NAME:_____ Section:_____ Student Number:_____

Spring 2020 **Chemistry 2000 Midterm #1A** ____/65 marks

INSTRUCTIONS:
1) Please read over the test carefully before beginning. You should have 8 pages of questions, a blank "overflow" page and a periodic table page.
2) If your work is not legible, it will be given a mark of zero.
3) Marks will be deducted for incorrect information added to an otherwise correct answer.
4) Calculators are not permitted.
5) 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 8:30 pm Mountain Time on Tuesday, February 11th, 2020. I understand that breaking this agreement would constitute academic misconduct, a serious offense with serious consequences. The minimum punishment would be a mark of 0/65 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 2020
The University of Lethbridge

Question Breakdown

Q1	/ 16
Q2	/ 7
Q3	/ 20
Q4	/ 16
Q5	/ 6

Total	/ 65

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1. **[16 marks]**

(a) Develop the valence molecular orbital energy level diagram for B_2. *[7 marks]*

Your diagram must include:

- labeled molecular orbital energy levels (you don't need to draw pictures of the MOs)
- identification of each molecular orbital as bonding, nonbonding or antibonding
- electrons in the appropriate molecular orbitals

(b) Calculate the bond order for B_2 *[1 mark]*

(c) Identify and sketch the HOMO and LUMO of B_2. *[4 marks]*

HOMO: LUMO:

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1. …*continued*

(d) Sketch the UV photoelectron spectrum of B_2. Assume that the UV photon used has enough energy to remove electrons from any of the valence orbitals. While you won't be able to put numbers on the horizontal axis, do indicate what quantity is plotted along this axis and the direction in which this quantity increases. The vibrational "frequency" of the neutral B_2 molecule is 1051.3 cm^{-1}. Indicate how the relevant feature(s) of the spectrum relate to this frequency. *[4 marks]*

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2. Consider a piece of sodium. Use the symbol *N* to represent the number of sodium atoms. **[7 marks]**

(a) Draw a band diagram for sodium. Indicate the atomic orbital(s) that contributed to the band(s) in your diagram. *[3 marks]*

(b) Indicate how many states exist in each band on your diagram. *[1 mark]*

(c) Indicate how many electrons occupy each band on your diagram. *[1 mark]*

(d) Is sodium a conductor, semiconductor or insulator? Justify your answer with reference to your band diagram. *[2 marks]*

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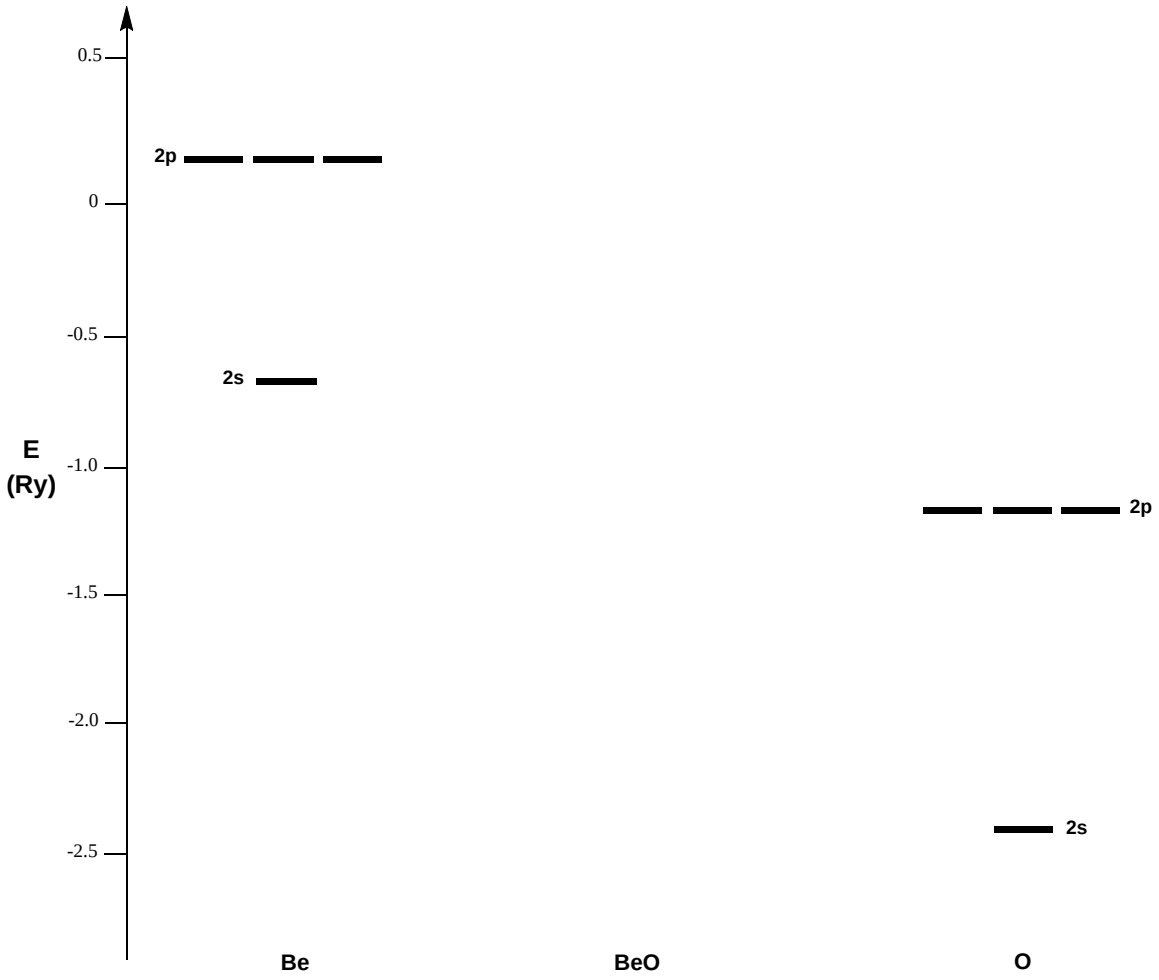
3. Consider beryllium oxide (BeO) according to molecular orbital theory. **[20 marks]**

