Chapter 7. Quantum Theory and Atomic Structure

Electromagnetic Radiation:

λ

ν

amplitude

E

h

c

continuous spectrum

line spectrum

Fundamental equations:

You must know the relative ordering of the various regions of the electromagnetic spectrum:

λ $\longrightarrow$

$\longleftarrow$ E, ν

What is the wavelength range of visible light?

Example: What is the wavelength of a radio signal operating at a frequency of 90.1 MHz?

Example: What is the energy of this radio signal, expressed in kJ/mol?

The Distinction Between Energy and Matter

	wave	***particle***
refraction		
diffraction		

So at the end of the 19th century, the prevailing view among physicists (*classical mechanics*):

matter *energy*

But at the beginning of the 20th century, two theories became prominent which challenged the classical approach:

Three pieces of evidence for the Particle Nature of Light:

1) blackbody radiation

- Planck's proposal: a hot, glowing object can only give off ____________ _______________ of energy.
- Thus, an atom can only have ___________________ ___________________ of energy.
- That is, the energy of an atom is ______________________.

2) the photoelectric effect

Two observations that did not fit with classical mechanics:

- Presence of a ________________ frequency
  Example: Na(s) $\nu_0 = 6.7 \times 10^{14}$Hz, blue light
  but red light (4.0×10^{14}Hz)
- Absence of a _____________ lag

Einstein proposed that a beam of light behaves as if it were composed of a string of small __________ called ______________

The energy of a photon depends only on _________________ and not on _______________.

A rough analogy: ping pong balls thrown at a window.

The main conclusion: In addition to behaving as ____________, light also behaves as _______________.

3) atomic spectra

Observation: The light given off by excited H atoms is not a _____________ spectrum, but rather a ________ spectrum.

$E_n =$

where $E_n =$

$Z =$

$n =$

$\Delta E =$

$\Delta E =$

Example: Calculate the wavelength of light emitted/absorbed when a hydrogen electron makes a transition from the n =_________ state to the n = ___________________ state.

Show the energy diagram for a hydrogen atom.

Summary Points:

• Quantum Mechanics says that the amount of energy that can be transferred is _______________________.

That is, energy can only be transferred in discrete units of size ______. ***Energy is __________________.***

• The smallest "packet" of energy is called a _______________.

• An individual "packet" or "particle" of electromagnetic radiation is called a __________________.

7.3 The Wave-Particle Duality of Matter and Energy

• *So up to this point, science was indicating that light, which is ________________ has _______________ characteristics.*

• de Broglie proposed that if energy is __________________ then perhaps matter is ___________________.

Since E_{photon} =

and E = Einstein's relativistic equation

substitute:

solve for λ:

This indicates that a photon with wavelength λ exhibits a ________________.

For a particle traveling at velocity u: de Broglie equation

____

Example: What is the characteristic wavelength associated with an electron moving at a velocity of 5.97×10^{6} m/s? (Given: mass of an electron is 9.11×10^{-31} kg)

Example: What is the characteristic wavelength associated with a baseball thrown 95 mi/hr?
(Given: mass of a baseball = 5.0 oz, and 16 oz = 0.4536 kg, and 1 mi = 1.609 km)

The Quantum Mechanical Model of the Atom

• Niels Bohr initially suggested that electrons exist in ________________.

• Quantum Mechanics treats electrons differently.
QM says that an electron has both ______________________ and ______________________ properties.

• The Heisenberg uncertainty principle says it is impossible to know both the ____________ and the ___________ of a particle simultaneously.

Mathematically:

• Thus, we cannot assign ________ __________ for electrons, and the most we can hope to know is the ____________ of finding an electron in a given region of space.

• Since an electron has wave-like properties, quantum mechanics is also called __________ _________________.

• QM is a ______________________ _______________________ of an electron.

