CHAPTER 4: Quantum Theory & Electron configuration

Part 1: Quantum Theory

In the early 1900s, scientists observed certain elements emitted visible light when heated in a flame.

• Analysis of the emitted light revealed that an element's chemical behavior is related to the arrangement of the electrons in its atoms.

The Wave Nature of Light

• Visible light is a type of electromagnetic radiation, a form of energy that exhibits wave-like behavior as it travels through space.

• All waves can be described by several characteristics.

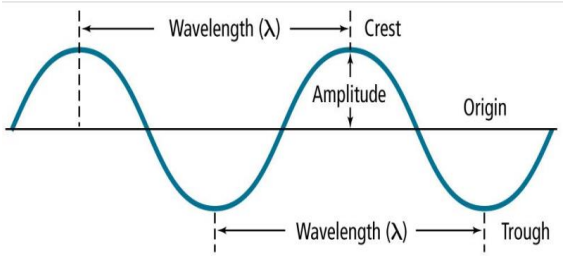
• The wavelength (λ) is the shortest distance between equivalent points on a continuous wave.

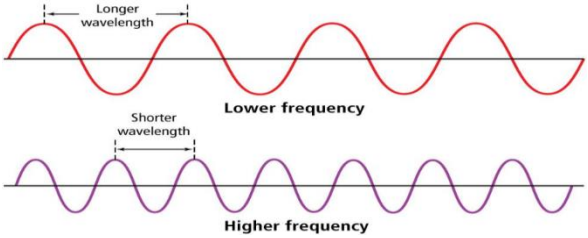
• The frequency (ν) is the number of waves that pass a given point per second.

• The amplitude is the wave's height from the origin to a crest.

• The speed of light **c** (3.00 x 10^8 m/s) is the product of it's wavelength and frequency

• **$C = \lambda\nu$**





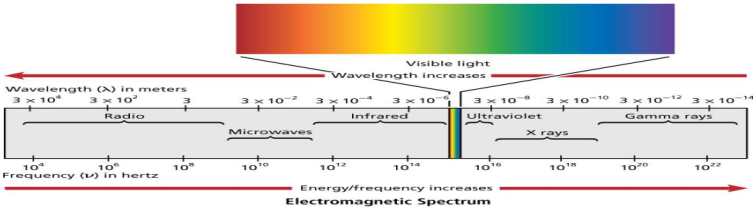
• Sunlight contains a continuous range of wavelengths and frequencies.

• A prism separates sunlight into a continuous spectrum of colors.

• The electromagnetic spectrum includes all forms of electromagnetic radiation.

• The wave model of light cannot explain all of light's Characteristics.

• In 1900, German physicist Max Planck (1858-1947) began searching for an explanation of this phenomenon as he studied the light emitted by heated objects.



• Planck's study led him to a startling conclusion:

–Matter can gain or lose energy only in small, specific amounts called quanta.

–A quantum is the minimum amount of energy that can be gained or lost by an atom.

–Planck's constant has a value of 6.626 x 10^{-34} J . s

• Albert Einstein proposed in 1905 that light has a dual nature.

– A beam of light has wavelike and particle-like properties.

– A photon is a particle of electromagnetic radiation with no mass that carries a quantum of energy.

• ***The atomic emission spectrum*** of an element is the set of frequencies of the electromagnetic waves emitted by the atoms of the element.

Each element's atomic emission spectrum is unique.

Energy of a Quantum

$E_{quantum} = h\nu$

$E_{quantum}$ represents energy.
h is Planck's constant.
ν represents frequency.

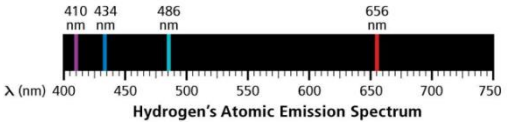
The energy of a quantum is given by the product of Planck's constant and the frequency.

Energy of a Photon

$E_{photon} = h\nu$

E_{photon} represents energy.
h is Planck's constant.
ν represents frequency.

The energy of a photon is given by the product of Planck's constant and the frequency.



