## UNIT 1 – CHAPTER 7 STUDENT NOTES: ATOMIC STRUCTURE AND PERIODICITY

### Atomic Model

**Max Planck** – discovered that matter is lost or gained in whole-number multiples

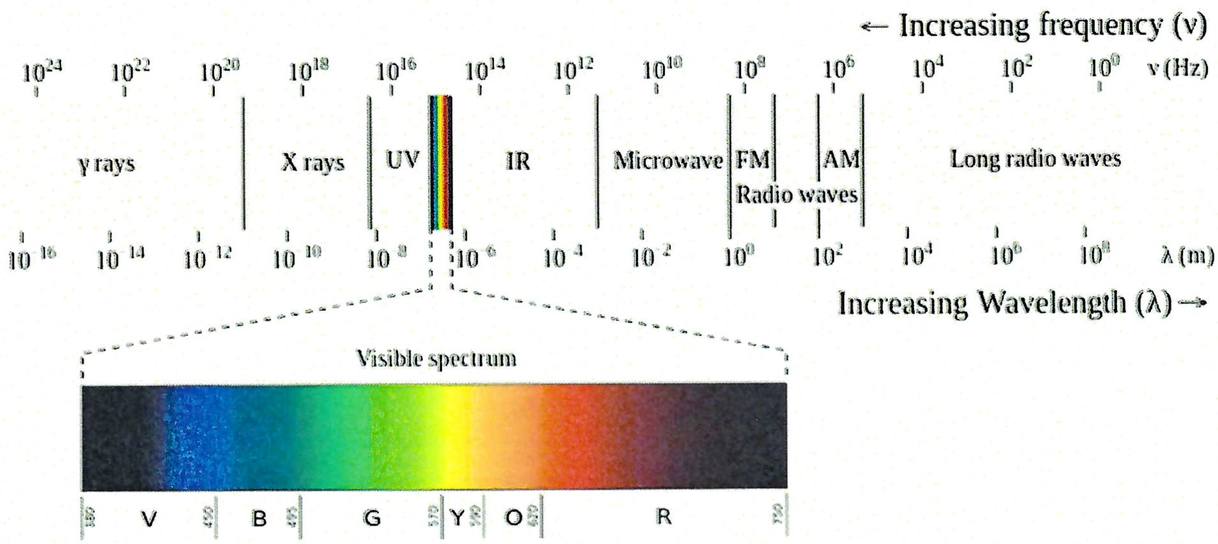
**E = hv**

E = energy (Joules)

h = Planck's constant ($6.63 \times 10^{-34}$ J-sec)

v = frequency (Hz) (waves/sec)

**Electromagnetic radiation** – form of energy emitted by matter




All electromagnetic radiations travel at the speed of light and follow the formula:

$c = \lambda \cdot v$ $\quad c = 3.0 \times 10^{8}$ m/sec

λ = wavelength

v - frequency

Energy of electromagnetic radiation:

$$E = hv, \quad E = \frac{h \cdot c}{\lambda}$$

EX 1: The blue color in fireworks is often achieved by heating copper (I) chloride (CuCl) to about 1200°C. Then the compound emits blue light having a wavelength of 450nm. What is the increment of energy (the quantum) that is emitted at $4.50 \times 10^{2}$ nm by CuCl?

$E = h \cdot v \rightarrow E = \frac{h \cdot c}{\lambda}$

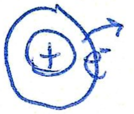
$E = \frac{(6.63 \times 10^{-34}\ \text{J}\cdot\text{SEC})(3.0 \times 10^{8}\ \text{M/SEC})}{4.50 \times 10^{-7}\ \text{M}}$

$E = 4.41 \times 10^{-19}$ J or $4.41 \times 10^{-21}$ KJ

PLANCK'S CONSTANT:
$h = 6.63 \times 10^{-34}$ J/SEC

EX 2: It takes 208.4 kJ of energy to remove 1 mole of electrons from an atom on the surface of rubidium metal. How much energy does it take to remove a single electron from an atom on the surface of solid rubidium? What is the maximum wavelength of light capable of doing this? What color range would this be?