(a) Draw the Lewis diagram for BeO. *[1 mark]*

(b) Complete the valence molecular orbital energy level diagram below by: *[9 marks]*

- drawing and labeling the molecular orbital energy levels (you don't need to draw pictures of the MOs themselves)
- identifying each molecular orbital as bonding, nonbonding or antibonding
- populating the diagram with the appropriate number of electrons
- labeling the HOMO and LUMO



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

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3. …*continued*

(d) Draw each of the **sigma-symmetric** valence molecular orbitals of BeO. *[4 marks]*

(e) When BeO acts as a Lewis acid, do you expect it to react at Be or at O? Justify your answer with reference to the relevant molecular orbital. *[3 marks]*

(f) Does the bond order implied by your MO diagram agree with that predicted from your Lewis diagram? Explain briefly. *[2 marks]*

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4. **[16 marks]**

(a) Draw a Lewis diagram (with resonance structures, if appropriate) of NO_2^-. *[3 marks]*
Include any non-zero formal charges on the appropriate atom(s).

(b) Use VSEPR theory to predict the shape of NO_2^-. *[1 mark]*

(c) Develop the π MO energy level diagram of NO_2^-. *[4 marks]*

Your diagram must include:

- labeled molecular orbital energy levels
- identification of each molecular orbital as bonding, nonbonding or antibonding
- electrons in the appropriate molecular orbitals

(d) Does the π bond order implied by your π MO diagram agree with that predicted from your Lewis diagram(s)? Explain briefly. *[2 marks]*

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4. *…continued*

(e) Draw the π MOs. Show both a top view and a side view for each π MO. Label each picture so that it is clear which π MO it shows. *[6 marks]*

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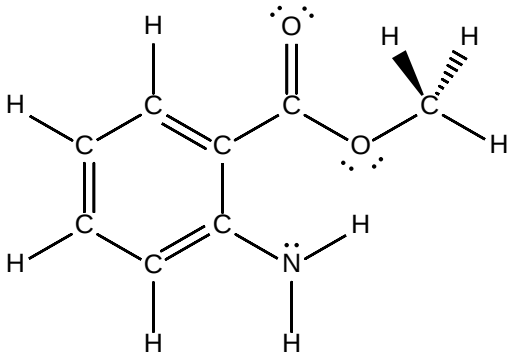
5. The following is a graphic of methyl anthranilate, a compound that occurs naturally in grapes and gives them some of the characteristic grape aroma and flavor. It is the main flavoring agent in grape Kool-Aid. **[6 marks]**



The following questions are to be answered using valence-bond theory.

(a) What is the hybridization of the nitrogen atom? *[1 mark]*

(b) What is the hybridization of the carbon atoms in the ring? *[1 mark]*

(c) How would valence-bond theory describe the bonding in the C=O group of this molecule? Make sure to provide the description of both the sigma and pi bonds. *[4 marks]*

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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.

