Unit 7/8 Review Packet

Electron Configuration, Quantum Mechanical Model, Periodic Trends

1) Explain how the Quantum Mechanical Model utilizes the theories proposed by Rutherford and Bohr.

Rutherford's e^- cloud model is adapted to specifically shaped/located cloud orbitals. Those orbitals make up sublevels, which are quantized similar to Bohr's quantized energy levels.

2) How is Schrödinger's equation used to express electron behavior? What is the disadvantage to specifying the location of an electron? (Hint: Uncertainty)

The wave equation is used to predict, w/ 95% probability, where a pair of electrons are likely to be found about the nucleus (ie probability maps / orbitals). By treating the e^- as waves to specify location, the ability to simultaneously describe their energy is limited.

3) An apple appears red to the eye, if a median wavelength for red light is about 655nm, what energy of photon is being absorbed by the photoreceptors in your retina?

$655\ nm = 6.55 \times 10^{-7}\ m$

$$E = \frac{hc}{\lambda} = \frac{(6.62 \times 10^{-34}\ Js)(3.0 \times 10^{8}\ \frac{m}{s})}{6.55 \times 10^{-7}\ m}$$

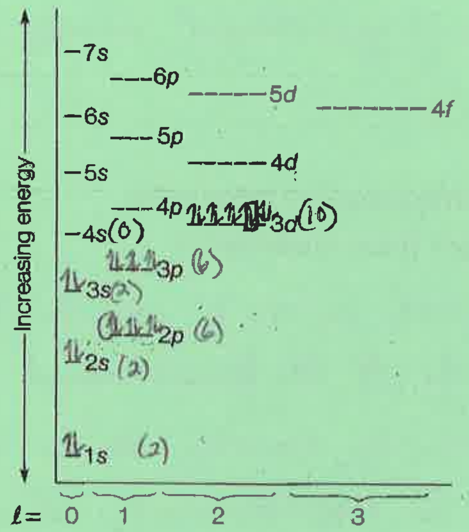
$$= \boxed{3.03 \times 10^{-19}\ J}$$

4) Which neutral element is represented by the following electron configuration?
   a. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$ Cu
   b. Write out the proper configuration for part a, explaining the reasoning behind any changes you made.

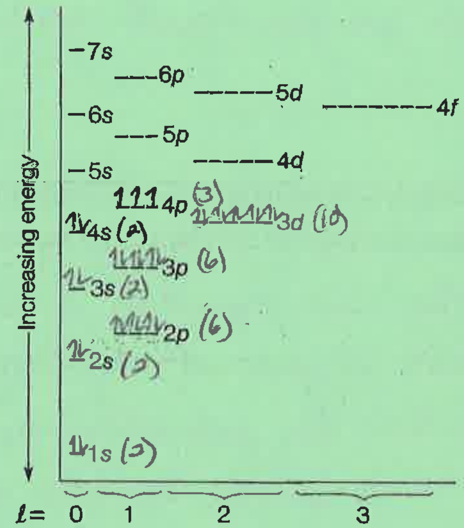
- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
- More stable configuration due to full 3d sublevel (stability from pairing opposing mag. poles) and half-full 4s

5) Follow the AUFBAU Principle, Hund's Rule, and the Pauli Exclusion Principle to complete the following orbital electron configurations. Make sure your diagram reflects the most stable configuration.

a. Cadmium $^{2+}$



b. Germanium^{1-}



6) How many orbitals are full in 5b?

15

7) For 5b: Identify the four quantum numbers for the 2nd electron in the 3rd orbital of 3d and explain the significance of each.

