Chemistry 4A Midterm 2

Please write your answers with pen or dark pencil. Answers will be graded only within the space provided. Extra work area is provided at the back of the exam.

1. Graph the radial distribution functions for 2s, 2p, and 3p orbitals. Be sure to label each diagram with the orbital name.
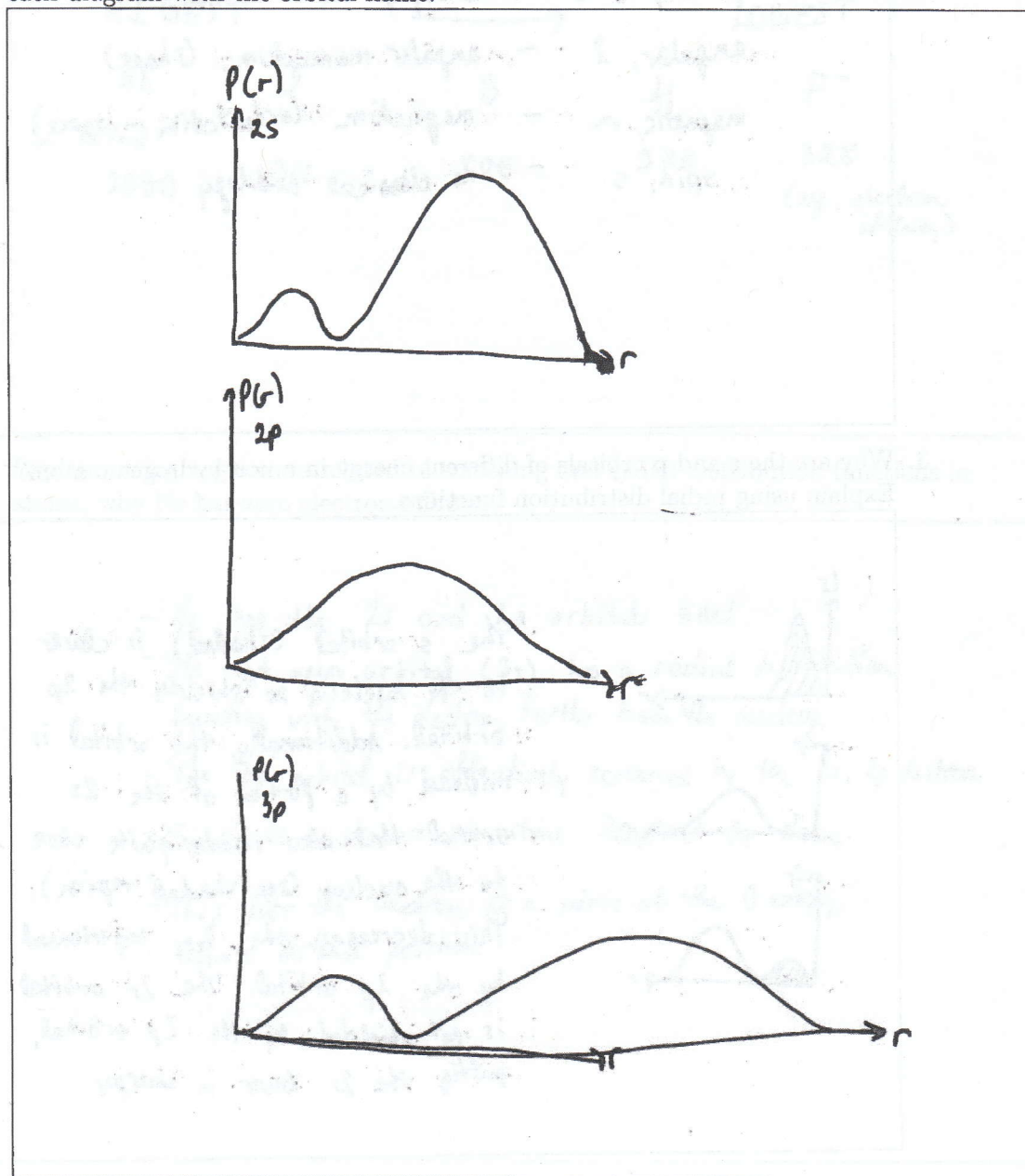
2. List the quantum numbers and state what they represent classically. Which quantum number lacks a classical analogy?

