Chapter 9: Electrons in Atoms

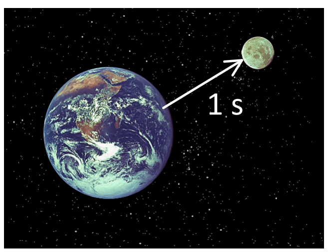
Why is hydrogen explosive?
Why are noble gases unreactive?
Why do F, Cl, Br, and I all form 1- ions?

The answers are all due to the behavior of the **electrons** in those atoms.

> … but if electrons are nearly massless and much smaller than an atom, how do we know anything about them? How can we figure out how they behave, or learn about their locations in an atom?

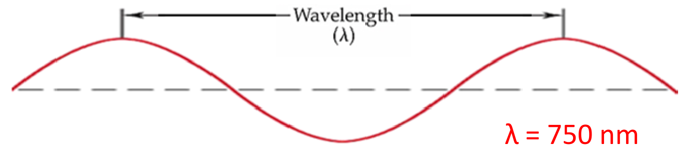
It all started by studying light.

Light (electromagnetic radiation), the form of energy that travels in waves at a speed of 3.00 x 10^8 m/s.



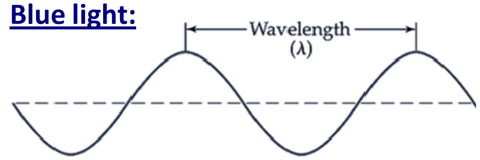
Wavelength and color

Red light:



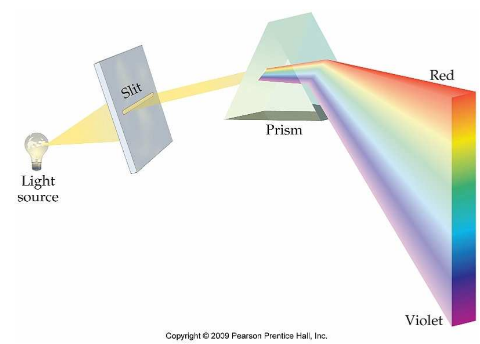
λ = 750 nm

Blue light:



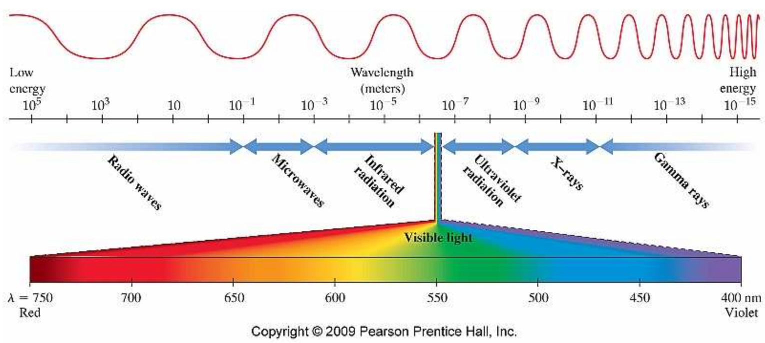
λ = 450 nm

The visible spectrum



R ≅ 750 nm
O
Y
G
B
I
V ≅ 380 nm

The electromagnetic spectrum



Energy and wavelength (λ) have what relationship?

Radio:

Microwaves:

Infrared:

Visible:

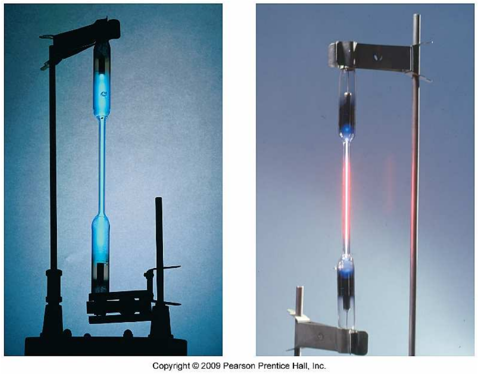
UV:

X-ray:

Gamma:

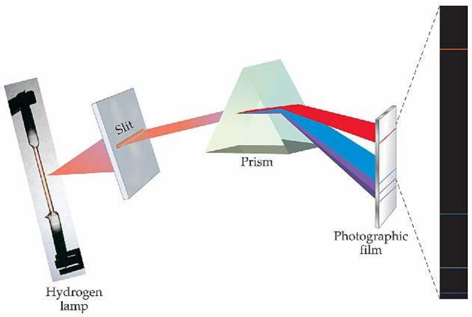
Atomic line spectra

A **gas lamp** is a sealed glass tube that contains a gas sample, and **glows** when a high voltage is applied to it.