Hydrogen's Atomic Emission Spectrum

Q1 **What is the smallest amount of energy that can be gained or lost by an atom?**

CH 4 **A** Electromagnetic photon **B** Beta particle **C** Quanta **D** Wave-particle

A quantum is the minimum amount of energy that can be gained or lost by an atom. →C

Q2 **What is a particle of electromagnetic radiation with no mass called?**

CH 4 **A** Beta particle **B** Alpha particle **C** Quanta **D** Photon

A photon is a particle of electromagnetic radiation with no mass that carries a quantum of energy. →D

Q3 **The shortest distance from equivalent points on a continuous wave is the:**

CH 4 **A** Frequency **B** Wavelength **C** Amplitude **D** Crest

The wavelength (λ) is the shortest distance between equivalent points on a continuous wave. →B

Q4 **The energy of a wave increases as ____.**

CH 4 **A** Frequency decreases **B** Wavelength decreases **C** Wavelength increases **D** Distance increases

The energy of a wave increase when wavelength (λ) is decreased. →B

Q5 **The energy of a wave increases as ____.**

CH 4 **A** Frequency decreases **B** Frequency increases **C** Wavelength increases **D** Distance increases

The energy of a wave increases as frequency of a wave increases. →B

Q6 **Albert Einstein proposed in 1905 that light has a …**

CH 4 **A** Dual nature. **B** Frequency only **C** Wavelength only **D** Proton

Albert Einstein proposed in 1905 that light has a dual nature. →A

Q7 **Which of the following spectrum has shortest wavelength**

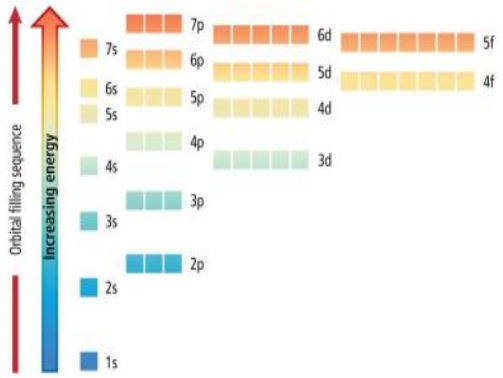
CH 4 **A** 100 Hz **B** 200 Hz **C** **300 Hz** **D** 400 Hz

Highest frequency has shortest wavelength →D

Part 2: Electron Configuration

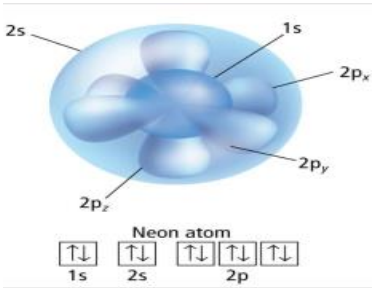
The arrangement of electrons in the atom is called the **electron configuration**.

- The aufbau principle states that each electron occupies the lowest energy orbital available.
- The Pauli exclusion principle states that a maximum of two electrons can occupy a single orbital, but only if the electrons have opposite spins.
- Hund's rule states that single electrons with the same spin must occupy each equal-energy orbital before additional electrons with opposite spins can occupy the same energy level orbitals.



Electron Configurations and Orbital Diagrams for Elements 1–10

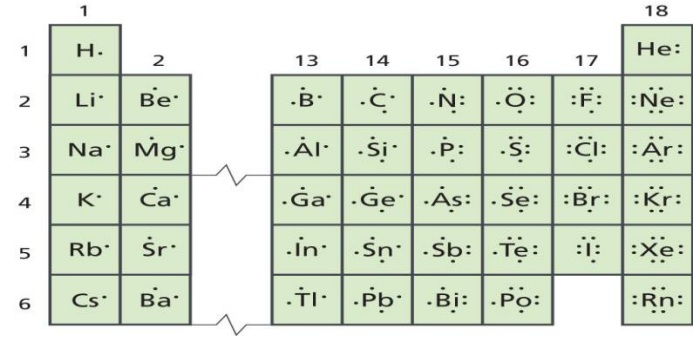
Element	Atomic Number	Orbital Diagram 1s 2s 2p$_x$ 2p$_y$ 2p$_z$	Electron Configuration Notation
Hydrogen	1	↑	$1s^1$
Helium	2	↑↓	$1s^2$
Lithium	3	↑↓ ↑	$1s^2\ 2s^1$
Beryllium	4	↑↓ ↑↓	$1s^2\ 2s^2$
Boron	5	↑↓ ↑↓ ↑	$1s^2\ 2s^2\ 2p^1$
Carbon	6	↑↓ ↑↓ ↑ ↑	$1s^2\ 2s^2\ 2p^2$
Nitrogen	7	↑↓ ↑↓ ↑ ↑ ↑	$1s^2\ 2s^2\ 2p^3$
Oxygen	8	↑↓ ↑↓ ↑↓ ↑ ↑	$1s^2\ 2s^2\ 2p^4$
Fluorine	9	↑↓ ↑↓ ↑↓ ↑↓ ↑	$1s^2\ 2s^2\ 2p^5$
Neon	10	↑↓ ↑↓ ↑↓ ↑↓ ↑↓	$1s^2\ 2s^2\ 2p^6$

