Spring 2018 **Chemistry 2000 Midterm #1** ____/64 marks

1) Please read over the test carefully before beginning. You should have 6 pages of questions and a blank "overflow" page. A periodic table has also been provided.
2) **DO NOT WRITE ON THE QR CODE!!!** Work on pages without a QR code will not be graded.
3) If your work is not legible, it will be given a mark of zero.
4) Marks will be deducted for incorrect information added to an otherwise correct answer.
5) Calculators are not permitted.
6) You have 90 minutes to complete this test.

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam until after 5:00 pm Mountain Time on Friday, February 19th, 2018. I understand that breaking this agreement would constitute academic misconduct. The minimum punishment would be a mark of 0/64 on this exam and removal of the "overwrite midterm mark with final exam mark" option for my grade in this course; the maximum punishment would include expulsion from this university.

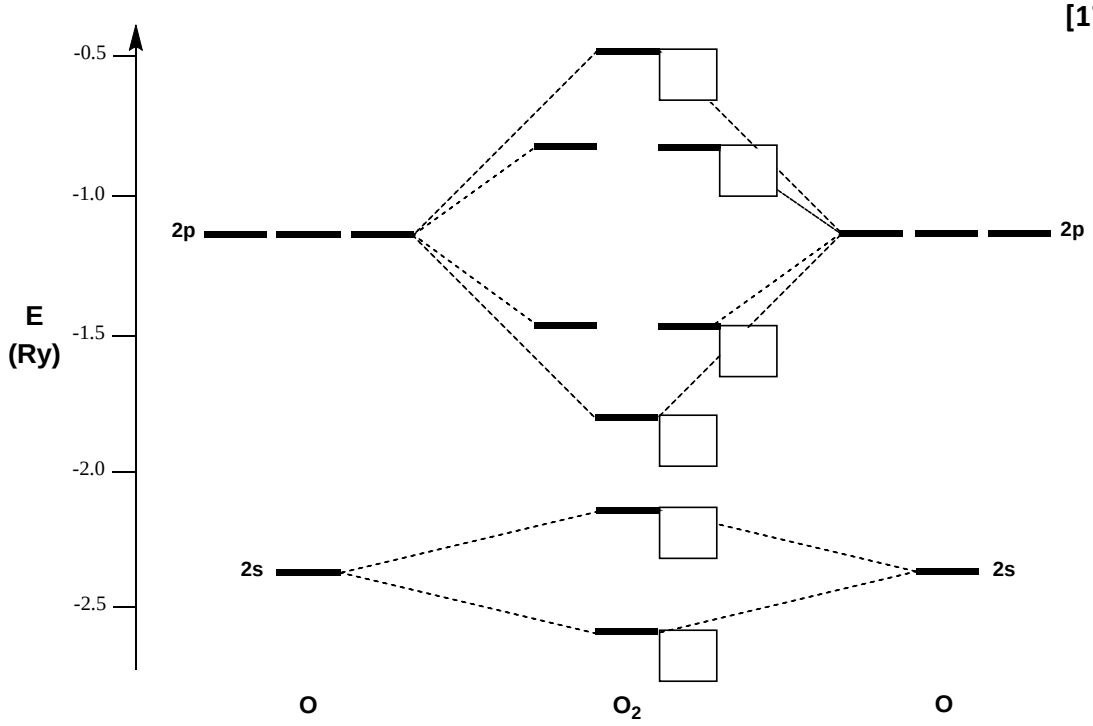
Signature: _____ Date: _____
Course: CHEM 2000 (General Chemistry II)
Semester: Spring 2018
The University of Lethbridge

Question Breakdown

Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**				**Total**
/ 17	/ 4	/ 12	/ 17	/ 5	/ 9				/ 64

1. The diagram below shows an incomplete valence molecular orbital energy level diagram for O_2.

[17 marks]



(a) Complete the diagram above by: *[4 marks]*

- labeling the molecular orbitals in the boxes provided, clearly indicating if each molecular orbital is bonding, nonbonding or antibonding, and
- placing the correct number of electrons in the molecular orbitals.

(b) In the space below, clearly identify which atomic orbitals combine to make each **sigma**-symmetric molecular orbital. For each sigma-symmetric molecular orbital, draw and name the atomic orbitals from which it is formed. Also, draw and name the molecular orbital itself. *[8 marks]*

1. *continued…*

(c) Is O_2 diamagnetic or paramagnetic? Justify your choice. *[1 mark]*
The mark is for the explanation. Answers without explanation will not get credit.

