

CH301H – Principles of Chemistry I: Honors
Fall 2016, Unique 50015

Exam 1
13 September 2016

Name: Key.

You may use any material you wish provided it does not have a heartbeat nor does it connect to a wireless or cellular network.

Honor Code:

“The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community.”

I certify that the work on this exam is entirely my own.

Signature

Date

1. (15 points) Determine whether the following statements are true or false.

a. True False The classical model of the atom predicts that the electron and the proton are separated by a distance of $r = 0$ m.

b. True False F_2 has a larger dipole moment than Cl_2 . *Neither has a dipole moment*

c. True False A correct Lewis dot structure gives the three dimensional structure of a molecule. *Only connectivity*

d. True False As an electron and proton approach each other, the potential energy of the electron decreases. *PE is of the system, not one part of it.*

e. True False The length of the C-H double bond is shorter than the C-H single bond. *C-H does not refer double bonds*

2. (15 points) The Rutherford backscattering experiment can be conducted on any atom in the periodic table. Rutherford estimated the size of the nucleus of the Au atom by bombarding his sample with α particles that were 2.0 MeV. Use this method to determine the accurate size of the C nucleus (for example in a one-atom-thick sheet of graphene).

This is directly from problem #5 on HW 1-2:

$$q_1(\text{He}) = +2e$$

$$q_2(\text{C}) = +6e$$

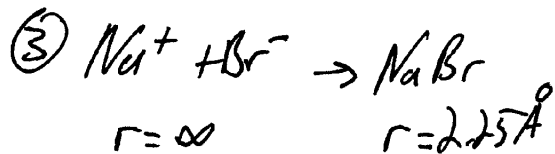
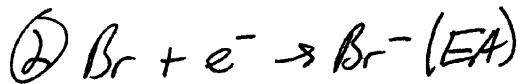
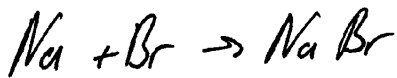
$$E = \frac{q_1 q_2}{4\pi\epsilon_0 r} \Rightarrow r = \frac{q_1 q_2}{4\pi\epsilon_0 E}$$

$$E = 2.0 \text{ MeV} = 2.0 \cdot 10^6 \text{ eV}$$

$$r = \frac{(2)(6)(1.602 \cdot 10^{-19} \text{ C})^2}{4\pi (8.854 \cdot 10^{-12} \text{ C}^2/\text{Jm})(2.0 \cdot 10^6 \text{ eV})}$$

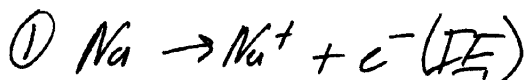
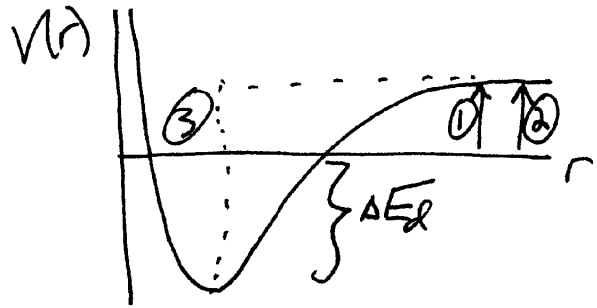
$$r = 1.38 \cdot 10^{-33} \frac{\text{Jm}}{\text{eV}} \left(\frac{\text{eV}}{1.602 \cdot 10^{-19} \text{ J}} \right) = \boxed{8.6 \cdot 10^{-15} \text{ m}}$$

3. (20 points) Determine the bond dissociation energy for NaBr, which has an equilibrium bond length of 2.25 Å.

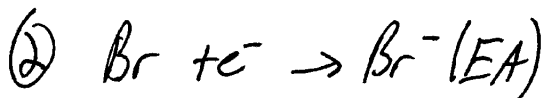


$$r = \infty \qquad r = 2.25 \text{ \AA}$$

$$\Delta E_d = \text{IE} + \text{EA} + V_{\text{bond}}$$



$$\text{IE}_1 = \frac{5.14 \text{ eV}}{\text{atom}} \left| \frac{1.602 \cdot 10^{-19} \text{ J}}{\text{eV}} \right| \left| \frac{6.022 \cdot 10^{23} \text{ atoms}}{\text{mol}} \right| // 4.96 \cdot 10^5 \text{ J mol}^{-1}$$



$$\text{EA} = -325 \text{ kJ mol}^{-1} \Rightarrow -3.25 \cdot 10^5 \text{ J mol}^{-1}$$

$$\textcircled{3} V_{\text{bond}} = \frac{q_1 q_2}{4\pi\epsilon_0 r} = \frac{(+1)(-1)(1.602 \cdot 10^{-19} \text{ C})^2}{4\pi(8.854 \cdot 10^{-12} \text{ C}^2/\text{Jm})(2.25 \cdot 10^{-10} \text{ m})} = -1.03 \cdot 10^{-18} \text{ J/bond}$$