principal, n — energy level (size)

angular, l — angular momentum (shape)

magnetic, m — magnetism (orientation in space)

spin, s — no classical analogy

3. Why are the s and p orbitals of different energy in a non-hydrogenic atom? Explain using radial distribution functions.
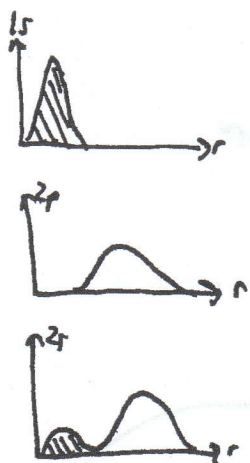
The s orbital (shaded) is closer to the nucleus, so shields the 2p orbital. Additionally, this orbital is shielded by a portion of the 2s orbital that also resides quite close to the nucleus (see shaded region). This decreases the Z_{eff} experienced by the 2p orbital. The 2s orbital is not shielded by the 2p orbital, putting the 2s lower in energy.
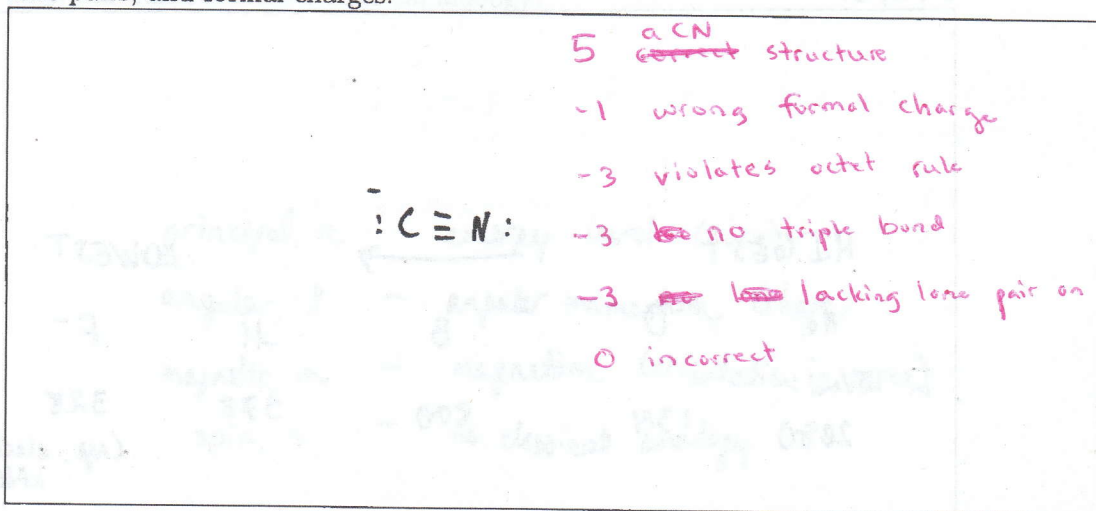
4. Rank the following atoms or ions from highest ionization energy to lowest: Al, Ne, F-, B, O.

HIGEST $\longrightarrow$ LOWEST

Ne	O	B	Al	F-

in kJ/mol:

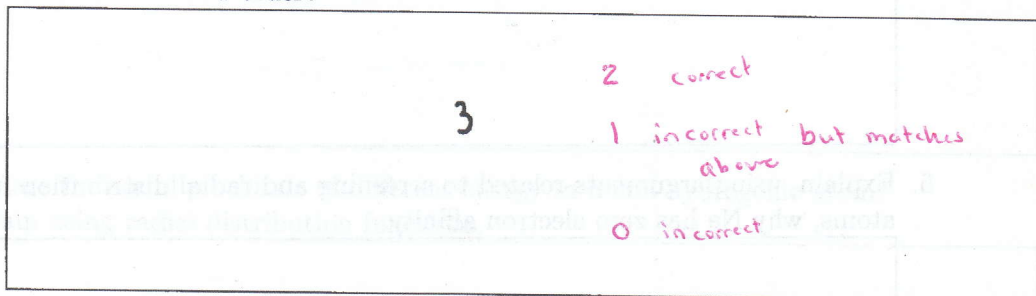| 2080	1314	800	578	328

(neg. electron affinity)

5. Explain, using arguments related to screening and radial distribution functions in atoms, why Ne has zero electron affinity.