$\{n = 3,\ l = 2,\ m_l = 0,\ m_s = -\tfrac{1}{2}\}$

↑ energy level ↑ sublevel ↑ orbital ↑ e⁻ spin

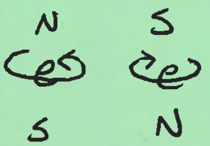
8) For the electron diagram in 5a:

a. Circle the {n = 2, l = 1, m_l = -1, m_s = 1/2} electron $2p_x$ ↑ 1st orb.

b. Put a box around the {n = 3, l = 2, m_l = 1, m_s = -1/2} electron 3d 4th orb. ↓

9) What allows electrons to pair-up in orbitals despite having repulsive electrostatic charges? Explain.

Opposing spins create opposing magnetic poles. Attraction b/w the opposing poles stabilized the electrostatic repulsion of their charge.



10) Which of the following are isoelectric with krypton?

~~Se^{2-}~~ ((Zr^{4+})) ~~Cd^{7+}~~ ((Sr^{2+})) Br^{-}

11) A sample of silver is exposed to electromagnetic energy with a frequency of $9.97 \times 10^{14}\ s^{-1}$

a. How much energy (in eV) are the electrons of the silver atoms being exposed to?

$$E = hf$$
$$= (6.62 \times 10^{-34}\ Js)(9.97 \times 10^{14}\ \tfrac{1}{s})$$
$$= \boxed{6.60 \times 10^{-19}\ J} = 6.60 \times 10^{-19}\ J \left(\frac{1\ eV}{1.602 \times 10^{-19}\ J}\right) = 4.12\ eV$$

b. If the binding energy for a silver 5s electron is 0.23eV, describe what you would see if the silver sample was being analyzed via photoelectron spectroscopy. The work function for silver is 4.26 eV.

$$E_k = E_{h\nu} - E_B - W_0$$
$$= 4.12\ eV - 0.23\ eV - 4.26\ eV$$
$$= -0.37\ eV$$

not enough energy was applied to the sample to emit 5s e⁻; those are the most weakly held e⁻, so no e⁻ (no peaks) would show on the data report.

c. What would be the minimum wavelength (nm) required to emit a 5s electron?

↳ $E_k = 0$

$$0 = E_{h\nu} - \underset{eV}{0.23} - \underset{eV}{4.26}$$
$$E_{h\nu} = 4.49\ eV \left(\frac{1.602 \times 10^{-19}\ J}{1\ eV}\right) = 7.19 \times 10^{-19}\ J$$
$$7.19 \times 10^{-19}\ J = E_{h\nu} = \frac{hc}{\lambda} = \frac{(6.62 \times 10^{-34}\ Js)(3.0 \times 10^{8}\ \tfrac{m}{s})}{\lambda}$$
$$\lambda = 2.76 \times 10^{-7}\ m \left(\frac{1 \times 10^{9}\ nm}{1\ m}\right) = \boxed{276\ nm}$$

d. If a 5s electron emitted from a sample of silver was found to have a KE = 3.77×10^{-18} J, what wavelength (nm) of electromagnetic energy was the sample likely hit with?

$$3.77 \times 10^{-18}\,J \left(\frac{1\,eV}{1.602 \times 10^{-19}\,J}\right) = 23.5\,eV$$

$$23.5\,eV = E_{hv} - 0.23\,eV - 4.26\,eV$$

$$E_{hv} = 27.99\,eV \left(\frac{1.602 \times 10^{-19}\,J}{1\,eV}\right) = 4.48 \times 10^{-18}\,J$$

$$4.48 \times 10^{-18}\,J = \frac{(6.62 \times 10^{-34}\,Js)(3.0 \times 10^{8}\,\tfrac{m}{s})}{\lambda} \quad \lambda = 4.43 \times 10^{-8}\,m \left(\frac{1 \times 10^{9}\,nm}{1\,m}\right) = \boxed{44.3\ nm}$$

e. How would the KE of a 5s and a 3p electron (E_B=58.3eV) compare if both were emitted from when exposed to x-rays with a frequency of $1.69 \times 10^{16}\ s^{-1}$?

$$E_{hv} = hf = (6.62 \times 10^{-34}\,Js) \times 1.69 \times 10^{16}\,\tfrac{1}{s} = 1.12 \times 10^{-17}\,J = 69.8\,eV$$

