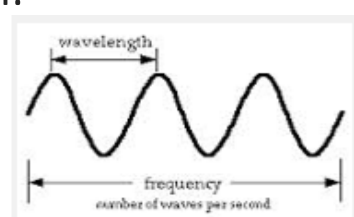
MODERN ATOMIC THEORY

1. Background (Light & Energy)

How do light and energy provide the background for the modern atomic theory?

A. Electromagnetic Radiation

- Definition: Energy that exhibits wave-like behavior.
- Illustration:

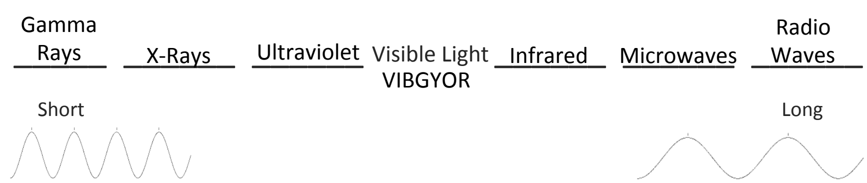


How do light and energy provide the background for the modern atomic theory?

A. Electromagnetic Radiation

Different types of electromagnetic radiation have <u>different</u> wavelengths (λ).

Chart:



How do light and energy provide the background for the modern atomic theory?

B. Dual Wave-Particle Nature

Wave

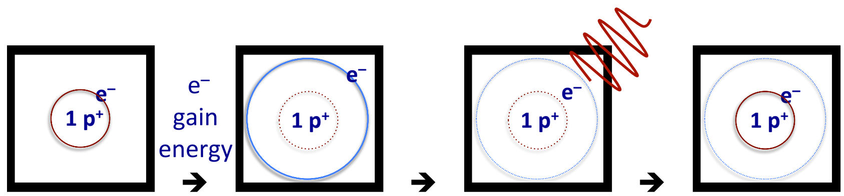
Particles o o o o o o o o o o o

⇧ Stream of **<u>Photons</u>**

"Particles" of Electromagnetic Radiation

How do light and energy provide the background for the modern atomic theory?

C. How Atoms Emit Energy



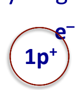
Ground State	Excited State	Photons Released	Ground State
e^- are in their lowest energy level	e^- move to higher energy level	e^- lose their energy in the form of light	e^- return to their lowest energy level

How do light and energy provide the background for the modern atomic theory?

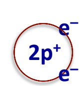
C. How Atoms Emit Energy

- THOUGHT QUESTION: If hydrogen and helium only have electrons in the first energy level, do they absorb and release the same amount of energy? Justify your answer.

Hydrogen



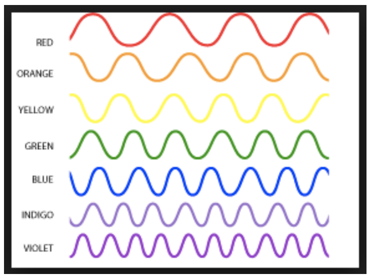
Helium



How do light and energy provide the background for the modern atomic theory?

C. How Atoms Emit Energy

- Different colors represent different wavelengths which correspond to different amounts of energy.



How do light and energy provide the background for the modern atomic theory?

D. Quantized Energy Levels

- Excited hydrogen atoms can emit photons only of certain energies (different wavelengths). They never emit photons with different energies (not 600 nm, 420 nm, etc.)

656 nm = **RED**	434 nm = **BLUE**
486 nm = **GREEN**	410 nm = **PURPLE**

How do light and energy provide the background for the modern atomic theory?

D. Quantized Energy Levels

- The energy levels are quantized, meaning only certain values are allowed.
- Excited States:

How do light and energy provide the background for the modern atomic theory?

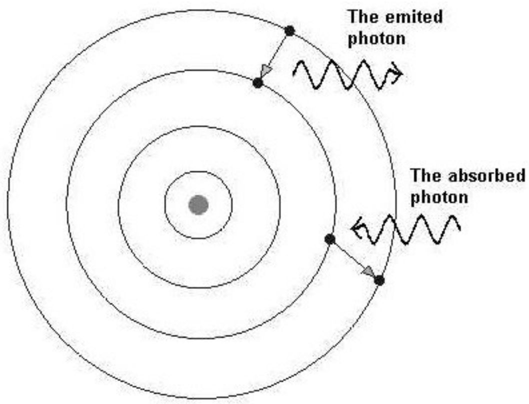
E. Bohr Model

- Electrons move in orbits that correspond to the different energy levels.
- Electrons can “jump” orbits by either absorbing or emitting photons.

