NAME:______________________________________
Student number: ____________________

Chemistry 2000 Spring 2019 Test 1
Version A

Time: 90 minutes

Aids permitted: none. See page 10 for useful data.

Overflow/scratch space: If you need the extra space at the end of this paper to continue an answer, **it is your responsibility to make it clear what I need to mark, i.e. what is your answer vs what is just scratch work.**

Question	Mark
1	/5
2	/9
3	/2
4	/5
5	/10
6	/18
7	/5
Total:	/54
Percentage:	%

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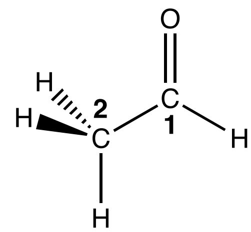
/5

1. The following is an incomplete Lewis diagram of ethanal:



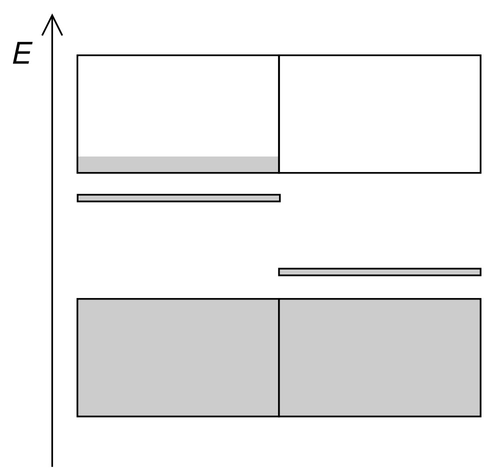
(a) Add any missing lone pairs directly on the diagram. [1 mark]

(b) According to valence-bond theory, the hybridization of carbon **1** is ______ while the hybridization of carbon **2** is ______. [2 marks]

(c) According to valence-bond theory, the carbon-oxygen sigma bond is made by overlapping a carbon ______ orbital with an oxygen ______ orbital. [2 marks]

/9

2. The following is a band diagram for a diode:



(a) On the diagram, label the p-type semiconductor, n-type semiconductor, valence band, conduction band, donor band, and acceptor band. Show the directions in which electrons and holes flow most easily given an appropriately configured external circuit. [5 marks]

(b) To use a diode as a solar (photovoltaic) cell, the ___ side of the junction is exposed to light. This causes electrons to be transferred from the ______________ band to the ______________ band. These electrons can then flow to the ___ side of the junction where they can be collected to power an external circuit. [4 marks]

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3. Nitric oxide (NO) is produced in lightning and in internal combustion engines, among other sources. Is NO a greenhouse gas? Explain briefly. [2 marks]

/5

4. Build a valence MO diagram for HeH. Populate your MO diagram with electrons. Use your diagram to explain whether you think such a molecule could exist. [5 marks]

/10

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5. Build a valence MO diagram for O_2. Populate your MO diagram with electrons. What features of the MO treatment do and do not agree with the Lewis diagram? (You may need to do additional work using the MO diagram to answer this question, and of course you will need a Lewis diagram as well.) [10 marks]

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6. (a) Draw an **octet rule** Lewis diagram for SO_2. If your Lewis diagram has resonance structures, draw those too. [3 marks]

   (b) Draw a $\boldsymbol{\pi}$ MO diagram for SO_2. Fill in the MO diagram with the appropriate number of electrons. Identify the HOMO and LUMO. [6 marks]

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(c) Sketch each of the π MOs. Show both top and side views of each orbital. [6 marks]

(d) You may recall that SO_2 is a Lewis acid. What does your MO analysis tell you about where (i.e. at which atom) a Lewis base would react with SO_2? Explain briefly. [3 marks]

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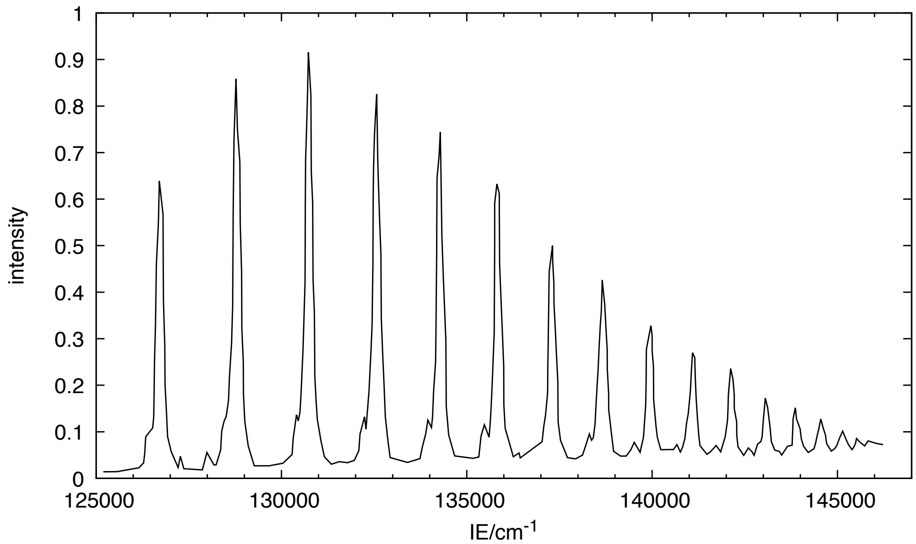
7. The photoelectron spectrum of H_2 has the following appearance:[1]



(IE = ionization energy)

Given that the vibrational frequency of H_2 is $4401.21\,\text{cm}^{-1}$, what information can you infer from this spectrum? Does this agree with our discussion of the molecular-orbital theory of H_2? Be specific. For full credit, you will need to read some data from the spectrum. [5 marks]

Notes: This spectrum was digitized from real experimental data, so it's a bit noisy. Ignore the little side-peaks and focus on the large peaks. (If you're really curious, I can explain where those little side peaks come from after the test.) The peaks in the photoelectron spectrum get closer together as we go up in energy for reasons that we did not discuss directly in class. Focus on the lower-energy peaks for your analysis.

[1] Adapted from L. Åsbrink, *Chem. Phys. Lett.* **7**, 549 (1970).

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Potentially useful formula

$$E = h\nu = \frac{hc}{\lambda} = hc\tilde{\nu}$$

Periodic table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											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 47.88	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 65.41	31 Ga 69.72	32 Ge 72.61	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 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Valence atomic orbital energies

Atom	Orbital	ε/Ry
H	1s	−1.00
He	1s	−1.81
O	2s	−2.38
	2p	−1.17
S	3s	−1.54
	3p	−0.86