(e) Write the valence orbital occupancy (electron configuration) for O_2. *[1 mark]*

(f) Calculate the bond order for O_2. *[1 mark]*

(g) Peroxide is the dianion formed from oxygen. It has the formula O_2^{2-}. Write the valence orbital occupancy for the peroxide ion **and** calculate the bond order in the peroxide ion. *[2 marks]*

2. The amount of *sp*-mixing observed in the homonuclear diatomic molecules varies dramatically across the periodic table. **[4 marks]**

(a) Give an example of a homonuclear diatomic molecule (from the second period) in which you would expect to see a significant amount of *sp*-mixing. *[1 mark]*

(b) Give an example of a homonuclear diatomic molecule (from the second period) in which you would expect to see a negligible* amount of *sp*-mixing. *[1 mark]*
**The word "negligible" means "an insignificant amount" or "very little".*

(c) What is the main factor influencing the amount of *sp*-mixing, and how does this factor relate to the amount of *sp*-mixing in a second period homonuclear diatomic molecule? *[2 marks]*

3. In the gas phase, sodium chloride $(NaCl)$ exists as molecules rather than an ionic lattice. Sodium chloride molecules can be studied at very high temperatures by boiling molten sodium chloride. Atomic energies for sodium and chlorine are provided below. **[12 marks]**

Orbital	Energy (Ry)
Na 3s	−0.38
Cl 3s	−1.86
3p	−1.01

(a) Draw a molecule orbital energy level diagram for $NaCl$. On your diagram: *[5 marks]*

- Label all atomic and molecular orbitals, clearly indicating if each molecular orbital is bonding, nonbonding or antibonding.
- Populate the molecular orbitals with the correct number of electrons.

(b) Compare your molecular orbital energy level diagram to the Lewis diagram for $NaCl$. Briefly discuss similarities and/or differences. *Factors to consider include bond order, nonbonding electrons and bond polarity.* *[4 marks]*

(c) What would happen to the vibrational frequency of this molecule if we removed an electron from the HOMO? Would it increase, decrease or stay approximately the same? Explain briefly. *[3 marks]*

4. The atoms of N_2O(nitrous oxide, laughing gas) are connected: N—N—O. **[17 marks]**

(a) Draw all resonance structures for N_2O that have minimum formal charges. Explicitly show (using curved arrows) the electron movements that transform one resonance structure into the other. *You must explicitly show all non-zero formal charges.* *[5 marks]*

(b) What N—N and N—O bond orders would you predict from the Lewis diagrams drawn in part (a)? *[2 marks]*

N—N bond order is _____ N—O bond order is _____

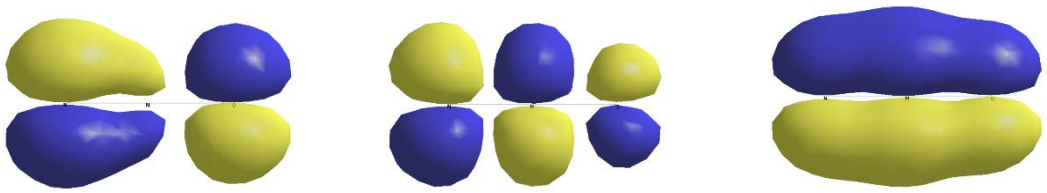
(c) While it is not obvious from the Lewis diagrams, there are **<u>eight</u>** π electrons in N_2O. Draw a π molecular orbital energy level diagram for N_2O. On your diagram: *[5 marks]*

- Label all molecular orbitals.
- Populate the molecular orbitals with the correct number of electrons.

4. *continued…*

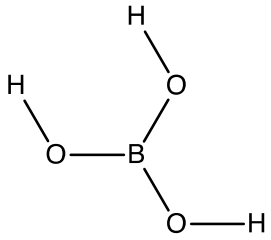
(d) The following images show some of the π molecular orbitals of N_2O. The images are not presented in any particular order. **Underneath each image**, write the correct orbital label.

[3 marks]



(e) Correlate your Lewis diagram bond orders with these orbital images. In other words, can you (or not) rationalize the Lewis bond orders from the shapes of the π orbitals and your orbital occupancies? *[2 marks]*

5. Boric acid has the following connectivity: **[5 marks]**



(a) Convert the diagram above into a Lewis diagram by adding lone pairs where necessary. *[1 mark]*

(b) According to valence bond theory, what is the hybridization of the boron atom? *[1 mark]*

(c) According to valence bond theory, what is the hybridization of the oxygen atoms? *[1 mark]*

(d) According to valence bond theory, how would we describe the B-O bond in boric acid? *[2 marks]*

6. **[9 marks]**

(a) Draw the band diagram for a p-type semiconductor, labeling all the relevant bands. *[3 marks]*

(b) Draw the band diagram for an n-type semiconductor, labeling all the relevant bands. *[3 marks]*

(c) A diode is composed of an n-type and a p-type semiconductor connected to each other. Explain how this device restricts the flow of electrons in one direction.
Your answer should include a diagram. *[3 marks]*

Overflow Page

If you use this page for any answers, please clearly indicate which question is being answered and make sure you note on the page for the question itself that the answer continues here.