How do light and energy provide the background for the modern atomic theory?

E. Bohr Model

- Illustration:



How do light and energy provide the background for the modern atomic theory?

F. Developing the QM Model

- Louis de Broglie – 1924
- Electrons have a dual **wave**–particle nature like light.
  - If light can act like a particle, can a particle act like a wave?

How do light and energy provide the background for the modern atomic theory?

F. Developing the QM Model

- Erwin Schrödinger – 1926
- Schrödinger Wave Equation: Mathematically described the wave properties of electrons.
  - Electrons exist in orbitals. Orbitals are 3D regions that indicate the probable location of an electron.

How do light and energy provide the background for the modern atomic theory?

F. Developing the QM Model

- Werner Heisenberg – 1927
- Quantum Mechanics: the study of subatomic particle motion and interaction
- Uncertainty Principle [$\Delta x \Delta p > h$; $\Delta E \Delta t > h$]
- The probability map for an electron is called an orbital.
- The *position* and *velocity* of electrons is always changing.

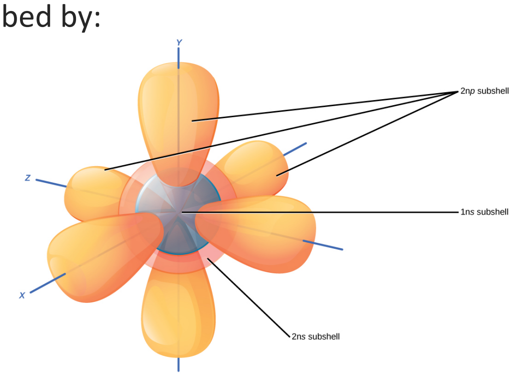
MODERN ATOMIC THEORY

2. Electron Orbitals

What are the various orbitals that hold electrons?

2. Electron Orbitals

- Electron Orbital: A 3-D region around an atom that indicates the PROBABLE location of an electron
- Orbitals can be described by:
  - Size / Energy Level
  - Shape
  - Orientation



What are the various orbitals that hold electrons?

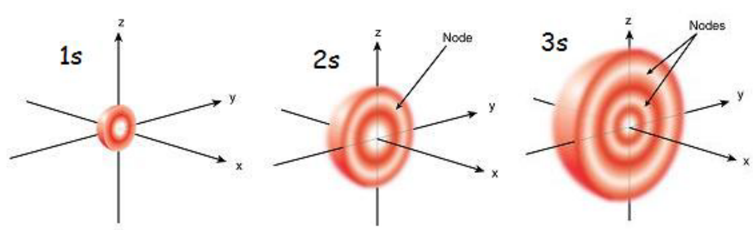
2. Electron Orbitals

- Electron Orbital: A 3-D region around an atom that indicates the PROBABLE location of an electron
- Orbitals can be described by:
  - Size / Energy Level
  - Shape
  - Orientation
- The first three quantum numbers are used to designate these features. The fourth quantum number describes the position of electrons inside an orbital. They are mathematically determined.

What are the various orbitals that hold electrons?

The 4 Quantum Numbers

- 1. Size / Energy Level (Principal Quantum Number: *n*)
- As *n* increases, the electron's <u>energy</u> and <u>distance</u> from the nucleus increases.
  - Illustration:

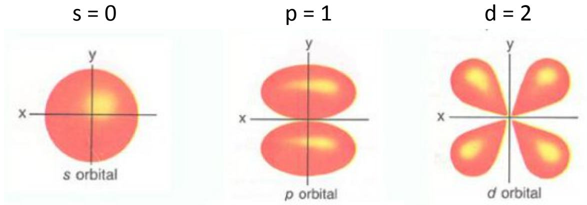


What are the various orbitals that hold electrons?

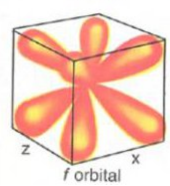
The 4 Quantum Numbers

- 2. Shape (Angular Momentum Quantum Number: *l*)

s = 0 p = 1 d = 2



EXTRA:

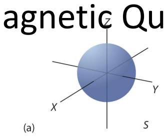


f = 0

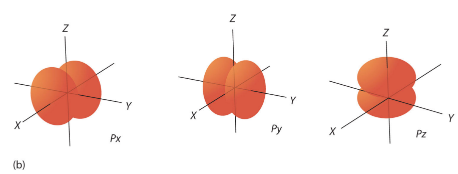
What are the various orbitals that hold electrons?