- Ne has the 2s and 2p orbitals filled.
- The next open orbital (3s) has a radial distribution function with the electron farther from the nucleus.
- The 3s orbital is effectively screened by the 2s, 2p electrons.
- Since #electrons = #protons, $Z_{eff} = 0$ for Neon
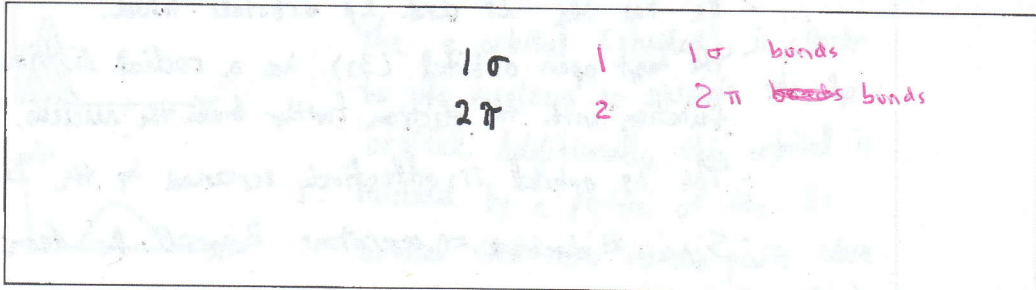- This puts the electron at a mimic of the 0 energy, infinite distance position.

6. Draw the Lewis dot structure for the cyanide anion (CN-), including all bonds, lone pairs, and formal charges.
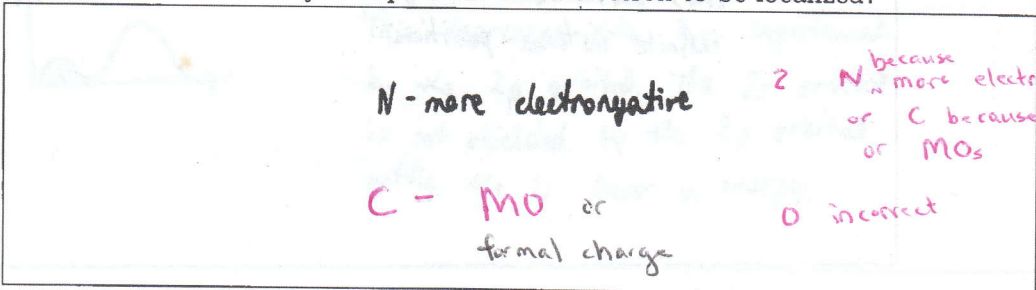
$$:C \equiv N:^{-}$$

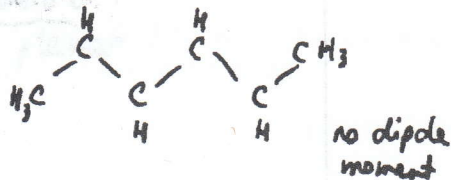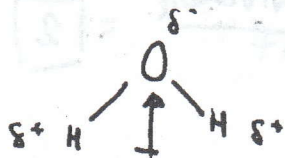5 a CN structure

~1 wrong formal charge

~3 violates octet rule

~3 no triple bond

~3 lacking lone pair on each atom

0 incorrect

(a) What is the bond order?

3

2 correct

1 incorrect but matches above

0 incorrect

(b) State whether the bonds are either σ or π.

1 σ
2 π

1 | 1 σ bonds
2 | 2 π bonds

(c) Around which atom do you expect the extra electron to be localized?

N - more electronegative

C - MO or
formal charge

2 N because more electronegative
or C because formal charge
or MOs

0 incorrect

4

7. Why does water responds to a charged rod, but hexane doesn't?

Water responds to a charged rod because it has a dipole moment: there is a big difference in electronegativity b/n O and H, but minimal difference b/n H and C. This dipole moment creates an electric field that can be attracted or repelled to a charged rod.