Chem 1000 Standard Periodic Table

1												13	14	15	16	17	18
1.0079 **H** 1	**2**																4.0026 **He** 2
6.941 **Li** 3	9.0122 **Be** 4											10.811 **B** 5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	20.1797 **Ne** 10
22.9898 **Na** 11	24.3050 **Mg** 12	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	26.9815 **Al** 13	28.0855 **Si** 14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	39.948 **Ar** 18
39.0983 **K** 19	40.078 **Ca** 20	44.9559 **Sc** 21	47.88 **Ti** 22	50.9415 **V** 23	51.9961 **Cr** 24	54.9380 **Mn** 25	55.847 **Fe** 26	58.9332 **Co** 27	58.693 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30	69.723 **Ga** 31	72.61 **Ge** 32	74.9216 **As** 33	78.96 **Se** 34	79.904 **Br** 35	83.80 **Kr** 36
85.4678 **Rb** 37	87.62 **Sr** 38	88.9059 **Y** 39	91.224 **Zr** 40	92.9064 **Nb** 41	95.94 **Mo** 42	(98) **Tc** 43	101.07 **Ru** 44	102.906 **Rh** 45	106.42 **Pd** 46	107.868 **Ag** 47	112.411 **Cd** 48	114.82 **In** 49	118.710 **Sn** 50	121.757 **Sb** 51	127.60 **Te** 52	126.905 **I** 53	131.29 **Xe** 54
132.905 **Cs** 55	137.327 **Ba** 56	**La-Lu**	178.49 **Hf** 72	180.948 **Ta** 73	183.85 **W** 74	186.207 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.967 **Au** 79	200.59 **Hg** 80	204.383 **Tl** 81	207.19 **Pb** 82	208.980 **Bi** 83	(210) **Po** 84	(210) **At** 85	(222) **Rn** 86
(223) **Fr** 87	226.025 **Ra** 88	**Ac-Lr**	(265) **Rf** 104	(268) **Db** 105	(271) **Sg** 106	(270) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112	(284) **Nh** 113	(289) **Fl** 114	(288) **Mc** 115	(293) **Lv** 116	(294) **Ts** 117	(294) **Og** 118

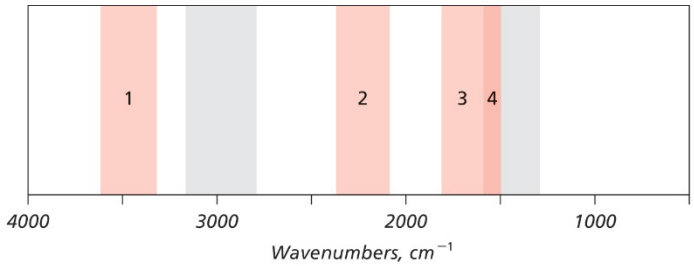
138.906 **La** 57	140.115 **Ce** 58	140.908 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.965 **Eu** 63	157.25 **Gd** 64	158.925 **Tb** 65	162.50 **Dy** 66	164.930 **Ho** 67	167.26 **Er** 68	168.934 **Tm** 69	173.04 **Yb** 70	174.967 **Lu** 71
227.028 **Ac** 89	232.038 **Th** 90	231.036 **Pa** 91	238.029 **U** 92	237.048 **Np** 93	(240) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(262) **Lr** 103

Developed by Prof. R. T. Boeré (updated 2016)

Table of atomic orbital energies. All energies are in Ry.

	1s	2s	2p
H	-1.00		
He	-1.81		
Li	-4.77	-0.40	
Be	-8.9	-0.69	
B	-14.5	-1.03	-0.42
C	-21.6	-1.43	-0.79
N	-30.0	-1.88	-0.95
O	-39.9	-2.38	-1.17
F	-51.2	-2.95	-1.37
Ne	-64.0	-3.56	-1.59

All energies are from J.C. Slater, *Physical Review* (1955) **98**, 1039-1045.



Region	Frequency range, (cm^{-1})	Bond types	Functional groups
1	3500 – 3200	O—H N—H	Alcohol, phenol Amine, amide
2	2300 – 2100	C≡C C≡N	Alkyne Nitrile
3	1800 – 1650	C═O	Aldehyde Amide Anhydride (2 bands) Carboxylic acid Acid chloride Ester
4	1650 – 1500	C═C C═C C═N N═O	Alkene Arene Imine Nitro compound