Second Hour Exam **5.111**

Write your name and your TA's name below**. Do not open the exam until the start of the exam is announced.** The exam is closed notes and closed book.

1. Read each part of each problem carefully and thoroughly.
2. Show your work. Indicate units. Use correct significant figures.
3. Make your dots on Lewis structures clearly visible.
4. If you don't understand what the problem is requesting, raise your hand and a proctor will come to your desk.
5. Physical constants, formulas and a periodic table are given on the last page. You may detach this page **once the exam has started**.

1.	Periodic Table Trends	(14 points)
2.	Bonding	(12 points)
3.	Lewis Structures and VSEPR	(28 points)
4.	Molecular Orbital Theory	(25 points)
5.	Hybridization and VSEPR	(21 points)

Total (100 points) ________________________

Name

TA ______________________________

1. (14 points) **Periodic Table trends**

(**a**) (8 points) **Ionization energy**

(**i**) Which of the following (**Li, Be, B, Na, K**) has the highest **second** ionization energy (IE_2)? Briefly explain your answer.

(**ii**) Which ionization energy is the **largest** of the following three: the fourth ionization energy for B, the third ionization energy for Be or the second ionization energy for Li? Briefly explain your answer.

(**b**) (3 points) Rank the following from smallest to largest **radius**: **Na, Na^{+}, Rb**

smallest… ….largest

(**c**) (3 points) Rank the **electron affinity** from smallest to largest for **P, Cl, Ar**.

smallest… ….largest

2. (12 points) **Bonding**

element	**ionization energy**	**electron affinity**
Rubridium (Rb)	403 kJ/mol	47 kJ/mol
Fluorine (F)	1680 kJ/mol	328 kJ/mol

(a) (8 points) For the ionic molecule RbF, calculate the maximum value of r for which the ionic bond is energetically allowed. For this problem, use the information above and assume Rb^+ and F^- are point charges.

(b) (4 points) Draw an energy plot (with energy on the y-axis and internuclear distance, r, on the x-axis) for H_2. Label the (i) equilibrium bond distance with a *, and (ii) the dissociation energy with a double-headed arrow. Set the separated atom limit at zero energy.

3. (28 points) **Lewis Structures and VSEPR**

(a) (i) (10 points) Draw the most stable Lewis structure for $(PO_4H)^{-2}$. Be sure to include any lone pairs and, if applicable, draw resonance forms. **I**ndicate the overall charge on the molecule as well as **any nonzero formal charges**. Note that there are **no** oxygen-oxygen bonds in this molecule.

(ii) (3 points) Name the geometry around the phosphorus atom (example: square planar).

(iii) (3 points) What is (are) the O-P-O bond angle(s) in $(PO_4H)^{-2}$?

(b) (i) (6 points) Draw the most stable Lewis structure for (SF_4). Be sure to include any lone pairs and, if applicable, draw resonance forms.

(ii) (3 points) Name the geometry around the sulfur atom (example: square planar).

(iii) (3 points) Name the formula type (example: AX).

4. (25 points) **Molecular Orbital Theory**

(a) (10 points) Draw the MO diagram for the **valence electrons** of **O_2**. Label the atomic and molecular orbitals, including the x, y and z designations where appropriate. Use the full space available to spread out your energy levels so that the labels for the orbitals fit easily.

(b) (3 points) Write the **valence electron configuration** for O_2 based on the diagram above.

(c) (3 points) Calculate the **bond order** for O_2.

(d) (1 point) Based on the above diagram, state whether O_2 is paramagnetic or diamagnetic.

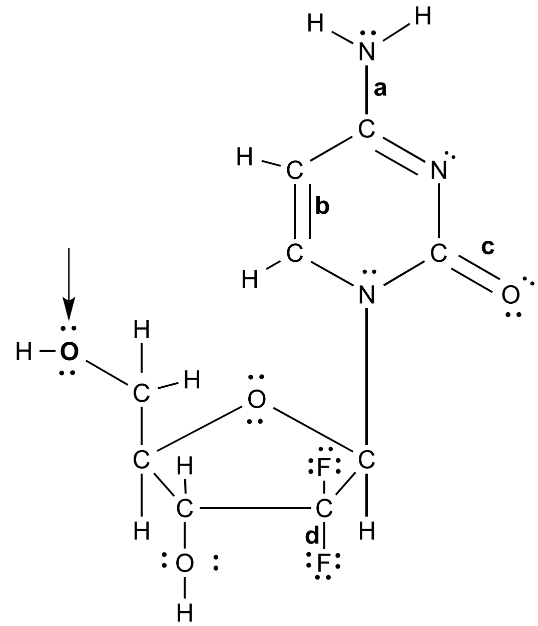
(e) (8 points) (i) Draw pictures of π_{2px} and π_{2px}* **molecular orbitals** in the boxes below, (ii) draw **nuclei**, (iii) draw and label the **bond axis**, (iv) draw and label **nodal planes** (if any), and (v) indicate the number of nodal planes below the boxes.