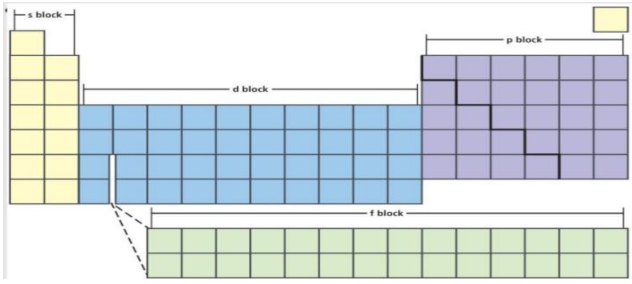


- Noble gas notation uses noble gas symbols in brackets to shorten inner electron configurations of other elements.
- **Valence electrons** are defined as electrons in the atom's outermost orbitals—those associated with the atom's highest principal energy level.
- **Electron-dot structure** consists of the element's symbol representing the nucleus, surrounded by dots representing the element's valence electrons.

Electron Configurations for Elements 11–18

Element	Atomic Number	Complete Electron Configuration	Electron Configuration Using Noble Gas
Sodium	11	$1s^2 2s^2 2p^6 3s^1$	[Ne]$3s^1$
Magnesium	12	$1s^2 2s^2 2p^6 3s^2$	[Ne]$3s^2$
Aluminum	13	$1s^2 2s^2 2p^6 3s^2 3p^1$	[Ne]$3s^2 3p^1$
Silicon	14	$1s^2 2s^2 2p^6 3s^2 3p^2$	[Ne]$3s^2 3p^2$
Phosphorus	15	$1s^2 2s^2 2p^6 3s^2 3p^3$	[Ne]$3s^2 3p^3$
Sulfur	16	$1s^2 2s^2 2p^6 3s^2 3p^4$	[Ne]$3s^2 3p^4$
Chlorine	17	$1s^2 2s^2 2p^6 3s^2 3p^5$	[Ne]$3s^2 3p^5$
Argon	18	$1s^2 2s^2 2p^6 3s^2 3p^6$	[Ne]$3s^2 3p^6$ or [Ar]





8 **In the ground state, which orbital does an atom's electrons occupy?**

CH 4

A The highest available
B The lowest available
C The n = 0 orbital
D The d suborbital

Ground state is the lowest orbital available that's an atom's electrons occupy →B

9 **The electron configuration of an atom is $1s^2 2s^2 2p^6$. The number of electrons in the atom is**

CH 4

A 1 **B** 2
C 6 **D** 10

The sum of electron in the electron configuration = 10 →D

10 **The electron configuration of fluorine F (atomic number = 9) is**

CH 4

A $1s^2 2s^1$
B $1s^2 2s^2 2p^3$
C $1s^2 2s^2 2p^5$
D $1s^2 2s^2 2p^6$

$1s^2 2s^2 2p^5$ →C

11 **The right electron configuration is**

CH 4

A $1s^2 2s^3$
B $1s^2 2s^2 2p^8$
C $1s^3 2s^1 2p^1$
D $1s^2 2s^2 2p^6 3s^1$

$1s^2 2s^2 2p^6 3s^1$, s orbital can be filled with 2 e , p orbital can be filled with 6 e →D

CHAPTER 4: Quantum Theory & Electron configuration

12 The electronic configuration of an atom an element with atomic number 8 is...

CH 4

A $1s^2 2s^2 2p^6$
B $1s^2 2s^2 2p^4$
C $1s^2 2s^2 2p^5$
D $1s^2 2s^2 2p^6 3s^1$

$1s^2 2s^2 2p^4$, because the sum of electrons = 8 →B

13 The electronic configuration of Calcium Ca (atomic number = 20) is...

CH 4

A $1s^2 2s^2 2p^6 3s^1$
B $1s^2 2s^2 2p^5 3s^3$
C $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
D $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ →C

