structural information, analogous to that provided by X-rays. This is possible because the helium atoms:

a. react with the crystal surface.
b. have quantized energy levels
c. have a high ioniozation energy
d. have wavelike properties
e. are large relative to the atoms composing the surface

The Lewis structure for cyanoacetic acid is shown below. The subscripts on the carbon and oxygen atoms are labels. Select the letter that correctly matches the hybridization of the nitrogen atom, the carbon atoms $C_{(a)}$, $C_{(b)}$, $C_{(c)}$, and the oxygen atom $O_{(a)}$ in cyanoacetic acid.

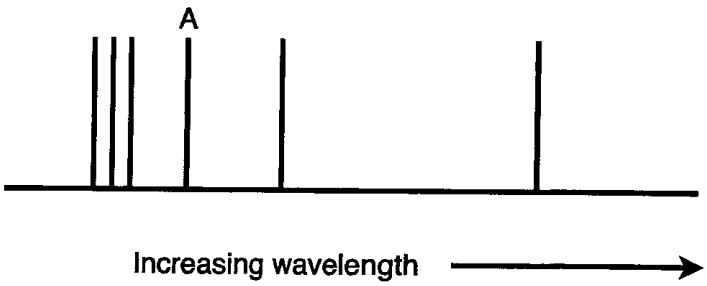


	N	$C_{(a)}$	$C_{(b)}$	$C_{(c)}$	$O_{(a)}$
a.	sp	sp	sp^3	sp^2	sp^3
b.	sp^2	sp^2	sp^3	sp^2	sp
c.	sp^3	sp^3	sp	sp^3	sp^2
d.	sp^2	sp	sp^2	sp^2	sp
e.	sp	sp^2	sp^2	sp^3	sp^3

What is the maximum number of atoms of cyanoacetic acid that can lie in the same plane?

a. 4
b. 5
c. 6
d. 7
e. 8

An electron gun continually excites a sample of gas phase hydrogen atoms to states with n = 1, 2, 3, and 4. These atoms eventually decay to the ground state by undergoing transitions to lower n states. The emission spectrum from all these transitions is shown below. The line labelled A arises from the transition.



a. 4 → 3
b. 4 → 2
c. 2 → 1
d. 3 → 2
e. none of the above

What is the formal charge on the nitrogen atom in the preferred resonance structure of $[OCN]^-$? Carbon is the central atom in this anion.

a. -2
b. -1
c. 0
d. +1
e. none of the above

The lanthanide metal europium (Eu) forms a crystalline solid with a cubic unit cell of edge length 4.583 Å. The density of europium is 5.243 g cm^{-3}. The crystal strucutre of solid europium is:

a. face-centered cubic
b. body-centered cubic.
c. simple cubic.
d. the sodium chloride structure.
e. hexagonal close packed.

The energy, in kJ/mol, of photons emitted with Li^{2+} ions decay from the n = 5 state to the n = 2 state is:

a. -276
b. 2.48×10^{3}
c. 6.91×10^{11}
d. 276
e. 6.22×10^{12}

Complete each row of the table below by choosing the entries in the "species" column that have the smallest and largest values of the property listed in the second column and writing these entries appropriately in the third and fourth columns. The first row is completed as an example.

Species	Property	Smallest	Largest
flea, cat, elephant	size	flea	elephant
Ca, S, F, Cs	electronegativity		
Na, K, Si, Ar	ionization energy		
Ne, Mg^{2+}, F^{-}, Na^{+}	size		
Cr, P, Co^{2-}, Mg	number of unpaired electrons		
O, Cl, Ge, Se	total number of electrons in p orbitals		

Write the molecular orbital configurations for O_2 and N_2. Using molecular orbital theory, explain why the removal of one electron in O_2 strengthens bonding, while the removal of one electron in N_2 weakens bonding.

For ICl_3, iodine is the central atom, with all chlorine atoms bonded directly to it.

a. Draw the Lewis structure. Show all of the non-bonding valence electrons as dots.

b. What is the arrangement of the electron pairs around the iodine atom in ICl_3?

c. Sketch structures representing all the possible distinct arrangements of the I-Cl bonds around the iodine atom in ICl_3.

d. Circle the preferred structure in Part c and briefly explain the reasons for your choice.

e. What is the hybridization at the iodine atom in ICl_3?

f. What is the name for the molecular molecular shape for ICl_3?

g. State whether ICl_3 is polar, and briefly explain the reasons for your answer.

Complete each entry below by supplying the symbol for a neutral atom with Z from 19 to 36, that is the groundstate has the property indicated. If an entry has more than one possible answer, please supply any one of them.

a. _____ has a half-filled 4p subshell.

