

# CHM151Y CHEMISTRY: THE MOLECULAR SCIENCE INORGANIC CHEMISTRY SECTION

**TEST #2: FEB 10, 2025****12:10 – 1:00 p.m.****Prof. John De Backere**

**INSTRUCTIONS:** The test time is fifty minutes. Please fill in your name, student number, **and TWO DIGIT lab demonstrator group** (where your marked exam will be returned) below. Molecular model kits and calculators are allowed. No other aids are permitted. When instructed to begin, you should write your initials at top of each page of the exam. **Read the instructions for each problem carefully.** Write your answers on the examination sheet in the space provided and use the back of each sheet for any rough work. Only answers written in pen will be considered for re-grading. A periodic table has been included on the last page.

***DO NOT LOOK AT THE OTHER TEST PAGES UNTIL  
INSTRUCTED TO BEGIN***

(LAST NAME, First name)	
Student number	Laboratory Demonstrator Group # (two digits)

Question	Total Marks Possible	Marks Awarded
1	5	
2	4	
3	8	
4	10	
5	15	
6	8	
Total	50	

**Question 1. [5 marks]**

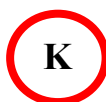
(a) In the space provided below, write down a *possible* set of three quantum numbers for an atomic 5p orbital.

$n =$  5       $l =$  1       $m_l =$  -1 or 0 or +1

(b) How many radial nodes are there in this atomic orbital: 3

(c) How many angular nodes are there in this atomic orbital: 1

**Question 2. [4 marks]** Circle which of the following species you expect to have a larger radius, and provide a brief justification of your prediction using fundamental chemical principles:



or

**Ge**

Justification:

Across period  $Z_{\text{eff}}$  increases so size decreases

$[\text{S}]^+$

or

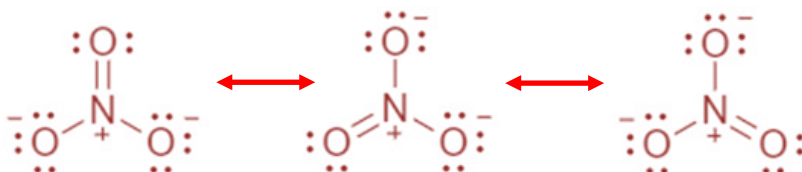


Justification:

Anions are larger than cations, shielding by additional electrons expands orbitals (or increased positive charge of cation pulls remaining electrons tighter)

**Question 3. [8 marks]** For the nitrate anion,  $[\text{NO}_3]^-$ :

(a) Draw the most reasonable Lewis dot structure(s) including any resonance form(s), making sure to show all non-bonding (lone pairs) and formal charges where appropriate.



Part marks possible if incorrectly charge minimized to give  $N > 4$  bonds

(b) Using VSEPR, the shape of this molecule is Trigonal planar

(c) Predict the approximate bond angle: 120°

(d) Would this molecule be polar or nonpolar: Non-polar

(e) According to valence bond theory, what is the hybridization(s) of each atom in the molecule?

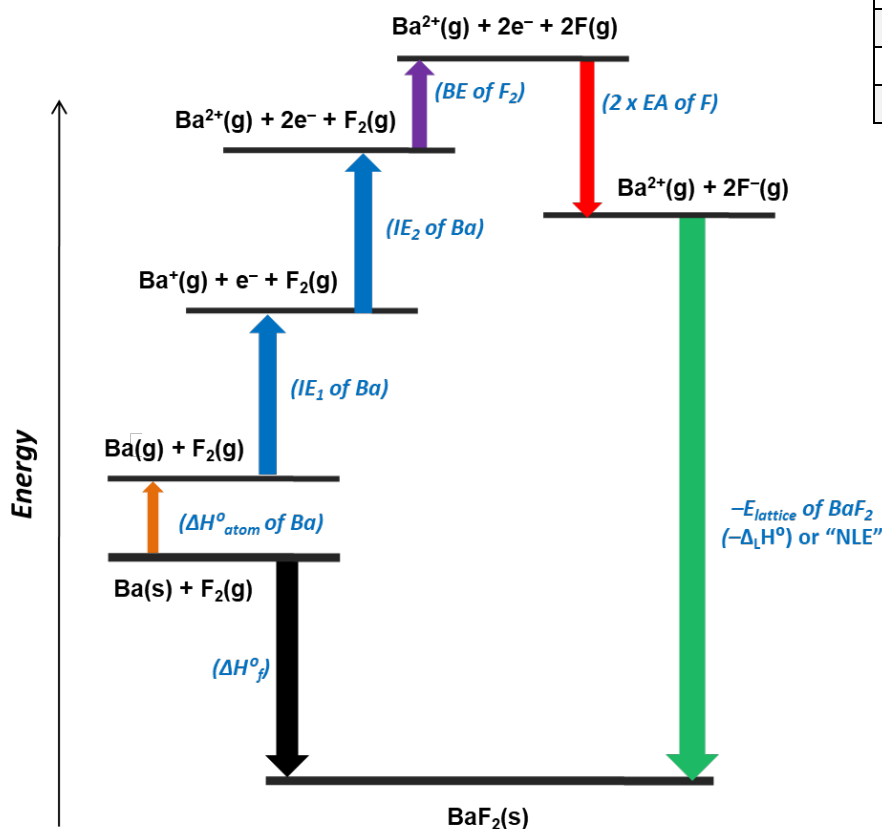
N :  $sp^2$       O :  $sp^2$  &  $sp^3$