14 Which one of the following is the electronic configuration of atom of a noble gas?

CH 4

A $1s^2 2s^2 2p^6 3s^1$
B $1s^2 2s^2 2p^5 3s^3$
C $1s^2 2s^2 2p^6 3s^2 3p^6$
D $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

$1s^2 2s^2 2p^6 3s^2 3p^6$, because its include 18 e →C

15 Which one of the following is the electronic configuration of sulfur S. (atomic number of S = 16)

CH 4

A $[Ne]3s^1$
B $[Ar]4s^2$
C $[Ne]3s^2 4p^4$
D $[He]2s^2 2p^4$

$[Ne]3s^2 3p^4$, Ne have 10 e, and the sum →C

16 Which one of the following is the electronic configuration of Iron Fe (atomic number of Fe = 26)

CH 4

A $[Ar]4s^1 3d^7$
B $[Ar]4s^2 3d^7$
C $[Ar]4s^2 3d^6$
D $[Ar]2s^3 3d^5$

$[Ne]3s^2 3p^4$, Ne have 10 e, and the sum →C

17 Which one of the following is the electronic configuration of Chromium Cr (Atomic number of Cr = 24)

CH 4

A $[Ar]4s^2 3d^4$
B $[Ar]4s^3 3d^3$
C $[Ar]4s^1 3d^6$
D $[Ar]2s^1 3d^5$

$[Ar]2s^1 3d^5$ because is more stable → D

18 Which one of the following is the electronic configuration of Copper Cu (Atomic number of Cu = 29)

CH 4

A $[Ar]4s^2 3d^9$ B $[Ar]4s^1 3d^{10}$
C $[Ar]4s^3 3d^8$ D $[Ar]2s^1 3d^9$

$[Ar]2s^1 3d^{10}$ because is more stable →B

19 The electron configuration of an element is $[Ar]4s^2 3d^7$. The atomic number of an element is

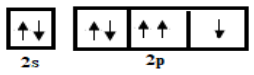
CH 4

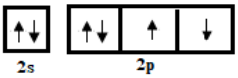
A 9 B 18
C 29 D 27

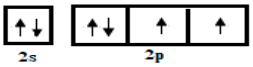
The sum of electron in the electron configuration = 27 →D

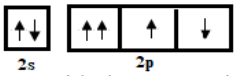
20 The right electronic configuration according to hunds role is...

CH 4

A 

B 

C 

D 

Hund's rule states that single electrons with the same spin must occupy each equal-energy orbital before additional electrons with opposite spins can occupy the same energy level orbitals. →C

21 The right electron dot of Florine F (atomic number is 9)

CH 4

A 
B 
C 
D

Fluorine has 7 valence electrons in the outer most shell in according to it electron configuration →B

22 Which of the following is NOT one of the elemental blocks of the periodic table?

CH 4

A s-block B d-block C g-block D f-block

There are 4 Blocks s, p, d, f →C

Do it?

1 The electron configuration for a carbon atom in ground state is (Atomic number =6)

A $1s^2 2s^2 2p^3$
B $1s^2 2s^2 2p^4$
C $1s^2 2s^2 2p^6$
D $1s^2 2s^2 2p^2$

2 The right electron configuration is

A $1s^2 2s^2 2p^7$
B $1s^1 2s^3 2p^3$
C $1s^2 2s^1 2p^5$
D $1s^2 2s^2 2p^6 3s^1$

3 Which one of the following is the electronic configuration of Nickel Ni (Atomic number of Ni = 28)

A $[Ar]4s^2 3d^4$
B $[Ar]4s^3 3d^5$
C $[Ar]4s^2 3d^8$
D $[Ar]2s^1 3d^9$

4 The right electron dot of Carbon (Atomic number is 6)

A 
B 
C 
D 

5 The electron configuration of an element is $[Ne]3s^2 3p^3$. The atomic number of an element is

A 5 B 15
C 10 D 8

Chapter 4: Do It Answer key				
1	2	3	4	5
D	D	C	D	B