REMOVE



A) $\frac{208.4 \text{ KJ}}{\text{MOL}} \cdot \frac{1 \text{ MOLE}}{6.02 \times 10^{23} \text{ PARTICLES}} = 3.46 \times 10^{-22}$ KJ / PARTICLE OR $3.46 \times 10^{-19}$ J / PARTICLE

B) $E = \frac{h \cdot c}{\lambda}$ $\quad 3.46 \times 10^{-19} \text{ J} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{\lambda}$

$\lambda = 5.73 \times 10^{-7}$ M → GREEN LIGHT

**Albert Einstein** – developed the formula **$E = mc^2$** which proved **waves should have mass**

**Louis de Broglie** – asked the question: Do particles have wave properties?

If: $m = \frac{h}{(\lambda \cdot \text{velocity} \cdot c)}$

Then: $\lambda = \frac{h}{(m \cdot \text{velocity} \cdot c)}$

**Small objects ($e^-$)** have large wavelengths

**Large objects (bowling balls)** have small wavelengths

EX 3: Compare the wavelength for an electron (mass = $9.11 \times 10^{-31}$ kg) traveling at a speed of $1.0 \times 10^{7}$ m/sec with that for a ball (mass = 0.10 kg) traveling at 35 m/sec.

$\lambda = \frac{h}{m \cdot v}$

ELECTRON

MASS = $9.11 \times 10^{-31}$ Kg

SPEED = $1.0 \times 10^{7}$ m/SEC

$\lambda = \frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31} \text{ Kg})(1.0 \times 10^{7})}$

$e^- \lambda = 7.28 \times 10^{-11}$ m

BALL

MASS = 0.10 Kg

SPEED = 35 m/SEC

$\lambda = \frac{(6.63 \times 10^{-34})}{(0.10 \text{ Kg})(35 \text{ m/SEC})}$

BALL $\lambda = 1.9 \times 10^{-34}$ M

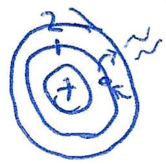
∴ BALL HAS MUCH SMALLER $\lambda$ THAN $e^-$

**Neils Bohr** – developed the quantum model of the atom.

- **Quantum model** – proposed that the electrons in a hydrogen atom move around the nucleus only in certain allowed circular orbits.
- Classical physics said as an electron circles an atom, it is accelerating because it is changing direction and a charged particle ($e^-$) should lose energy and fall into the nucleus. Bohr said an electron loses energy as it moves from level to level.

$E_{ELECTRON} = \frac{R_H}{n^2}$ $R_H$ = RYDBERG CONSTANT = $2.179 \times 10^{-18}$ J

EX 4: Calculate the energy evolved as an excited atom has an electron fall from n = 2 to n = 1. Calculate the wavelength of energy and the type of radiation needed to do this.



$E = -\frac{R_H}{n^2}$

1) $E = (-2.178 \times 10^{-18} J)\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = -1.63 \times 10^{-18} J$ (− INDICATES J GIVEN OFF)

2) $E = \frac{h \cdot c}{\lambda}$ $1.63 \times 10^{-18} J = \frac{(6.63 \times 10^{-34})(3.0 \times 10^8)}{\lambda}$

$1.63 \times 10^{-18} = \frac{1.989 \times 10^{-25}}{\lambda}$

$\lambda = 1.22 \times 10^{-7} m$

**Electron configurations** – model used to explain the electron arrangement of the atom.

- **Shell** – an area where the electrons are located
- **Subshell** – the shape of the area of the electrons
- **Orbital** is a position in a subshell

EX 5: Draw electron configurations for the following **atoms**:

K

Sn

(24+ 28n) Cr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$ (AUFBAU)
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ (EXCEPTION)

(47+ 61n) Ag $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^9$ (AUFBAU)
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1 4d^{10}$ (EXCEPTION)

(46+ 60n) Pd $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^8$ (AUFBAU)
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^0 4d^{10}$ (EXCEPTION)

EX 6: Draw electron configurations for the following **ions** (atoms with a charge):

Ca

34p⁺ 45n° — Se $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$ - Atom

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$ - ion ($Se^{2-}$)