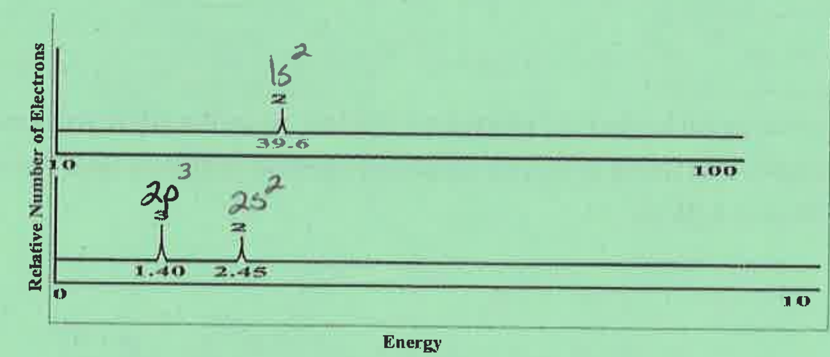
5s has a lower E_B to overcome, and therefore should have more E_K left over. Math support...

$$E_{K_{5s}} = 69.8\,eV - 0.23\,eV - 4.26\,eV = \boxed{65.3\,eV}$$

$$E_{K_{3p}} = 69.8\,eV - 58.3\,eV - 4.26\,eV = \boxed{7.24\,eV}$$

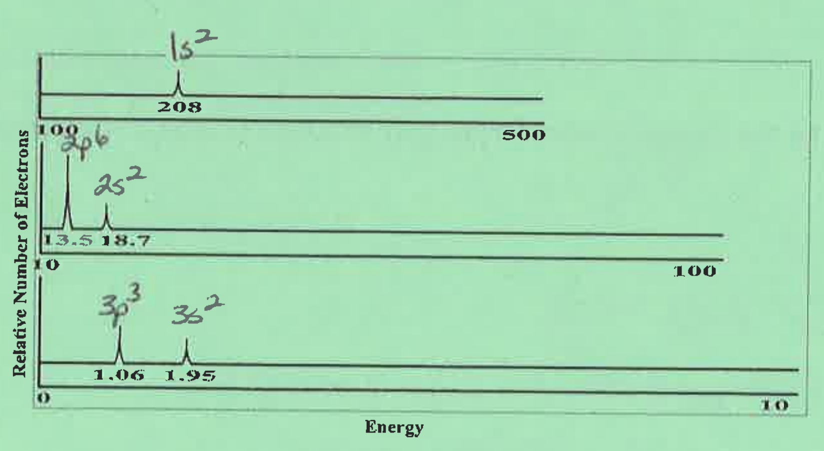
12) Label the peaks and identify the element given the following photoelectron spectroscopy data.

a.



(N)

b.



(P)

13) Referencing the photoelectron spec data in problem 12b, answer the following:

a) Describe what would happen to the data if a -3 ion of the same element was analyzed. the peak at 1.06 eV $(3p^3)$ would double in size $(3p^6)$ (same size as 13.5 eV peak)

b) Describe how the spec data for the element silicon would compare to 12b.

- the left peak (previously at 1.06 eV) $(3p^3)$ would be the same size as the (previously) 1.95 eV peak $(3s^2)$
- All peaks would shift left (lower binding energies)

c) If the light source used for the analysis of 12b could now create a maximum wavelength of 62 nm. (Work function of 12b is 1.2eV).

$62\ nm = 6.2 \times 10^{-8}\ m$

$E_{hv} = \frac{hc}{\lambda} = \frac{(6.62 \times 10^{-34}\ J s)(3.0 \times 10^{8}\ \frac{m}{s})}{6.2 \times 10^{-8}\ m}$

$= 3.2 \times 10^{-18}\ J \left(\frac{1 eV}{1.602 \times 10^{-19}\ J}\right)$

$= 19.9 = \boxed{20.\ eV}$

$E_k = 20.\ eV - E_B - 1.2$

minimum E_B that is emitted $= 18.8\ eV$ ∴ the 1s peak would not appear in the data

14) Describe the two atomic characteristics that influence radius and explain their effect using Coulomb's Law.