π_{2px}

π_{2px}*

5. (21 points) **Hybridization and VSEPR**

(a) (12 points) The structure of chemotherapeutic agent gemcitabine is shown. For the indicated bonds, **a-d**, write the symmetry of each bond, and give the hybrid or atomic orbitals (with their principal quantum numbers) that overlap to form each of the bonds. Where appropriate, include the x, y, or z designations with the orbitals.



(i) The single C-N bond **a**:

(ii) The double C=C bond **b**:

(iii) The double C=O bond **c**:

(iv) The single C-F bond **d**:

(b) (9 points) For oxygen indicated <u>with an arrow</u> in the above molecule

(i) (3 points) Write the SN number.

(ii) (3 points) Name the geometry around this oxygen (example: square planar).

(iii) (3 points) Circle the one value that best describes the H-O-C bond angle.

< 90°; 90°; > 90°; < 109.5°; 109.5°; > 109.5°; < 120°; 120°; > 120°

Metals

Semimetals

Nonmetals

Transition elements (groups 3–12)

I	II											III	IV	V	VI	VII	VIII
1 1.0079 H Hydrogen																	2 4.0026 He Helium
3 6.941 Li Lithium	4 9.0122 Be Beryllium											5 10.811 B Boron	6 12.011 C Carbon	7 14.007 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.180 Ne Neon
11 22.990 Na Sodium	12 24.305 Mg Magnesium											13 26.982 Al Aluminum	14 28.086 Si Silicon	15 30.974 P Phosphorus	16 32.065 S Sulfur	17 35.453 Cl Chlorine	18 39.948 Ar Argon
19 39.098 K Potassium	20 40.078 Ca Calcium	21 44.956 Sc Scandium	22 47.867 Ti Titanium	23 50.942 V Vanadium	24 51.996 Cr Chromium	25 54.938 Mn Manganese	26 55.845 Fe Iron	27 58.933 Co Cobalt	28 58.693 Ni Nickel	29 63.546 Cu Copper	30 65.409 Zn Zinc	31 69.723 Ga Gallium	32 72.64 Ge Germanium	33 74.922 As Arsenic	34 78.96 Se Selenium	35 79.904 Br Bromine	36 83.798 Kr Krypton
37 85.468 Rb Rubidium	38 87.62 Sr Strontium	39 88.906 Y Yttrium	40 91.224 Zr Zirconium	41 92.906 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.42 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.71 Sn Tin	51 121.76 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.29 Xe Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	71 174.97 Lu Lutetium	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.84 W Tungsten	75 186.21 Re Rhenium	76 190.23 Os Osmium	77 192.22 Ir Iridium	78 195.08 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.38 Tl Thallium	82 207.2 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 (226) Ra Radium	103 (262) Lr Lawrencium	104 (261) Rf Rutherfordium	105 (262) Db Dubnium	106 (266) Sg Seaborgium	107 (264) Bh Bohrium	108 (277) Hs Hassium	109 (268) Mt Meitnerium	110 (281) Uun Ununnilium	111 (272) Uuu Unununium	112 (285) Uub Ununbium		114 (289) Uuq Ununquadium				

Lanthanide series

57 138.91 La Lanthanum	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.36 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium

Actinide series

89 (227) Ac Actinium	90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 (237) Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (258) Md Mendelevium	102 (259) No Nobelium

$c = 2.99792 \times 10^{8}$ m/s

$h = 6.62608 \times 10^{-34}$ J s

$N_a = 6.02214 \times 10^{23}$ mol^{-1}

1 eV = 1.60218×10^{-19} J

$m_e = 9.10939 \times 10^{-31}$ kg

$e = 1.60218 \times 10^{-19}$ C

$U(r) = (z_1 z_2 e^2)/(4\pi\varepsilon_0 r)$

$\varepsilon_0 = 8.8542 \times 10^{-12}$ C^2/(Jm)

Electronegativity = (IE + EA)/2