(f) What are the formal oxidation states of each atom in the molecule?

N : +5      O : -2

**Question 4. [10 marks]** Draw the Born-Haber cycle for the formation of barium difluoride from the elements, making sure to provide thermochemical equations for each step. Use the values provided in the table to calculate its lattice energy.

Step	$\Delta H^\circ$ / (kJ/mol)
$\Delta H_f^\circ$ BaF <sub>2</sub> (s)	-1216
$\Delta H_{\text{atom}}^\circ$ Ba(s)	142
IE <sub>1</sub> Ba(g)	502
IE <sub>2</sub> Ba(g)	938
BE of F <sub>2</sub> (g)	152
EA <sub>1</sub> of F(g)	-318
Lattice Energy	?



**Note:** can combine both IE of Ba and the EA of F steps into one, respectively

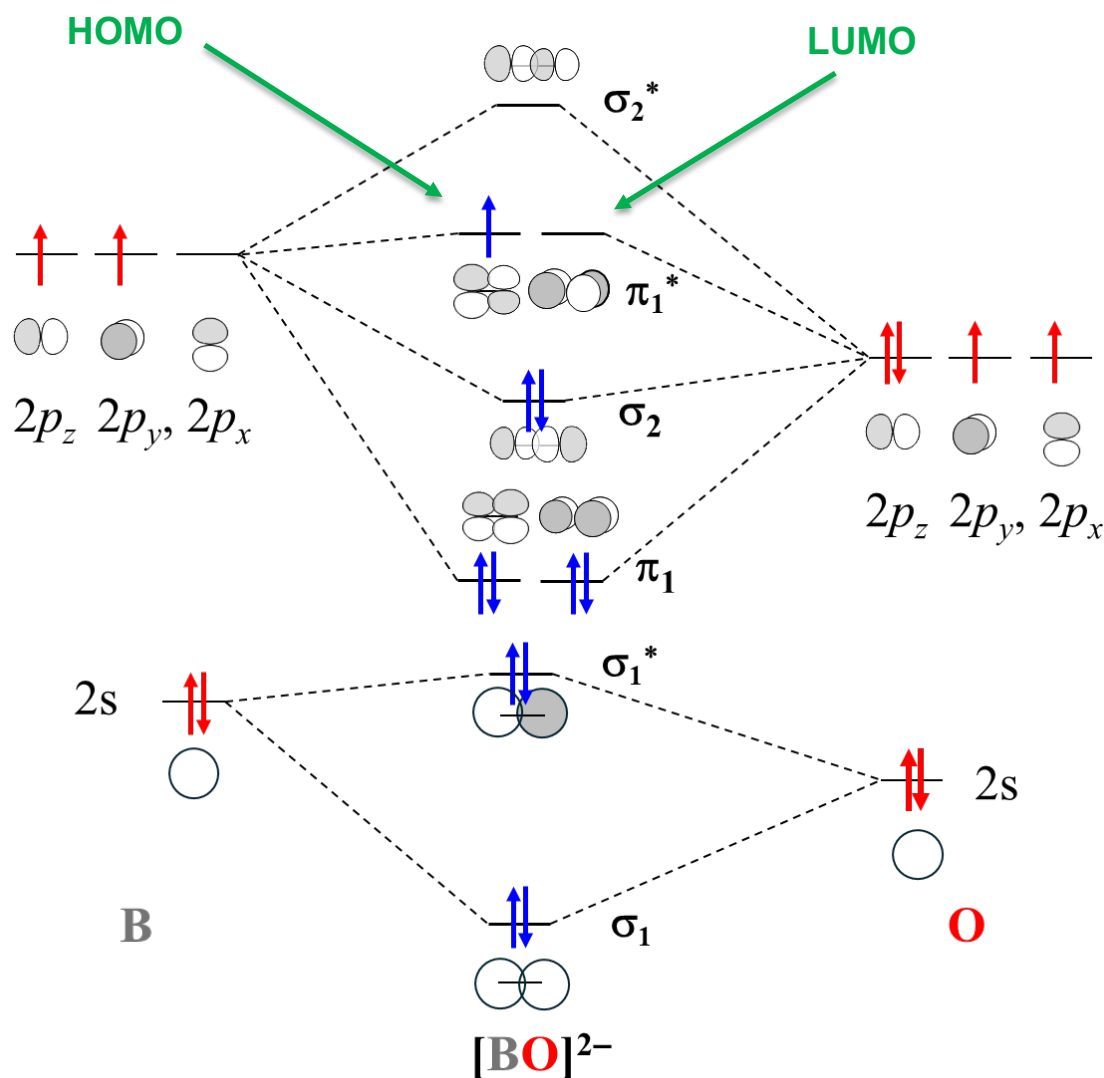
$$\Delta H_f^\circ = \Delta H_{\text{atom}}^\circ + IE_1 + IE_2 + BE + EA_1 + NLE$$

