CH301H – Principles of Chemistry I: Honors
Fall 2013, Unique 52195

Exam 3
31 October 2013

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) True / False. Determine whether each of the following statements are true or false.

a. (True) False The ground state electron configuration for $F_2(g)$ is $\sigma_g(2s)^2\sigma_u^*(2s)^2\sigma_g(2p_z)^2\pi_u(2p_x)^2\pi_u(2p_y)^2\pi_g^*(2p_x)^2\pi_g^*(2p_y)^2$.

b. True (False) An electron in a 3s orbital is always far away from the nucleus.

c. (True) False The ground state electron configuration for Mg^{2+} is $1s^22s^22p^6$.

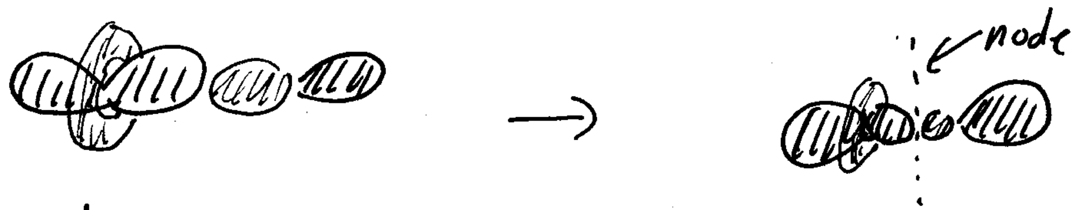
d. (True) False Electrons will fill a 5s orbital before a 4d orbital.

e. True (False) Violations of the Pauli exclusion principle are allowed but result in an excited state electron configuration.

2. (15 points) Draw and name the linear combination of the d_{z2} and p_z orbitals (i.e. the molecular orbitals formed from $d_{z2} + p_z$ and $d_{z2} - p_z$.

z is internuclear axis. Drawing MO's w/ d AO's follow exactly the same rules as s + p AO's

d_{z^2} + p_z → σ_g



d_{z^2} - p_z → σ_u^*

3. (15 points) Which would you expect to have a larger bond energy, $N_2(g)$ or $O_2(g)$? Use your understanding of MO's to justify your answer.

The MO diagram for N_2 results in a BO = 3, while O_2 results in BO = 2. We therefore expect N_2 to have a larger bond energy than O_2 because there are more e^- in bonding interactions in N_2 than in O_2.

4. (20 points) Name the orbital that corresponds to the following description.

a. The atomic orbital defined by $n = 3, l = 2$. 3d

b. The molecular orbital containing one angular node perpendicular to the z axis between the two nuclei and one angular node parallel to the z axis. ⇒ * ⇒ π

π_g^* ← only possibility to give both angular nodes

c. The atomic orbital containing one radial node and one angular node.

3p

d. The molecular orbital that is cylindrically symmetric about the z axis and containing no angular nodes. ⇒ σ

⇓ no *, g

σ_g

5. (20 points) The radial part of the wavefunction for the 3d orbital is given below:

$$R_{3d} = \frac{4}{81\sqrt{30}}\left(\frac{Z}{a_0}\right)^{3/2}\sigma^2 \exp\left(\frac{-\sigma}{3}\right)$$

where

$$\sigma = \frac{Zr}{a_0} \quad \text{and} \quad a_0 = \frac{\varepsilon_0 h^2}{\pi e^2 m_e}$$

How many radial nodes are described by this function? You must describe how you are answering this question, not simply put it in your graphing calculator and copy the answer it gives you.

This function goes to zero when $\sigma^2 \to 0$ and when $\exp[-\sigma] \to 0$

$\sigma^2 \to 0$ when $r \to 0$; $\exp[-\sigma] \to 0$ when $r \to$ large

So this function will go to 0 when $r \to 0$ and $r \to$ large. These are the endpoints of the standing wavefunction, not nodes.

So **# radial nodes = 0**

6. (15 points) The uncertainty in the energy of a certain excited state (ΔE) and the time required to measure the energy of the excited state (Δt) are related through the uncertainty principle:

$$\Delta E \Delta t \geq \frac{h}{4\pi}$$

A certain atomic excited state has an average lifetime of 10 ps (10×10^{-12} s). What is the uncertainty in the frequency of the photon emitted from this atom when the excited state decays to the ground state?

$$\Delta E = \frac{h}{4\pi \Delta t} = \frac{(6.626\times10^{-34}\,\text{Js})}{4\pi(10\times10^{-12}\,\text{s})} = 5.27\times10^{-24}\,\text{J}$$

$$E = h\nu, \quad \nu = \frac{E}{h} = \frac{5.27\times10^{-24}\,\text{J}}{6.626\times10^{-34}\,\text{Js}} = \boxed{7.96\times10^{9}\,\text{s}^{-1}}$$

(also do in one step: $\nu = \frac{\Delta E}{h} = \left(\frac{h}{4\pi\Delta t}\right)\left(\frac{1}{h}\right) = \frac{1}{4\pi\Delta t} = \nu$)