8. Draw the molecular orbital energy level diagram for O_2 (where there is no s-p mixing) and fill in the valence electrons. In the diagram, label atomic energy levels their atomic orbitals and the molecular energy levels with σ, π, σ^*, and π^*.
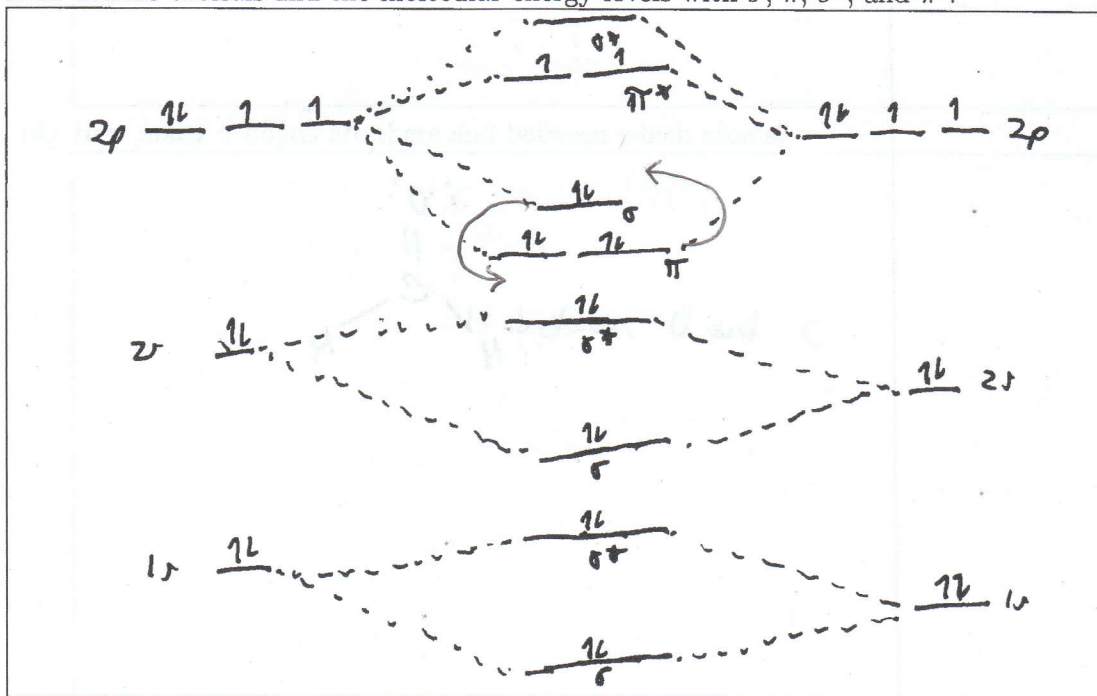
(a) Calculate the bond order for O_2.

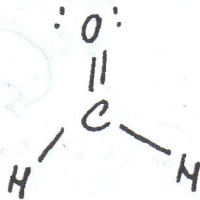$$\frac{6 \text{ bonding} - 2 \text{ antibonding}}{2} = \boxed{2}$$

(b) How many electrons would have to be promoted to the nearest, higher energy molecular orbitals in order for the O_2 molecule to dissociate?

$$\frac{(6-2) - (4+2)}{2} = 0$$

$$\boxed{2 \text{ electrons}}$$

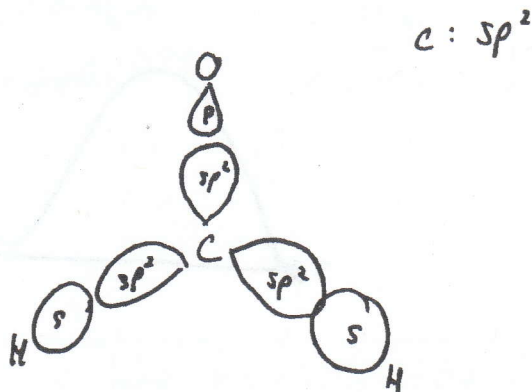9. The following concern the molecule formaldehyde, CH_2O:

(a) Draw out the Lewis strucutre, including lone pairs and bonds.

(b) What is the VSEPR predicted geometry?

trigonal planar

(c) For this geometry, draw out the σ bond framework for C and O and state how the s-p orbitals are hybridized.

$C : sp^2$

(d) How many π bonds are there and between which atoms?

1: between O and C