$$LE = \Delta H_{\text{atom}}^\circ + IE_1 + IE_2 + BE + (2 \times EA_1) - \Delta H_f^\circ$$

$$= 142 + 502 + 938 + 152 + (2 \times -318) + 1216$$

$$\text{Lattice Energy} = 2314 \text{ kJ/mol}$$

**Question 5. [15 marks]** (a) In the space provided, draw a complete and detailed molecular orbital diagram for the hypothetical diatomic boron oxide dianion,  $[\text{BO}]^{2-}$ . For full marks, make sure to: (i) clearly draw and label the valence atomic orbitals considering their relative energies, (ii) draw all molecular orbitals indicating which atomic orbitals are combining and their relative phasing, and (iii) properly label every orbital.



(b) Label the **HOMO** and **LUMO** on your diagram above.

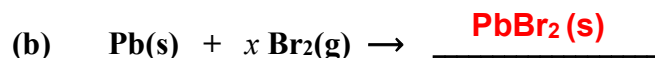
(c) What is the bond order for  $[\text{BO}]^{2-}$ : **2.5**

(d) Do you expect it to be diamagnetic or paramagnetic: **paramagnetic**

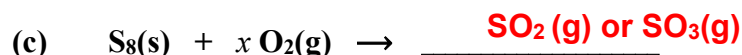
**Question 6. [8 marks]** Predict the product formed in the following reactions including their state (*s*, *l*, *g*). Provide a brief rationale for your prediction and the expected state of matter. **Note:** “*x*” indicates an excess of reagent, do not worry about balancing the equation just provide the product.



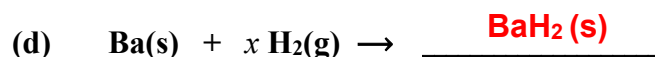
*Justification(s):* Group 13 element with more EN (Cl) = +3 ox. of B  
Covalent molecule = typically gaseous (*l* also acceptable)



*Justification(s):* Pb usually +2 very (low in group down) due to TMs and Br not as  
oxidizing . Expect solid since more metallic bonding nature but



*Justification(s):* Heavier Group 16 can be +4 or +6 after oxygen  
Covalent molecule = gaseous



*Justification(s):* Group 2 gives up 2 electrons  
Metallic Hydride = solid

**END OF TEST**

**USE THE SPACE BELOW FOR ROUGH WORK (IT WON'T BE MARKED)**

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.9	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 (284)	114 (289)	115 (288)	116 (292)	(294)	

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

USE THE SPACE BELOW FOR ROUGH WORK (IT WON'T BE MARKED)