Exam I

CH 301H Fall '10

Vanden Bout

Name: KEY

Carefully read all the problems (your exam should have 12 problems)

Show all your work on numerical problems

Clearly mark your answers

If you think a problem cannot be worked out with the information provided write "this problem can not be worked with the information provided"

Problems may contain extraneous information

Please sign at the bottom to certify that you have worked on your own.

I certify that I have worked the following exam without the help of others, and that the work I am turning in is my own.

Signed: _____

Signature Date

1. True/False (6 points each, 30 total) Circle the **best** answer

T (F) The second ionization energy of Ca is lower than the first. $IE_2 > IE_1$ always

(T) F In the Rutherford back scattering experiment, back scattered alpha particles were very rarely observed.

T (F) Electron affinity <u>always</u> increases left to right on the periodic table. mostly

T (F) CCl_4 has a small but finite dipole moment. completely non-polar

T (F) The effective nuclear charge felt by the electron in Li^{2+} is slightly less than 3.

one 1 e^- $\therefore Z_{eff} = Z$

NO SHIELDING!

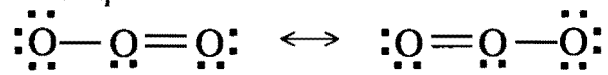
Multiple choice (10 points each, 30 total) For each question give the "best choice" in the space provided

2. In the Milliken oil drop experiment, Milliken was able to determine the charge on the electron because

A. every oil drop in the experiment had one electron
B. every oil drop had an integer number of electrons
C. every oil drop had the same charge
D. every oil drop was the same size
E. Millken's experiment determined the mass to charge ratio of the electron, not the charge

B

3. Below are two equivalent resonance structures for ozone, O_3



Which of the following would you expect for molecular ozone?

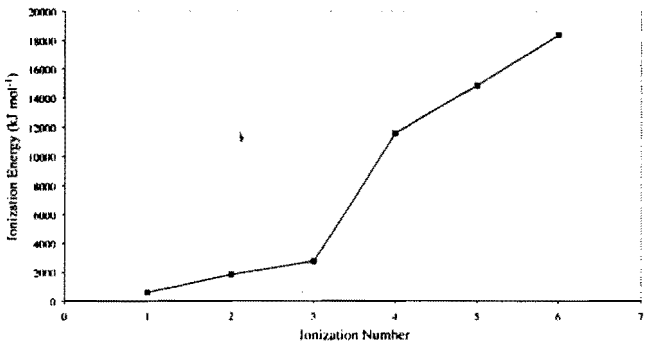
A. it has one O-O bond that is shorter than the other.
B. it has one O-O bond that alternates between being shorter and longer than the other.
C. it has two O-O bonds that are identical.
D. the partial charge on the oxygen atoms on each end of the molecule are different.
E. both b & d

C

4. Below is a graph of the ionization energies for a particular element.

Based on the trend in the ionization energies the element is

A. Ne
B. B
C. S
D. Al
E. K



Not B as it does have enough e⁻

D

5 The density of solid sodium is approximately 0.97 g cm^{-3}. Use this to estimate the radius of a single sodium atom (this will obviously be approximate).(10 points)

$$\frac{9.7 \cdot 10^{-1}\ g\ cm^{-3}}{23\ g\ mol^{-1}} = 4.2 \cdot 10^{-2}\ mol\ cm^{-3}$$

$$\frac{1}{(4.2 \cdot 10^{-2}\ mol\ cm^{-3})(6.02 \cdot 10^{23}\ atm\ mol^{-1})} = 3.94 \cdot 10^{-23}\ cm^3\ atm^{-1} = \frac{4}{3}\pi r^3$$

$$r = 2.1 \cdot 10^{-8}\ cm \quad \text{or} \quad 2.1\ \text{Å}$$

Taking that same radius and the fact that the first ionization energy of Na is 496 kJ mol^{-1}, estimate the effective nuclear charge felt by the outermost valence electron in Na. (10 points)

$$I.E. = -V(R) = -\frac{(-1e)(+Z_{eff}e)}{4\pi\epsilon_0 R}$$

$$Z_{eff} = 0.75$$

$$\frac{N_A}{10^3} \times \frac{Z_{eff}\, e^2}{4\pi\epsilon_0 (2.1 \cdot 10^{-10}\ m)} \times \frac{10^3\ J\ kJ^{-1}}{6.02 \cdot 10^{23}\ atm\ mol^{-1}} = 496\ kJ\ mol^{-1}$$