Effective Nuclear Charge: Higher ENC = ↑q = ↑$F_{attraction}$ b/w nucleus & e^- = ↓ radius

Energy Levels: More energy levels (occupied) = ↑d = ↓$F_{attraction}$ b/w nucleus & e^- = ↑ radius

15) Explain why the trends for ionization energy and electronegativity are related to radius.

Electronegativity = ability to attract other atoms' e⁻; closer you can get a nucleus to the e⁻ it is attracting the stronger force of attraction ∴ ↓ radius = ↑ EN

Ionization Energy = energy to remove an electron from an atom; closer the e⁻ is to the nucleus, the stronger the attractive force, the more energy needed to remove ∴ ↓ radius = ↑ IE

16) Explain how Coulomb's Law provides information on the 1st ionization energy for an atom.

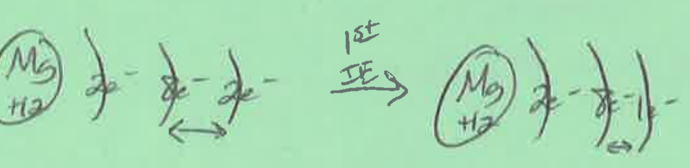
Coulomb's Law relates charge & distance for particles, specifically the positive charge of a nucleus and the negative charge of an electron.

$F = \frac{k q_1 q_2}{d^2}$ illustrates that increasing the nuclear charge, q_1, will increase attraction & therefore increase IE. Similarly, decreasing distance b/w the particles, d, via radius will increase particle attraction and therefore increase IE.

17) Explain why 2nd ionization energy is always larger than 1st ionization energy. Reference radius and Coulomb's Law.

When a cation is formed (via 1st IE), the radius of the atom always decreases either due to losing an energy level or due to decreased repulsion b/w energy levels.

energy level loss (huge increase in IE)



decreased repulsion (smaller increases in IE)

A smaller radius, per coulomb, will always increase attractive force felt by the e⁻ remaining, increasing their IE.

18) Which trend is a good predictor of metal reactivity? Explain your reasoning.

Ionization Energy - Due to the larger radii, metals have low IE & EN, predicting they lose e⁻ rather than gain. IE will predict how easily they lose an e⁻ via bonding & therefore how reactive they are.

19) Which trend is a good predictor of non-metal reactivity? Explain your reasoning.

Electronegativity - Due to their smaller radii, non-metals have high IE & EN, predicting they gain e⁻ rather than lose. EN will predict how likely they are to gain e⁻ via bonding & therefore how reactive they are.

20) If the first ionization energy for calcium is 1200 kJ/mol, predict the relative energies associated with the following.

a. Ca 2nd ionization energy slightly > 1200 kJ/mol (~1400)

b. Ca 3rd ionization energy much larger than 1200 (~12,000)

c. K 1st ionization energy less than Ca (~1000)

d. Se 1st ionization energy larger than K & Ca (~1800)

21) Discuss the duality of light and of electrons, referencing the laboratory evidence that supports the theory.

Photoelectric Effect - shows particle nature of light as ↑ intensity (brightness/amplitude) ↑ # of e⁻ emitted, not their energy.
- ↑ brightness = ↑ # of light "packets" shown on the sample = ↑ # e⁻ emitted

Dual-Slit - Shows wave behavior of both light & e⁻. Both exhibit wave-like behavior of constructive and destructive interference.

Cathode Ray - shows particle behavior of e⁻. Current (beam of e⁻) can be manipulated/bent in a specific charge/angle of deflection ratio, showing the particle has mass. Additionally, the signature is a precise beam on the detector rather than an expanded wave-type signature of a flash light.