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

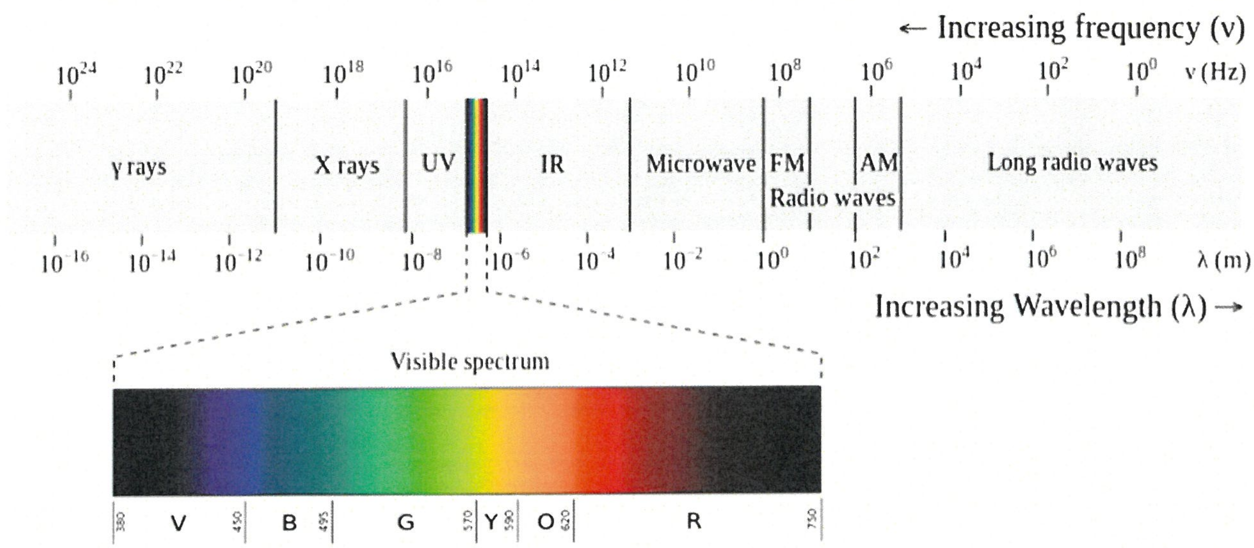
E = hv

E = energy (Joules)

h = Planck's constant (6.63×10^{-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:

$c = \lambda \cdot v$

$c = 3.0 \times 10^8$ m/sec

λ = wavelength

v - frequency

Energy of electromagnetic radiation:

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

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 4.50×10^2 nm by CuCl?

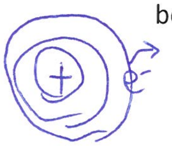
$$E = h \cdot v \rightarrow E = \frac{h \cdot c}{\lambda}$$

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

$$\boxed{E = 4.41 \times 10^{-19}\ \text{J} \quad \text{OR} \quad 4.41 \times 10^{-22}\ \text{KJ}}$$

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?



A) $\frac{208.4 \text{ KJ}}{\text{MOL}} \cdot \frac{1 \text{ MOL}}{6.02\times10^{23} \text{ PARTICLES}} = \boxed{3.46\times10^{-22} \text{ KJ/PARTICLES OR } 3.46\times10^{-19} \text{ J/PARTICLES}}$

B) $E = \frac{h \cdot c}{\lambda}$ $\quad 3.46\times10^{-19} \text{ J} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{\lambda}$

$\boxed{\lambda = 5.73\times10^{-7} \text{ M} \rightarrow \text{GREEN LIGHT}}$

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

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

If: $m = \frac{h}{(\lambda \cdot \text{velocity})}$ m - kg velocity – m/sec h – Plank's constant (J/Hz) λ - meters

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

Small objects (e^-) have large wavelengths

Large objects (bowling balls) have small wavelengths

EX 3: Compare the wavelength for an electron (mass = 9.11×10^{-31} kg) traveling at a speed of 1.0×10^{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 = 9.11×10^{-31} Kg
SPEED = 1.0×10^{7} M/SEC

$\lambda = \frac{(6.63\times10^{-34})}{(9.11\times10^{-31} \text{ Kg})(1.0\times10^{7})}$

$\boxed{e^- \; \lambda = 7.28\times10^{-11} \text{ M}}$

BALL

MASS = 0.10 Kg
SPEED = 35 M/SEC

$\lambda = \frac{(6.63\times10^{-34})}{(0.10 \text{ Kg})(35 \text{ M/SEC})}$

$\boxed{\text{BALL } \lambda = 1.9\times10^{-34} \text{ M}}$

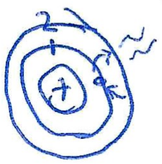
$\boxed{\therefore \text{ BALL HAS MUCH SMALLER } \lambda \text{ THAN } e^-}$

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.

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

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

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

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 $\quad$ Cr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$ (AUFBAU)
$1s^2 2s^2 2p^6 3s^2 3p^6 \underline{4s^1 3d^5}$ (EXCEPTION)

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

46+ 60n $\quad$ 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 (ℓ): 0 to n-1 = subshell

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

Magnetic spin quantum number ($m_ℓ$): = 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:

	1s	2s	2p	3s	3p	4s	3d	4p
				A			B	C
Br	↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑

	n	l	m_l	s
$1s^2$	1	0	0	+1/2
	1	0	0	−1/2
$2s^2$	2	0	0	+1/2
	2	0	0	−1/2
$2p^6$	2	1	−1	+1/2
	2	1	0	+1/2
	2	1	+1	+1/2
	2	1	−1	−1/2
	2	1	0	−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

0.32 H 1																	VIII
																	0.31 He 2
I	II											III	IV	V	VI	VII	
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