13p⁺ 14n° — Al $1s^2 2s^2 2p^6 3s^2 3p^1$ - Atom

$1s^2 2s^2 2p^6 3s^0 3p^0$ - ion ($Al^{3+}$)

17p⁺ 18n° — Cl

**Quantum numbers**

**Principle quantum number ($n$):** 1, 2, 3, 4… = shell

**Angular quantum number ($\ell$):** 0 to n-1 = subshell

s = 0, p = 1, d = 2, f = 3

**Magnetic spin quantum number ($m_\ell$):** = position in the orbital

s = 0

p = -1, 0, 1

d = -2, -1, 0, 1, 2

f = -3, -2, -1, 0, 1, 2, 3

**Spin quantum number ($s$):** +1/2 or -1/2 = spin of the electron

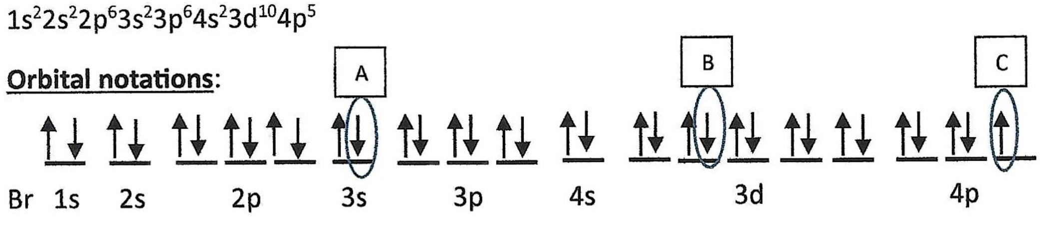
**Pauli exclusion principle**:

Br (Bromine) Atomic #35, Mass #80

**Electron configuration notation:**

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

**Orbital notations**:



| | n | l | $m_l$ | s |
|---|---|---|---|---|
| $1s^2$ | 1 | Ø | Ø | +1/2 |
| | 1 | Ø | Ø | −1/2 |
| $2s^2$ | 2 | Ø | Ø | +1/2 |
| | 2 | Ø | Ø | −1/2 |
| $2p^6$ | 2 | 1 | −1 | +1/2 |
| | 2 | 1 | Ø | +1/2 |
| | 2 | 1 | +1 | +1/2 |
| | 2 | 1 | −1 | −1/2 |
| | 2 | 1 | Ø | −1/2 |
| | 2 | 1 | +1 | −1/2 |

EX: Assign quantum numbers for **ALL** the electrons in the Neon atom.