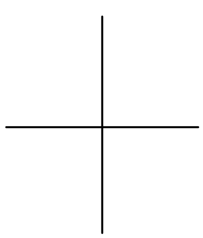
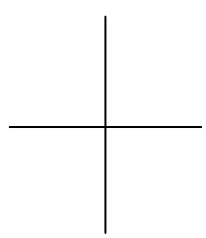
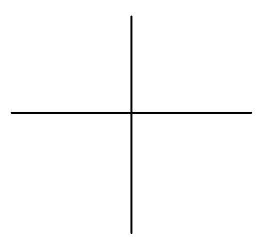
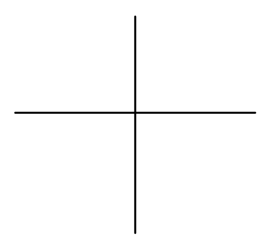
• Schrödinger's equation:

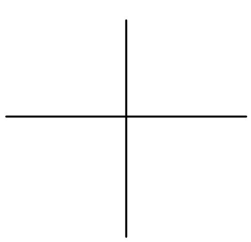
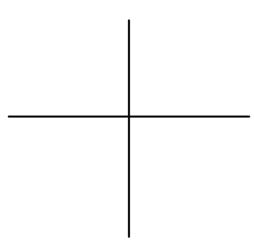
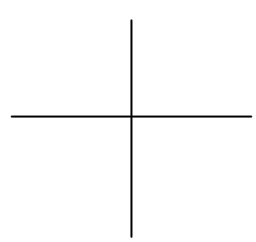
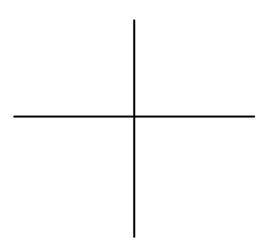
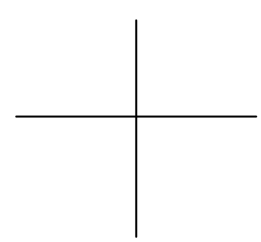
where

• What is the physical meaning of ψ ?

• So when Schrodinger's equation is solved for the lowest energy electron in hydrogen, you get a _________________.

Shapes of Orbitals

Quantum Numbers

- Quantum mechanics uses *quantum numbers* to describe the allowable states of an electron in an atom. Four quantum numbers completely describe the state of an electron in an atom: n, l, m_l, and m_s.

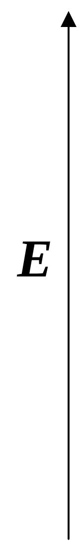
  Important: *If you understand electron configurations, then you can understand quantum numbers. Electron configurations are just a simpler way of communicating much of the information that we get from quantum numbers.*

- You need to know four things about quantum numbers: the letter designation, the name, what that quantum number describes, and the possible values of that quantum number.

letter designation	*name*	*what the quantum number describes*	*possible values*

Give the 4 quantum numbers and electron configuration for:

H	**He**		**Li**	**Be**	**B**	**C**
	(both electrons)		*(only the last electron added)*			
n =	n =	n =	n =	n =	n =	n =
l =	l =	l =	l =	l =	l =	l =
m_l =	m_l =	m_l =	m_l =	m_l =	m_l =	m_l =
m_s =	m_s =	m_s =	m_s =	m_s =	m_s =	m_s =



Terms to know:

- ground state
- excited state
- degenerate
- node
- shell
- subshell

Chapter 8. Electron Configuration and Chemical Periodicity

Three rules for determining the ground-state electron configuration:

