Name:__________

A Quest for Quantum

1. For each question provide information points that help to explain and/or differentiate (i.e point out the differences) Note the marking scheme. One mark is equivalent to one good point of information, therefore brief answers are sufficient.

a) Dalton (1 marks) **idea of different types of atoms**

Thomson (2 points) **discovered electron, plum pudding model of the atom**

Rutherford (2 points) **discovered the nucleus, small dense postive charge at the centre of the atom**

b) absorption spectra (2 points) **absorption of photons causes outward transition, produces dark absorption lines in a continuous spectra**

emission line spectra (2 points) **emission of photons produced by inward transition, produces bright spectral lines in a line spectra – negative of absorption**

c) Heisenberg uncertainty principle, $\sigma_x \sigma_p \geq \frac{\hbar}{2}$ (1 point)

cannot know both the location and the momentum of a particle to a great degree of accuracy

d) photoelectric effect (2 points) **when a photon of sufficient energy (above threshold energy value) strikes a metal surface, an electron is ejected from the surface of the metal**

2. Fill out the following table to show the possible quantum numbers in the first three princple energy levels for a one electron hydrogen. Be sure to use the Aufbau principle (as well as the Pauli exclusion principle)

n	l	m_l	m_s	# e^- per energy level	# e^- per energy shell
1	**0**	**0**	**-1/2**	**s**	**2**
1	**0**	**0**	**+1/2**		
2	**0**	**0**	**-1/2**	**s**	**2**
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**
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**		

3. Do you know your quantum numbers?

Symbol	Allowed Values (Use Set Notation)	Physical Properties And/or Name
n	**{n∈I|n>0}**	**principle Q.N., # of de Broglie wavelength**
l	**{l∈I|0≤l<n}**	**angular momentum Q.N.**
m_l	**{m_l∈I|−l≤m_l≤l}**	**magnetic Q.N.**
m_s	**{m_s∈R|m_s=±1/2}**	**spin Q.N.**

4. For the quantum number l (i.e. angular momentum) it has been suggested that there is the possibility of l=4. If this is so, how many different l=4 elements could exist (i.e what would the width of the "g" block be). What is the minimum number of de Broglie wavelengths that are required to produce an l=4? Make clear and concise reference to the other three quantum numbers in your answer.

- **for the "g"-block, l=4 therefore there are 9 different m_l values ➔ {m_l∈I|−l≤m_l≤l} (−4,−3,−2,−1,0,+1,+2,+3,+4)**

- **each m_l value in turn can have 2 m_s values {m_s∈R|m_s=±1/2}**

- **{−4,−3,−2,−1,0,+1,+2,+3,+4} x {−½,+½} ➔ 9 x 2 = 18**

- **n must be 5 or more because l must be less than n {l∈I|0≤l<n} therefore at least 5 deBroglie wavelengths**

5. Write the complete electron configuration for the newly discovered element, Schlenkium, symbol Slk. The atomic number of this element is 118, making it the next noble gas.

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

6. Complete the following table.

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	4**f^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**	**$4f^{14}$**

7. How many elements wide would the periodic table be if the spin quantum number could have values of −3/2, −1/2, +1/2, +3/2 ? Explain briefly

64 elements wide, twice as many possible spin states would produce four states per m_l instead of two states (−1/2, +1/2)

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

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

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

$$R = 1.096833522\times10^7\ m^{-1}$$

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

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

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

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

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

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

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

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

$$= m^{-1}$$

9.

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

Look what light through yonder window duth break! Is it the sun? Is it the moon? No of course not, it is the third line in the Balmer Series of hydrogen. And what is the wavelength of yonder light? To figure that out, show a calculation for n=5 to n=2! Show a separate conversion to express your final answer in nanometers (1 x 10^9 nm = 1 m).

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

$$\frac{1}{\lambda} = 1.09737 \text{ x } 10^7 \text{ m}^{-1} \left[\left(\frac{1}{5^2} \right) - \left(\frac{1}{2^2} \right) \right]$$

$$\frac{1}{\lambda} = 1.09737 \text{ x } 10^7 \text{ m}^{-1} [-0.21]$$

$$\frac{1}{\lambda} = -\ 2304484 \text{ m}^{-1}$$

$$\lambda = -4.33937 \text{ x } 10^{-7} \text{ m}$$

$$-4.33937 \text{ x } 10^{-7} \text{ m x } \frac{1 \text{ x } 10^9 \text{ nm}}{1 \text{ m}} = -433.937 \text{ nm}$$

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

a) emission of 376.97 nm
b) absorption of 3738.53 nm
c) absorption of 93.03 nm
d) emission of 1004.67 nm

wavelength	emitted or absorbed	n_i	n_f
376.97 nm	emitted	11	2
3738.53 nm	absorbed	5	8
93.03 nm	absorbed	1	7
1004.67 nm	emitted	7	3