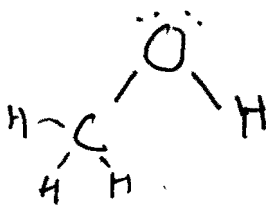
What does this say about "electron shielding" in Na? (5 points)

$Z = 11 \quad Z_{eff} = 0.75$

∴ the inner core of 10 e^- essentially cancels out 10 protons in the nucleus

∴ $Z_{eff} \sim 1$.

6. Methanol CH_3OH is like water with a CH_3- group (methyl) in place of one hydrogen. Given the following electronegativities (H = 2.1, C= 2.5, O = 3.5). Which do you think will have a larger dipole moment, water or methanol? Why? (10 points)



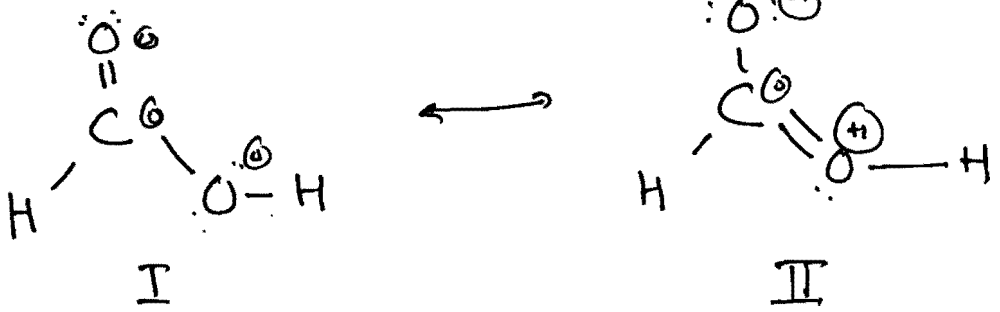
ΔEN for O-C is smaller than ΔEN for O-H.

∴ the O-C bond will be less polar & contribute less to the overall dipole.

Water is more polar

7.

Formic acid H_2CO_2 is an organic acid with a central carbon atom bonded to two oxygens and hydrogen. The other hydrogen is bonded to one of the oxygens. (20 points)
Draw all possible resonance structures for formic acid that satisfy the octet rule.
Are these structures equivalent?
If not, why is one a better structure than the other?

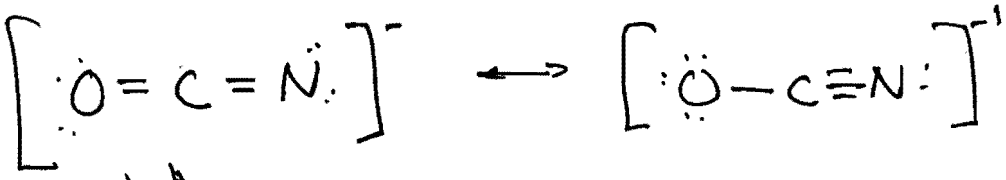


I ⟷ II

not equivalent

Structure I is better as it has no formal charges.

8. What is the bond angle of the cyanate ion, OCN^-? (If it is not exact, state that it is less than or greater than a particular angle). (15 points)

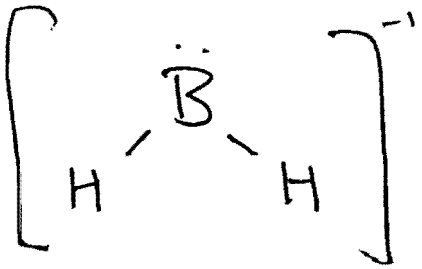


better

But Both structures are linear.