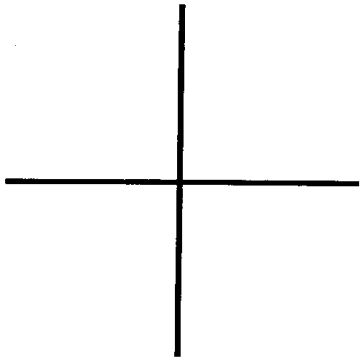
b. _____ has 6 unpaired electrons.

c. _____ has three electrons in the 3d subshell.

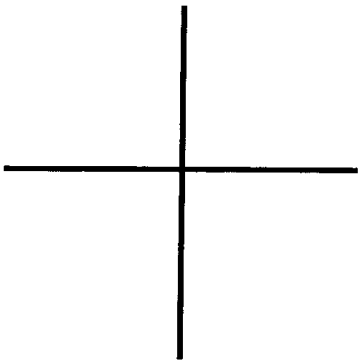
d. _____ has a completely filled 3d subshell.

e. _____ is diamagnetic.

Sketch the indicated orbitals on the axes below. Please label all nodal surfaces and indicate the phases of the orbitals.



$2p_y$



$3d_{x2-y2}$

Consider the boiling points of the compounds shown in the table below. Using arguments based upon intermolecular forces, explain the trend of increasing boiling points seen in this experimental data.

Compound	Boiling Point (°C)
CH_4	-164
CH_2F_2	-52
CH_2Cl_2	40
CH_2Br_2	97
CH_2I_2	182

Sketch cross sections of the molecular orbitals indicated below. Please indicate the positions of all nodal planes with dashed lines. The nuclei are shown as dots.

π^*_{2p}

σ_{2p}

σ^*_{1s}

Write the balanced equations to represent the chemical reactions involved in each of the following statements. It is not necessary to specify the states of the reactants or products.

a. The manufacture of household bleach.

b. The reaction of magnesium metal with carbon dioxide.

c. The production of aluminum from its oxide.

d. The production of sulphuric acid from sulphur trioxide.

e. The electrolysis of an aqueous solution of sodium chloride.

f. The reaction of aluminum with water.

g. The synthesis of silicones from $SiCl_2(CH_3)_2$ (2 steps).

Calculate the frequency of light, in Hz, necessary to promote gaseous He^+ ions from the 2p electron configuration to the 3d electron configuration.

One fundamental deficiency of the Bohr model of the atom is that Bohr orbits violate the Uncertainty Principle.

a. State the Uncertainty Principle in words.

b. Explain how Bohr orbits violate the Uncertainty Principle.

c. How does the theory of quantum mechanics correct this deficiency of the Bohr model?

Some of the properties of magnesium are presented in the following table:

Atomic Number (Z) = 12	Electronegativity = 1.31
First Ionization Energy = 737.7 kJ/mol	Melting Point = 648.8 °C
Enthalpy of vapourization = 127.6 kJ/mol	Atomic Radius = 1.60 Å

a. Write the ground state electronic configuration of magnesium.

b. Calculate the maximum wavelength of light that will ionize neutral, gas phase magnesium atoms in the ground state. Express your answer in nm.

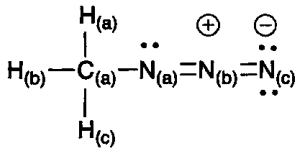
c. Will the light in part b also ionize neutral, gas phase cesium atoms? Why?

The table below provides values for the ratio r_+/r_-, in which r_+ is the radius of an atom/ion that can fit exactly into each of the holes identified, and r_- is the radius of an atom/ion that forms the cubic lattice within which the hole exists.

Name of Hole	r_+/r_-
trigonal	0.155
tetrahedral	0.225
octahedral	0.414
cubic	0.732

The mineral Tiemannite (HgSe) is grayish black in colour, is found in the state of Utah and is found to crystallize with a cubic unit cell. The smallest distance between the centers Hg^{2+} and Se^{2-} is 0.2634 nm and the ionic radius of Se^{2-} is 0.1910 nm. Estimate the density, in g/cm^3, of Tiemannite.