- Aufbau procedure

- Pauli Exclusion Principle

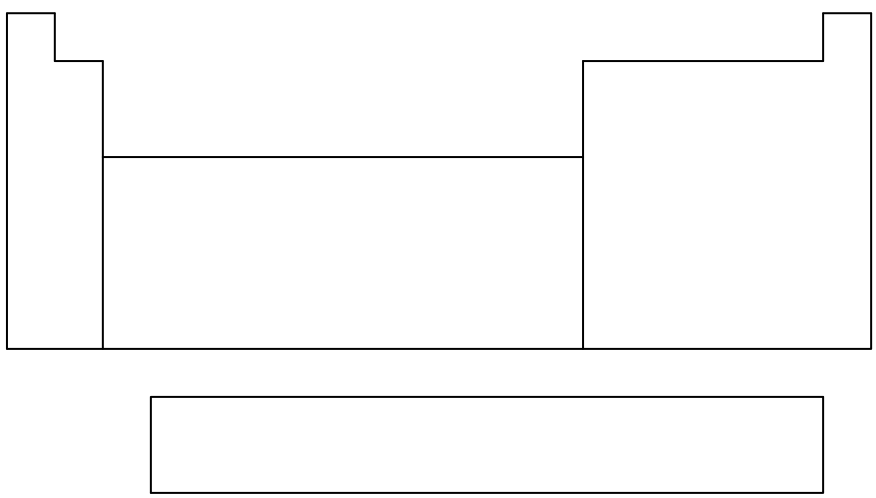
- Hund's Rule

Using the periodic table to determine electron configuration.

- Identify the s, p, d, and f blocks.

- Remember, the s block starts with _________, the p block starts with __________, the d block starts with _______ and the f block starts with ____.

- Beginning with the first period, proceed across the periodic table horizontally, counting the electrons in the s, p, d, and f blocks.



Example: Write the complete electron configuration of Titanium.

Three other points concerning electron configurations:

1) There is a special stability associated with ____.

2) There is a special stability associated with ____.

3) When determining the electron configuration of cations, the first electrons removed are

Know these terms:

- Isolectronic
- Paramagnetic
- Diamagnetic
- valence electrons
- core electrons

Example: Write the complete ground state electron configuration for:

F

F^{-}

Ne

Na

Na^{+}

Example: Write the abbreviated electron configuration for:

V

Cr

Cu

Fe

Fe^{2+}

Fe^{3+}

Mn^{2+}

Ag

Ag^{+}

W

Example: Write the four quantum numbers for the last electron added in:

K	**Ga**	**Br**
n =	n =	n =
l =	l =	l =
m_l =	m_l =	m_l =
m_s =	m_s =	m_s =

Periodic Trends.

Know these terms

- shielding
- penetration
- effective nuclear charge

To predict periodic trends, consider two things:

1.
2.

Summary of periodic trends:

Atomic and ionic radii

Atomic size ____________________ going from left to right across the periodic table because:

Atomic size ____________________ going down the periodic table because:

Ionic size:

1.
2.
3.

Example: Which is bigger, Na or Cl?

Example: Which is bigger, Na^+ or Cl^-?

Ionization Energy

Definition of Ionization Energy:

General Trend:

But there are important exceptions that you have to know!

IE_1 =

IE_2 =

IE_3 =

etc.

IE_1(Na)

IE_2(Na)

Two points:
- For a given element,
- Notice the ______________ _______________ for Na going from IE_1 to IE_2. This is because:

IE_1(Mg)

Which is greater, IE_1(Na) or IE_1(Mg)? Why?

IE_2(Mg)

Which is greater, IE_2(Na) or IE_2(Mg)? Why?

IE_3(Mg)

Notice the _______ ________ for Mg going from IE_2 to IE_3. This is because:

Which is greater, and why?

IE_1(Mg) IE_1(Al)

IE_1(Al) IE_1(Si)

IE_1(P) IE_1(S)

Where are the exceptions? Why?

Which is greater?

IE_1(S) IE_1(Cl)

IE_6(S) IE_6(Cl)

IE_7(S) IE_7(Cl)

Problem: Place in order of increasing IE1: Li Be B C N O F

Electron Affinity

Definition:

Some electron affinities are _______________ and some are __________________.

If the electron affinity is negative, that means:

When we say that the electron affinity "increases", that means:

The trend is not as clear, and there are lots of exceptions, but we can say:

1. Groups _____ and ______ have_____________________________ electron affinities.
2. The ________________ have the most _______________________ electron affinities.
3. Make individual predictions based on:

    1)

    2)

Which has the greater electron affinity, Li or Be?

Which has the greater electron affinity, Be or B?

Which has the greater electron affinity, B or C?

Which has the greater electron affinity, C or N?

Which has the greater electron affinity, C or O?

Which has the greater electron affinity, O or F?

Trends in Metallic Character