Name:________________

Quest for Quantum

1. In your answers to the following questions, be sure to **INCLUDE THE NAME OF THE PRINCIPLE** that you have used as a part of your answers:

a) When filling orbitals around an atom that happen to be of equal energy (i.e. the values of n and l are the same) what happens as you add electrons to fill the orbitals?

orbitals of equal energy fill one electron at a time first – Hund's principle

b) When adding electrons to a bare nucleus to build an atom, what orbital would fill first?

the orbital with n=1 l=0 and m_l = 0 (i.e the first available orbital) – Aufbau principle

c) If you knew how much energy was required to remove an electron from the surface of a metal (Electron Binding Energy) and you knew the exact energy (Photon Energy) of the type of light photon that you were using to perform the removal, how could you calculate the kinetic energy (Electron Kinetic Energy)of the electron? Show a simple equation for your answer in addition to the principle at work.

Electron Kinetic Energy = Photon Energy – Electron Binding Energy

Photoelectric Effect

d) Why is it difficult to know both the location and the momentum of an electron through any possible experimental technique?

it is not possible to know both the location and momentum of any small particle in accord with the Heisenberg Uncertainty Principle

$$\Delta x \Delta p > h/2$$

- absorption spectra
- Aufbau principle
- atomic absorption
- Bohr Model
- cathode ray
- de Broglie wavelength
- emission spectra
- Heisenberg uncertainty principle
- Hund's Rule
- law of conservation of mass energy
- line spectra matter waves
- Pauli Exclusion Principle
- photoelectric effect
- quantum hypothesis
- Rutherford Model
- spin coupling

2. Do you know your quantum numbers? List in the order that the quantum numbers were presented in class.

Symbol	Allowed Values (Use Set Notation)	Physical Properties And/or Name
n	$\{n \in I \mid n > 0\}$	**principle Q.N., # of de Broglie wavelength**
l	$\{l \in I \mid 0 \leq l < n\}$	**angular momentum Q.N.**
m_l	$\{m_l \in I \mid -l \leq m_l \leq l\}$	**magnetic Q.N.**
m_s	$\{m_s \in R \mid m_s = \pm 1/2\}$	**spin Q.N.**

3. Write the complete electron configuration of Caldwellium, element number 111 (also known as unununium).

$1s^2$
$2s^2\ 2p^6$
$3s^2\ 3p^6$
$4s^2\ 3d^{10}\ 4p^6$
$5s^2\ 4d^{10}\ 5p^6$
$6s^2\ 4f^{14}\ 5d^{10}\ 6p^6$
$7s^2\ 5f^{14}\ 6d^9$

4. Complete the following table by filling in whatever is missing:

element	n	l	m_l	m_s	end of config.
$_{16}S$	**3**	**1**	**0**	**+½**	$3p^4$
Ta	**5**	**2**	**−1**	**−½**	$5d^3$
Pr	**4**	3	−2	−½	$4f^3$
$_{32}Ge$	**4**	**1**	**−1**	**+½**	$4p^2$
He	**1**	**0**	**0**	**+½**	$1s^2$
Md	**5**	**3**	**3**	**−½**	$5f^{13}$
Ca	4	0	0	+½	$4s^2$
Mo	4	2	−1	+½	$4d^4$
$_{103}Lr$	**6**	**2**	**−2**	**−½**	$6d^1$
$_{70}Yb$	**4**	**3**	**3**	**+½**	$4f^{14}$

5. What is true about the odd/eveness of the number of electrons in an atom and the resulting spin state of the last electron?

$m_s = -1/2$ ➜ odd number of electrons
$m_s = +1/2$ ➜ even number of electrons

6. Demonstrate a working knowledge of how allowed values work by explaining why the p-block is 6 columns long and does not appear until $n \geq 2$. Make reference to **all four** quantum numbers. Use point form.

- **for the p-block, l=1 therefore there are 3 different m_l values ➜ $\{m_l \in I \mid -l \leq m_l \leq l\}$**

- **each m_l value in turn can have 2 m_s values $\{m_s \in R \mid m_s = \pm 1/2\}$**

- **$\{-1, 0, +1\} \times \{-½, +½\}$ ➜ $3 \times 2 = 6$**

- **n must be 2 or more because l must be less than n $\{l \in I \mid 0 \leq l < n\}$**

7. What would happen to the periodic table if an electron was able to spin four different ways (i.e m_s = −3/2, −1/2, +1/2, and +3/2)? What would the widths of each "angular momentum" block become?