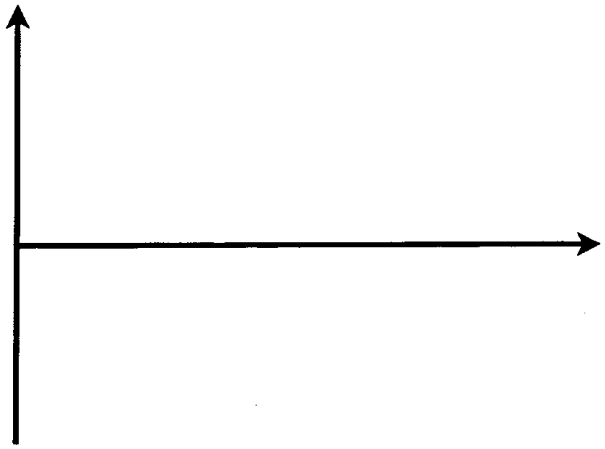
The Lewis structure for methylazide (CH_3N_3) is shown below. The subscripts on the atoms in the figure are labels.



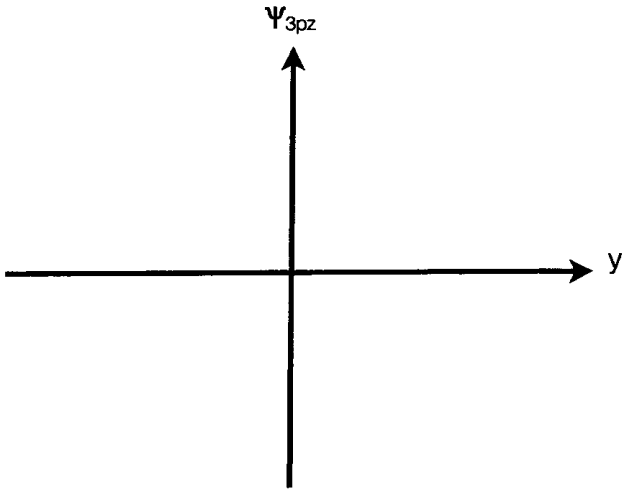
a. On the figure, write the formal charge on each nitrogen atom.

b. Utilizing the overlap of atomic orbitals and hybridization, describe in detail the origin of all the sigma and pi bonds in methylazide.

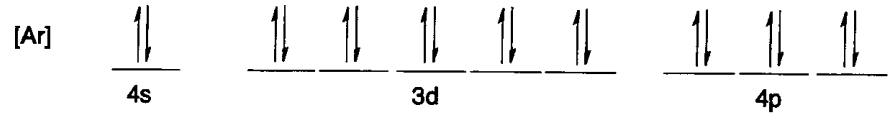
Sketch the wavefunction Ψ_{3pz} (r) vs. z (along the z axis). Identify on the plot where the radial nodes are. Label the axes.

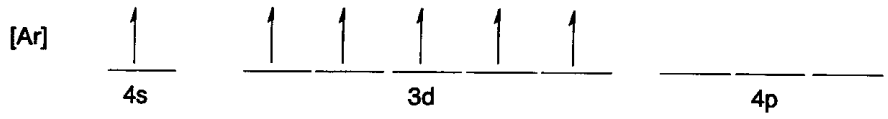


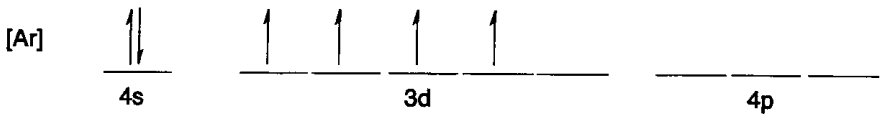
Sketch the wavefunction Ψ_{3pz} along the y axis. Label the axes

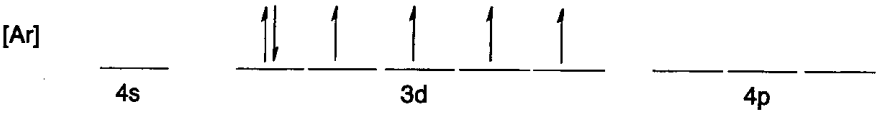


Identify each of the following electron configurations for chromium in its ground state as either ACCEPTABLE (A) or UNACCEPTABLE (U). If the configuration is unacceptable, briefly explain why.









Describe the phenomena of "mixing" in MO theory and give an example of this.

Benzene has six carbon atoms arranged in a hexagon.

a. Draw the pi molecular orbitals for benzene (C_6H_6) as viewed from above.

b. Order the MOs that you have above from lowest energy to highest energy.

c. Draw an energy level diagram showing the relative energy levels of each orbital. Place an appropriate number of electrons in each orbital and indicate which are bonding and which are anti-bonding orbitals.

d. Label on the diagram above the LUMO and the HOMO.

e. Is benzene diamagnetic or paramagnetic?

f. What is the bond order for benzene?