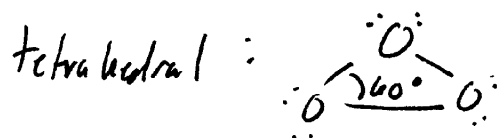
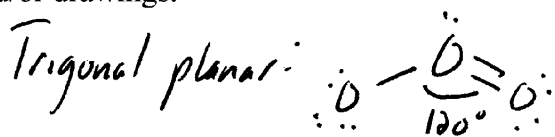
$$\frac{-1.03 \cdot 10^{-18} \text{ J}}{\text{bond}} \left| \frac{6.022 \cdot 10^{23} \text{ bonds}}{\text{mol}} \right| // -6.17 \cdot 10^5 \text{ J mol}^{-1}$$

$$\Delta E_d = V_{\infty} + V_{\text{bond}} = \text{IE}_1 + \text{EA} + V_{\text{bond}}$$

$$= 4.96 \cdot 10^5 \text{ J mol}^{-1} + \cancel{+3.25} - 3.25 \cdot 10^5 \text{ J mol}^{-1} - 6.17 \cdot 10^5 \text{ J mol}^{-1}$$

$$\Delta E_d = -4.46 \cdot 10^5 \text{ J mol}^{-1} \text{ or } -446 \text{ kJ mol}^{-1}$$

4. (20 points) In class, we drew a Lewis dot structure of O_3 in which the central O was trigonal planar. An alternative, perfectly legitimate Lewis dot structure of O_3 makes every O in the molecule tetrahedral. Which of these structures is more likely to be the correct, experimentally observed structure? Use any argument you need to justify your answer, using words, equations, and/or drawings.



In the tetrahedral structure, $SN=4$ would have its lowest energy configuration w/ O atoms 109.5° apart from each other (slightly lower w/ distortion from the lone pair). This Lewis structure forces the O atoms to be 60° apart from each other, which is highly unfavorable.

5. (15 points)

a) What is the dipole moment for a diatomic molecule with bond length 1.5 \AA with 100% ionic character?

$$\delta = 1.0; \mu(D) = \frac{r(\text{\AA}) \delta}{0.2082 \frac{\text{\AA}}{D}} = \frac{(1.5 \text{\AA})(1.0)}{0.2082 \frac{\text{\AA}}{D}} = \boxed{7.2 D}$$

b) Table 3.7 in your text book lists diatomic molecules with dipole moments greater than your answer for part a), yet still having partial covalent character. Why?

The molecules w/ $\mu > 7.2 D$ also have $r > 1.5 \text{ \AA}$. Since $\delta = \frac{\mu(D)(0.2082 \frac{\text{\AA}}{D})}{r(\text{\AA})}$, larger r in denominator will lower δ .

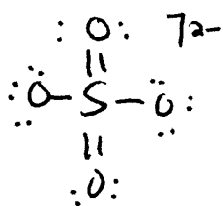
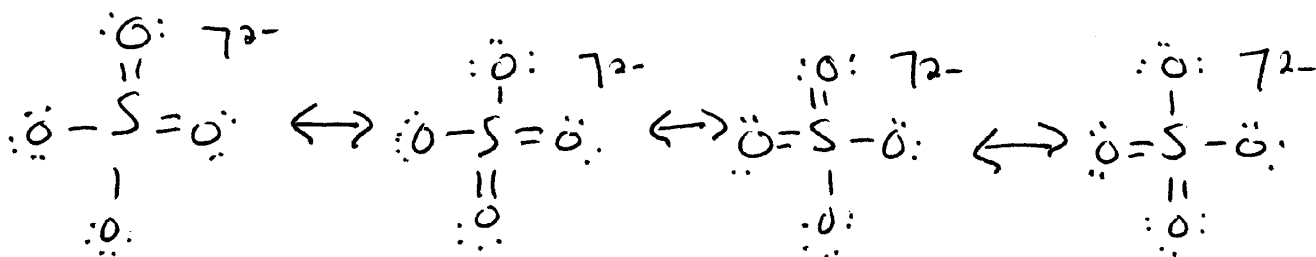
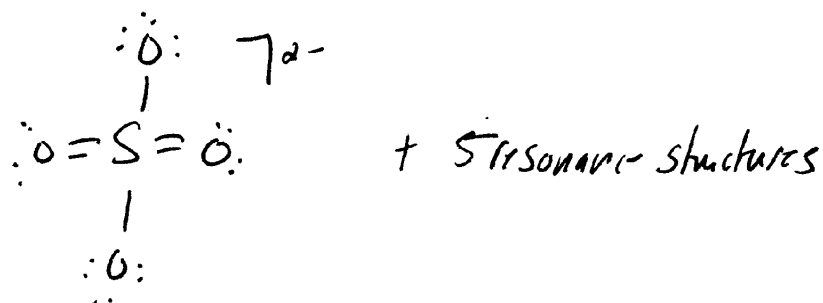
c) Why might even diatomic molecules with very large dipole moments still have some covalent character? Justify your answer.

Even in strongly ionic molecules, where e^- in the anion are tightly held, e^- in the valence shell are still between the two nuclei. Since the separation between e^- and both nuclei is roughly the same distance, there will always be some sharing of e^- .

6. (15 points) The average length of the S-O single bond is 1.55 Å and that of the S=O double bond is 1.65 Å. From this information, predict the length of the S-O bond in SO_4^{2-} .

This problem reduces to being able to draw a correct Lewis dot

Structure of SO_4^{2-} :



So at the very least, the S-O bond will be between the S-O single + S=O double bond lengths. Since any given S-O is a single bond in half the resonance structures and a double bond in the other half, I will estimate that the bond length is ~~top~~ halfway between the two extremes: 1.60 Å.

Scratch paper