∴ 180° exactly

9. What is the bond angle in BH_2^-?(If it is not exact, state that it is less than or greater than a particular angle). (15 points)



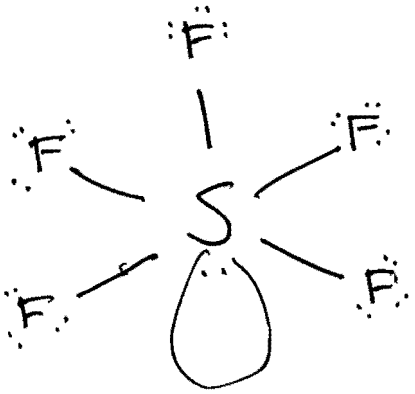
SN = 3

Ideal 120°

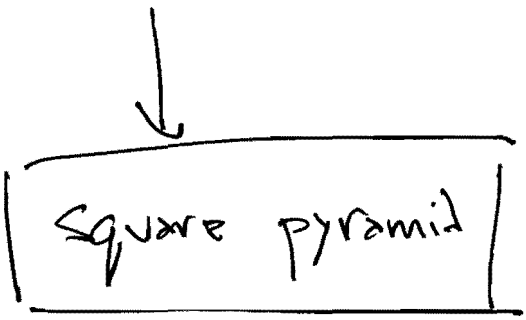
Bent

less than 120°

10. What is the geometry of the SF_5^- ion? (15 points)

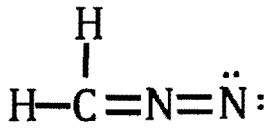


SN=6 one LP



square pyramid

12. Below are two structural isomers (same atoms different bonding) of CH_2N_2. Based on the geometries explain which you think would be the most stable of the two. (15 points)



diazomethane

diazirine

In diazirine there is a three-member ring whose angles must be ~60°. VSEPR would lead us to conclude the angles should be 109.5 (tetrahedral C) & 120° (trigonal planar N). Therefore this compound will be highly strained & ~~unstable~~ less stable.

13.
You have the following information about the molecule HBr

Element	Ionization Energy (kJ mol^{-1})	Electron Affinity (325 kJ mol^{-1})
H	1310	73
Br	1140	325

The bond length in HBr is 1.424 Å

Assuming that HBr was a purely ionic compound what would you expect the dissociation energy to be in kJ mol^{-1}? (you can ignore the small contribution to the potential energy from the repulsion) (10 points)

$\Delta E_{ion} = IE_H - EA_{Br} = 1300 - 325 = 985 \text{ kJ mol}^{-1}$

$\Delta E_{coulomb} = \frac{-(1)^2 e^2}{4\pi\epsilon_0 R} \frac{N_A}{10^3} = -975 \text{ kJ mol}^{-1}$

$\Delta E_1 = -(985 - 975) = -10 \text{ kJ mol}^{-1}$ NOT STABLE!

The actual dissociation energy of HBr is 363 kJ mol^{-1}.
What does this say about the bonding in HBr? (is it purely ionic, mostly covalent, 50/50 ionic/covalent,....) (5 points)

As the ionic model predicts a dissociation energy of -10 kJ mol^{-1} that is very far from the exp. measurement of 363 kJ mol^{-1}, ionic bonding is a poor model for HBr. MOSTLY COVALENT

The dipole moment of HBr is 0.828 D. From this estimate the partial charges on each atom. Does this make sense given your answer to the previous part of the problem? (does it seem too small, too big, about right,...) (10 points)

$\mu(D) = \frac{R(\text{Å})}{.2082 \text{ Å}} \times \delta$

$\delta = \frac{.2082 \times .828}{1.424} = .12$

$\pm 0.12 e$. only 12% of an e^-.

this is 88% covalent. MOST COVALENT

makes sense.