Ne: $1s^2 2s^2 2p^6$

__PERIODICITY__: The chemical and physical properties of atoms are periodic functions of their atomic number.

__Atomic radii__

*Periodic Table of Atomic Radii*

| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 H 1 | | | | | | | | | | | | | | | | | 0.31 He 2 |
| 1.23 Li 3 | 0.89 Be 4 | | | | | | | | | | | 0.82 B 5 | 0.77 C 6 | 0.74 N 7 | 0.70 O 8 | 0.68 F 9 | 0.67 Ne 10 |
| 1.54 Na 11 | 1.36 Mg 12 | | | | | | | | | | | 1.18 Al 13 | 1.11 Si 14 | 1.06 P 15 | 1.02 S 16 | 0.99 Cl 17 | 0.98 Ar 18 |
| 2.03 K 19 | 1.74 Ca 20 | 1.44 Sc 21 | 1.32 Ti 22 | 1.22 V 23 | 1.18 Cr 24 | 1.17 Mn 25 | 1.17 Fe 26 | 1.16 Co 27 | 1.15 Ni 28 | 1.17 Cu 29 | 1.25 Zn 30 | 1.26 Ga 31 | 1.22 Ge 32 | 1.20 As 33 | 1.17 Se 34 | 1.14 Br 35 | 1.12 Kr 36 |
| 2.16 Rb 37 | 1.91 Sr 38 | 1.62 Y 39 | 1.45 Zr 40 | 1.34 Nb 41 | 1.30 Mo 42 | 1.27 Tc 43 | 1.25 Ru 44 | 1.25 Rh 45 | 1.28 Pd 46 | 1.34 Ag 47 | 1.48 Cd 48 | 1.44 In 49 | 1.40 Sn 50 | 1.40 Sb 51 | 1.36 Te 52 | 1.33 I 53 | 1.31 Xe 54 |
| 2.35 Cs 55 | 1.98 Ba 56 | 1.56 Lu 71 | 1.44 Hf 72 | 1.34 Ta 73 | 1.30 W 74 | 1.28 Re 75 | 1.26 Os 76 | 1.27 Ir 77 | 1.30 Pt 78 | 1.34 Au 79 | 1.49 Hg 80 | 1.48 Tl 81 | 1.47 Pb 82 | 1.46 Bi 83 | 1.46 Po 84 | 1.45 At 85 | Rn 86 |
| Fr 87 | 2.20 Ra 88 | Lr 103 | Unq 104 | Unp 105 | Unh 106 | Uns 107 | Uno 108 | Une 109 | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.69 La 57 | 1.65 Ce 58 | 1.64 Pr 59 | 1.64 Nd 60 | 1.63 Pm 61 | 1.62 Sm 62 | 1.85 Eu 63 | 1.62 Gd 64 | 1.61 Tb 65 | 1.60 Dy 66 | 1.58 Ho 67 | 1.58 Er 68 | 1.58 Tm 69 | 1.70 Yb 70 |
| 2.0 Ac 89 | 1.65 Th 90 | Pa 91 | 1.42 U 92 | Np 93 | Pu 94 | Am 95 | Cm 96 | Bk 97 | Cf 98 | Es 99 | Fm 100 | Md 101 | No 102 |

__Why are there differences in sizes of the atoms?__

__Coulombs Law__: $U_E \propto q1*q2/d$

(11+) Na: $1s^2 2s^2 2p^6 3s^1$

(18+) Ar: $1s^2 2s^2 2p^6 3s^6$

(9+) F: $1s^2 2s^2 2p^5$

(53+) I: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^5$

**Effective Nuclear Charge**: the pull created by the protons in a nucleus

**The size of ions**

**Anions**

(17+) Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$ (17e⁻)

(17+) $Cl^-$: $1s^2 2s^2 2p^6 3s^2 3p^6$ (18e⁻)

**Cations**

(20+) Ca: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ (20e⁻)

(20+) $Ca^{2+}$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0$ (18e⁻)

**First Ionization Energy** (energy required to give up electrons)

**Periodic Table of First Ionization Energies**

| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 314 H 1 | | | | | | | | | | | | | | | | | 567 He 2 |
| 124 Li 3 | 215 Be 4 | | | | | | | | | | | 191 B 5 | 260 C 6 | 335 N 7 | 314 O 8 | 402 F 9 | 497 Ne 10 |
| 119 Na 11 | 176 Mg 12 | | | | | | | | | | | 138 Al 13 | 188 Si 14 | 242 P 15 | 239 S 16 | 299 Cl 17 | 363 Ar 18 |
| 100 K 19 | 141 Ca 20 | 151 Sc 21 | 157 Ti 22 | 155 V 23 | 156 Cr 24 | 171 Mn 25 | 181 Fe 26 | 181 Co 27 | 176 Ni 28 | 178 Cu 29 | 217 Zn 30 | 138 Ga 31 | 182 Ge 32 | 226 As 33 | 225 Se 34 | 272 Br 35 | 323 Kr 36 |
| 96 Rb 37 | 131 Sr 38 | 147 Y 39 | 158 Zr 40 | 159 Nb 41 | 164 Mo 42 | 168 Tc 43 | 170 Ru 44 | 172 Rh 45 | 192 Pd 46 | 175 Ag 47 | 207 Cd 48 | 133 In 49 | 169 Sn 50 | 199 Sb 51 | 208 Te 52 | 241 I 53 | 280 Xe 54 |
| 90 Cs 55 | 120 Ba 56 | 125 Lu 71 | 161 Hf 72 | 182 Ta 73 | 184 W 74 | 182 Re 75 | 201 Os 76 | 210 Ir 77 | 208 Pt 78 | 213 Au 79 | 241 Hg 80 | 141 Tl 81 | 171 Pb 82 | 168 Bi 83 | 196 Po 84 | At 85 | 248 Rn 86 |
| Fr 87 | 122 Ra 88 | Lr 103 | Unq 104 | Unp 105 | Unh 106 | Uns 107 | Uno 108 | Une 109 | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 129 La 57 | 126 Ce 58 | 125 Pr 59 | 127 Nd 60 | 128 Pm 61 | 130 Sm 62 | 131 Eu 63 | 142 Gd 64 | 135 Tb 65 | 137 Dy 66 | 139 Ho 67 | 141 Er 68 | 143 Tm 69 | 144 Yb 70 |
| 159 Ac 89 | Th 90 | Pa 91 | U 92 | Np 93 | 134 Pu 94 | 138 Am 95 | Cm 96 | Bk 97 | Cf 98 | Es 99 | Fm 100 | Md 101 | No 102 |

