Name:__________

A Quest for Quantum

1. For each group of terms or persons, **PICK ONE** and explain. For persons, fully explain their role in the evolution of the atomic model. Note the marking scheme. One mark is equivalent to one good point of information. Diagrams are valid responses

a) Dalton, Thomson or Rutherford (2 marks)

Dalton: different types of atoms, atoms combine to form compounds in whole number ratios

Thomson: discovered electron and proposed the plumb-pudding model of the atom

Rutherford: deduced the existence of the nucleus (small dense positive core)

b) line spectra or energy level diagram (2 marks)

Line Spectra: pattern of coloured lines seen in the spectrum of the light given off by excited elements, produced by electron transitions form one n value to another.

Energy Level Diagram: shows the relative energy for different n and l values, usually labeled using the 1s, 2s, 2p, etc format, will fill with electrons from the bottom up, can be used to determine electron configuration

c) electromagnetic spectrum or mass spectrometer (2 marks)

Electromagnetic Spectrum: shows all types of electromagnetic radiation from lowest to highest energy (or frequency): radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays

d) quantum hypothesis or photoelectric effect (2 marks)

Quantum Hypothesis: energy is released in small packages of energy, rather than a continuum of energy, was able to explain the colour temperature relationship exhibited by hot objects

Photoelectric Effect: electrons can be ejected from the surface of a metal if the metal is struck with a photon of sufficiently high energy (energy must be above a threshold value), any excess photon energy will show up as additional energy in the electron

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	2	2
1	0	0	+1/2		
2	0	0	-1/2	2	8
2	0	0	+1/2		
2	1	-1	-1/2	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	2	18
3	0	0	+1/2		
3	1	-1	-1/2	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	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	$\{n \in I \mid n > 0\}$	principle Q.N., # of de Broglie wavelengths
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.

4. For the quantum number l (i.e. angular momentum) it has been suggested that there is the possibility of l=5. If this is so, how many different l=5 elements could exist. What is the minimum number of de Broglie wavelengths that are required to produce an l=5? Make clear and concise reference to the other three quantum numbers in your answer.

- if l = 5, m_l can = −5,−4,−3,−2,−1,0,1,2,3,4,5 (11 possible values)
- each m_l can have an m_s of −1/2 and +1/2 (2 possibilities)
- 11 x 2 = 22 ➜ therefore a total of 22 possible elements can have l=5
- n must be 6 or more since l is always less than n, therefore there must be at least 6 de Broglie wavelengths in an l=5 element

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. The first line is done as an example

Element Symbol	n	l	m_l	m_s	Electon Configutration Ending
$_{56}Ba$	6	0	0	+1/2	$6s^2$
$_{72}Hf$	**5**	**2**	**−2**	**0.5**	**$5d^2$**
Ti	3	2	−2	0.5	**$3d^2$**
Sn	**5**	**1**	**−1**	**0.5**	$5p^2$
Tb	**4**	**3**	**1**	**−1/2**	$4f^9$
Md	5	**3**	3	−1/2	**$5f^{13}$**
$_{71}Lu$	**5**	**2**	**−2**	**−1/2**	**$5d^1$**

7. Why are multi-electron atoms considerably more complicated than a single electron atoms such as hydrogen. How does this relate to the relative energy for different values of quantum number l

electron/electron repulsions add an extra layer of difficulty

this raises the relative energy of l value states such that the effect is greater as l increases (i.e. s < p < d < f)

ultimately gives us the periodic table shape that we know and love!

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

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

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

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

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

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

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

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

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

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

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

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

$$= m^{-1}$$

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 93.82 nm

b) absorption of 1876.44 nm

wavelength	emitted or absorbed	n_i	n_f
93.73 nm	emitted	**6**	**1**
1874.61 nm	absorbed	**3**	**4**