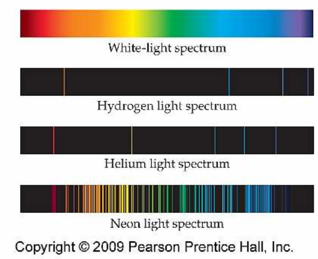


Hg(*g*) $H_2(g)$

But **only certain wavelengths** of light are given off by a gas lamp.



Compare with the continuous spectrum given off by a white light source like a light bulb.

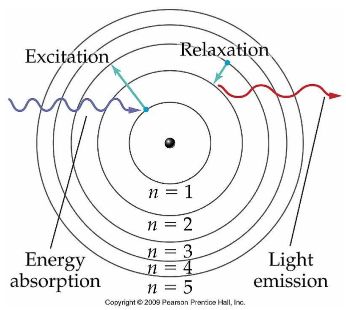


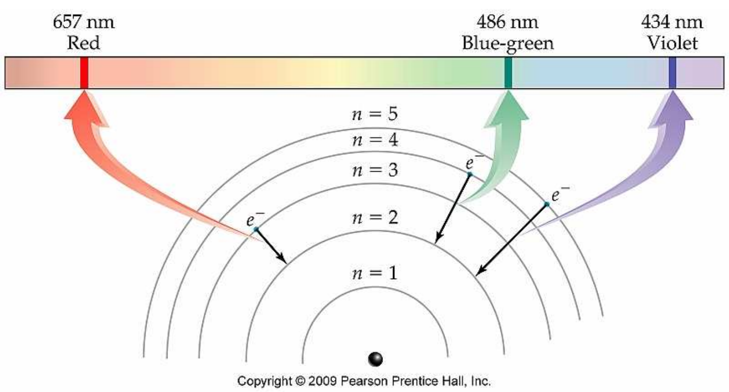
Bohr model

<u>Why</u> are only **<u>certain</u>** colors of light given off by a pure gas sample?

The **<u>Bohr model</u>** can help explain why:

- Electrons orbit in specific fixed distances from nucleus, called **<u>shells</u>**
- Electrons **jump** to higher, more distant orbits when they **absorb** energy (excitation)
- They **drop** down to lower orbits when they **give off** energy, usually as <u>light</u> (relaxation)





Quantum-mechanical model

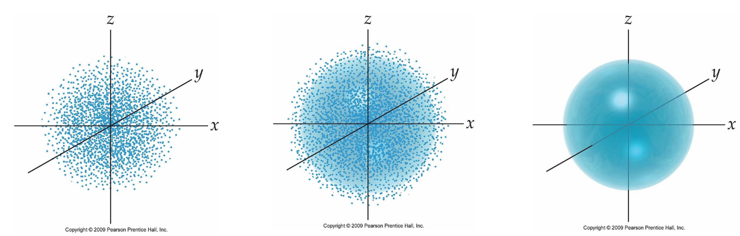
Shortcomings of the Bohr model:

- Can predict the energies of electrons in a hydrogen atom, but not for any other element
- Assumes electrons travel in single circular paths, not likely
- Does not explain periodic table behavior

<u>Quantum mechanical model:</u>

- Assumes electrons can act like particles **<u>or</u>** waves (supported by experimental evidence)
- Exact position or path of a single electron are impossible to predict
- But, you can predict the probability of finding an electron within a certain space:

<u>Orbital</u>: 3-dimensional shape that defines the **probability** of finding an electron



Shells, subshells, and orbitals

The quantum mechanical model has **shells** like the Bohr model

- n = 1, 2, 3, 4, … (principal quantum number)
- As n increases, energy of the electron increases, and **average** distance from the nucleus increases.