**Electronegativity** (force it exerts to take in electrons – "how much they like taking in electrons")

## Periodic Table of Electronegativities

| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.1 H 1 | | | | | | | | | | | | | | | | | He 2 |
| 1.0 Li 3 | 1.5 Be 4 | | | | | | | | | | | 2.0 B 5 | 2.5 C 6 | 3.0 N 7 | 3.5 O 8 | 4.0 F 9 | Ne 10 |
| 0.9 Na 11 | 1.2 Mg 12 | | | | | | | | | | | 1.5 Al 13 | 1.8 Si 14 | 2.1 P 15 | 2.5 S 16 | 3.0 Cl 17 | Ar 18 |
| 0.8 K 19 | 1.0 Ca 20 | 1.3 Sc 21 | 1.5 Ti 22 | 1.6 V 23 | 1.6 Cr 24 | 1.5 Mn 25 | 1.8 Fe 26 | 1.8 Co 27 | 1.8 Ni 28 | 1.9 Cu 29 | 1.6 Zn 30 | 1.6 Ga 31 | 1.8 Ge 32 | 2.0 As 33 | 2.4 Se 34 | 2.8 Br 35 | 3.0 Kr 36 |
| 0.8 Rb 37 | 1.0 Sr 38 | 1.2 Y 39 | 1.4 Zr 40 | 1.6 Nb 41 | 1.8 Mo 42 | 1.9 Tc 43 | 2.2 Ru 44 | 2.2 Rh 45 | 2.2 Pd 46 | 1.9 Ag 47 | 1.7 Cd 48 | 1.7 In 49 | 1.8 Sn 50 | 1.9 Sb 51 | 2.1 Te 52 | 2.5 I 53 | 2.6 Xe 54 |
| 0.7 Cs 55 | 0.9 Ba 56 | 1.2 Lu 71 | 1.3 Hf 72 | 1.5 Ta 73 | 1.7 W 74 | 1.9 Re 75 | 2.2 Os 76 | 2.2 Ir 77 | 2.2 Pt 78 | 2.4 Au 79 | 1.9 Hg 80 | 1.8 Tl 81 | 1.8 Pb 82 | 1.9 Bi 83 | 2.0 Po 84 | 2.2 At 85 | 2.4 Rn 86 |
| 0.7 Fr 87 | 0.9 Ra 88 | Lr 103 | Unq 104 | Unp 105 | Unh 106 | Uns 107 | Uno 108 | Une 109 | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 La 57 | 1.1 Ce 58 | 1.1 Pr 59 | 1.1 Nd 60 | 1.1 Pm 61 | 1.1 Sm 62 | 1.1 Eu 63 | 1.1 Gd 64 | 1.1 Tb 65 | 1.1 Dy 66 | 1.1 Ho 67 | 1.1 Er 68 | 1.1 Tm 69 | 1.1 Yb 70 |
| 1.1 Ac 89 | 1.3 Th 90 | 1.5 Pa 91 | 1.7 U 92 | 1.3 Np 93 | 1.3 Pu 94 | 1.3 Am 95 | 1.3 Cm 96 | 1.3 Bk 97 | 1.3 Cf 98 | 1.3 Es 99 | 1.3 Fm 100 | 1.3 Md 101 | 1.3 No 102 |