The width of the periodic table would become double that of what it is. For every possible n, l, m_l, value there would be four possible spin states instead of two. Therefore double width!

orbital type	l – value	normal width	width for question
s	**0**	**2**	**4**
p	**1**	**6**	**12**
d	**2**	**10**	**20**
f	**3**	**14**	**28**
total table width		**32**	**64**

8. Use this quantum number organizer to generate the quantum numbers for the first 28 electrons in an atom.

n	l	m_l	m_s	orbital type (use letter notation)	# e^- per energy level	# e^- per energy shell
1	0	0	−1/2	s	2	2
1	0	0	+1/2			
2	0	0	−1/2	s	2	8
2	0	0	+1/2			
2	1	−1	−1/2	p	6	
2	1	−1	+1/2			
2	1	0	−1/2			
2	1	0	+1/2			
2	1	1	−1/2			
2	1	1	+1/2			
3	0	0	−1/2	s	2	18
3	0	0	+1/2			
3	1	−1	−1/2	p	6	
3	1	−1	+1/2			
3	1	0	−1/2			
3	1	0	+1/2			
3	1	1	−1/2			
3	1	1	+1/2			
3	1	−2	−1/2	d	10	
3	2	−2	+1/2			
3	2	−1	−1/2			
3	2	−1	+1/2			
3	2	0	−1/2			
3	2	0	+1/2			
3	2	1	−1/2			
3	2	1	+1/2			
3	2	2	−1/2			
3	2	2	+1/2			

9. The Rydberg constant is itself a combination of different constants. Use the constants listed to determine the correct value of the Rydberg constant. Then perform a complete unit analysis. Be sure to start with the format "units ="

$$R = \frac{-e^4 m}{8\varepsilon_o^2 h^3 c}$$

$e = 1.6022 \times 10^{-19}$ C (fundamental unit of charge)
$m = 9.110 \times 10^{-31}$ kg (resting mass of an electron)
$\pi = 3.1415926536$ (circumference / diameter for a circle)
$\varepsilon_o = 8.854 \times 10^{-12}\ C^2N^{-1}m^{-2}$ (dielectric constant)
$h = 6.626 \times 10^{-34}$ Js (Planck's constant
$c = 3.00 \times 10^8\ ms^{-1}$ (speed of light)

$$J = \frac{kgm^2}{s^2} \qquad N = \frac{kgm}{s^2}$$

$$R = \frac{-(1.6022\times10^{-19})^4\, 9.11\times10^{-31}}{8(8.854\times10^{-12})^2(6.626\times10^{-34})^3(3\times10^8)}$$

$$R = 1.096833522 \times 10^7\ m^{-1}$$

$$\text{units} = \frac{C^4\,kg}{(C^2N^{-1}m^{-2})^2(Js)^3\ ms^{-1}}$$

$$= \frac{C^4\,kg}{C^4N^{-2}m^{-4}\,J^3s^3\,ms^{-1}}$$

$$= \frac{Kg\,N^2\,m^3}{J^3\,s^2}$$

$$= \frac{\frac{Kg}{1}\times\left(\frac{Kg\,m}{s^2}\right)^2\times\frac{m^3}{1}}{\left(\frac{kg\,m^2}{s^2}\right)^3\left(\frac{s^2}{1}\right)}$$

$$= \frac{\frac{Kg}{1}\times\frac{Kg^2m^2}{s^4}\times\frac{m^3}{1}}{\frac{Kg^3m^6}{s^6}\times\frac{s^2}{1}}$$

$$= \frac{\frac{Kg^3m^5}{s^4}}{\frac{Kg^3m^6}{s^4}}$$

$$= \frac{Kg^3m^5}{s^4}\times\frac{s^4}{Kg^3m^6}$$

$$= \frac{1}{m}$$

$$= m^{-1}$$

10.

$$\frac{1}{\lambda} = 1.09737 \text{ x } 10^7 \text{ m}^{-1} \left[\left(\frac{1}{n_i^2} \right) - \left(\frac{1}{n_f^2} \right) \right]$$

Look what light through yonder window duth break! Is it the sun? Is it the moon? No of course not, it is the fifth line in the Balmer Series of hydrogen. And what is the wavelength of yonder light? To figure that out, show a calculation for the appropriate initial and final states! Show a separate conversion to express your final answer in nanometers ($1 \text{ x } 10^9$ nm = 1 m).

$$\frac{1}{\lambda} = 1.0963 \text{ x } 10^7 \text{ m}^{-1} \left[\left(\frac{1}{n_i^2} \right) - \left(\frac{1}{n_f^2} \right) \right]$$

$$\frac{1}{\lambda} = 1.0963 \text{ x } 10^7 \text{ m}^{-1} \left[\left(\frac{1}{7^2} \right) - \left(\frac{1}{2^2} \right) \right]$$

$$\frac{1}{\lambda} = 1.0963 \text{ x } 10^7 \text{ m}^{-1} \left[-0.229592 \right]$$

$$\frac{1}{\lambda} = -\ 2519479 \text{ m}^{-1}$$

$$\lambda = -3.9691 \text{ x } 10^{-7} \text{ m}$$

$$-3.9691 \text{ x } 10^{-7} \text{ m x } \frac{1 \text{ x } 10^9 \text{ nm}}{1 \text{ m}} = -396.91 \text{ nm}$$

11. Using the equation from question 9, determine the initial and final states for:

a) absorption of 380.07 nm

b) emission of 102.62 nm

wavelength	emitted or absorbed	n_i	n_f
379.70 nm	absorbed	**2**	**10**
102.52 nm	emitted	**3**	**1**