The 4 Quantum Numbers

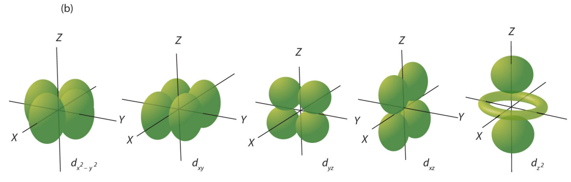
- 3. Orientation (Magnetic Quantum Number: m_l)
  - s



  - p



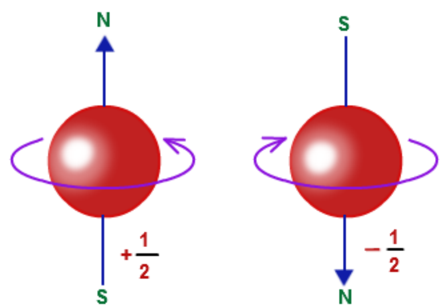
  - d



What are the various orbitals that hold electrons?

The 4 Quantum Numbers

- 4. Spin (Magnetic Quantum Number: m_s)
  - Spin up: Spin down:



What are the various orbitals that hold electrons?

The 4 Quantum Numbers

- 1. Size / Energy Level (Principal Quantum Number: n)
  - n = 1, 2, 3, 4, 5, etc.
- 2. Shape (Angular Momentum Quantum Number: l)
  - $l = n - 1$; 0, 1, 2, 3, 4, 5, etc.
- 3. Orientation (Magnetic Quantum Number: m_l)
  - $m_l = \pm l$; -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, etc.
- 4. Spin (Magnetic Quantum Number: m_s)
  - $m_s = \pm½$

What are the various orbitals that hold electrons?

Principles/Rules

- Aufbau Principle
  - An electron occupies the <u>lowest</u> energy ORBITAL it can.

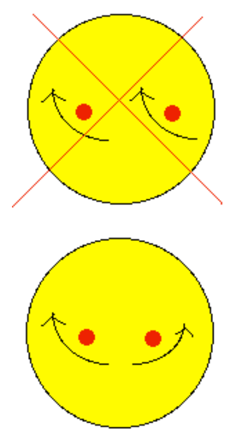
PUT THIS ON YOUR CONVERSION SHEET:

1s						
2s	2p					
3s	3p	3d				
4s	4p	4d	4f			
5s	5p	5d	5f	5g		
6s	6p	6d	6f	6g	6h	
7s	7p	7d	7f	7g	7h	7i

What are the various orbitals that hold electrons?

Principles/Rules

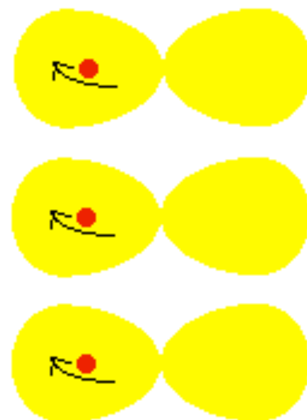
- Pauli Exclusion Principle
  - No two electrons in the same atom can have the same set of <u>4 quantum numbers</u>. (No two electrons can have the <u>same spin</u> in the <u>same orbital</u>.)



What are the various orbitals that hold electrons?

Principles/Rules

- Hund's Rule
  - Orbitals of equal energy are each occupied by 1 electron before any orbital is occupied by a second electron, and these first electrons all have the same spin.



What are the various orbitals that hold electrons?

Chart – Orbitals

Energy Level n	Shape $\ell \le n - 0$	Number of Orientations; $m_\ell \le \pm\ell$	Number of Electrons
1	s ($\ell = 0$)	1; 0	1 x 2 = 2
2	s ($\ell = 0$)	1; 0	1 x 2 = 2
2	p ($\ell = 1$)	3; −1 0 1	3 x 2 = 6
3	s ($\ell = 0$)	1; 0	1 x 2 = 2
3	p ($\ell = 1$)	3; −1 0 1	3 x 2 = 6
3	d ($\ell = 2$)	5; −2 −1 0 1 2	5 x 2 = 10