But shells alone cannot explain electron behavior. Each new row on the periodic table is a new shell, and the major sections (main group, transition, etc) each have their own **subshell**.

Each shell has n subshells:

Shell	**# subshells**	**Subshell letters**
$n = 1$	1	1s
$n = 2$	2	2s, 2p
$n = 3$	3	3s, 3p, 3d
$n = 4$	4	4s, 4p, 4d, 4f

Electron configurations

Period	H							He
1	($1e^-$)							($2e^-$)
Period	Li	Be	B	C	N	O	F	Ne
2	($3e^-$)	($4e^-$)	($5e^-$)	($6e^-$)	($7e^-$)	($8e^-$)	($9e^-$)	($10e^-$)

If the elements in period 1 have their electrons in the 1s subshell,
the s subshell can hold a maximum of ___ electrons.

Electron configuration: subshell$^{\# e-}$

H: 1s **He**: 1s

Actually, **every s subshell** can hold a max of ___ electrons (including 2s, 3s, 4s, 5s, etc)

In period 2, we fill the 2nd shell (2s and 2p subshells)

Li: **Be**:

When we cross to a new section on the periodic table, a new subshell is being filled. B-Ne fill into the ___ subshell

B: **C**: **N**:

O: **F**: **Ne**:

Electron configurations and the rest of the periodic table

Available subshells to fill:

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d
7s 7p

Subshell	Max # e^-
s	
p	
d	
f	

Na:

Ar:

Ca:

Sc:

Ba:

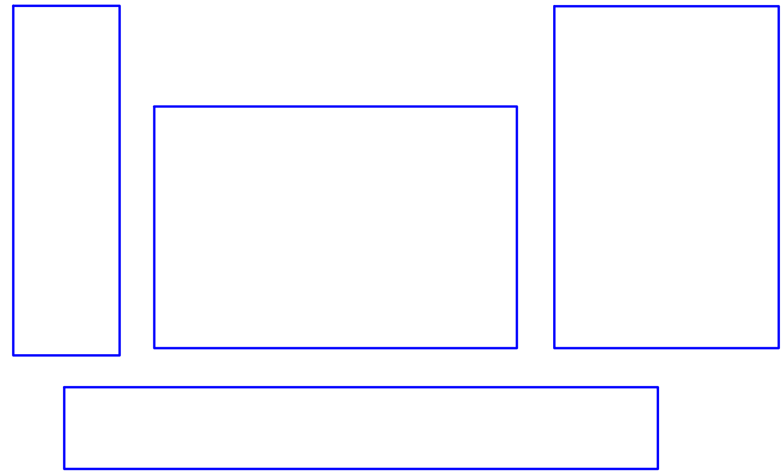
Periodic Table of the Elements

Period	1 IA	2 IIA		3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008																		2 He 4.003
2	3 Li 6.939	4 Be 9.012												5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31												13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08		21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62		39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 *Tc* (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
6	55 Cs 132.90	56 Ba 137.34	*	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	**	103 *Lr* (257)	104 *Rf* (261)	105 *Db* (262)	106 *Sg* (266)	107 *Bh* (264)	108 *Hs* (269)	109 *Mt* (268)	110 *Ds* (271)	111 *Uuu* (272)	112 *Uub* (285)	113 *Uut* (284)	114 *Uuq* (289)	115 *Uup* (288)	116 *Uuh* (292)	117	118

*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 *Pm* (147)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
**	89 Ac (227)	90 Th 232.04	91 Pa (231)	92 U 238.03	93 *Np* (237)	94 *Pu* (242)	95 *Am* (243)	96 *Cm* (247)	97 *Bk* (248)	98 *Cf* (251)	99 *Es* (252)	100 *Fm* (257)	101 *Md* (258)	102 *No* (255)

Reference for elements 106-116: http://www.webelements.com

Sections of the periodic table



Filling order (to check work only!)

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d
7s 7p

W:

Abbreviated electron configurations, valence electrons

Noble gases all have **full subshells**

Abbreviated electron configuration starts with the nearest smaller noble gas in brackets, then continues

W:

Uuh:

Valence electrons: electrons in the outermost **shell** (not subshell)

4s subshell is in the n = 4 shell
5p subshell is in the n =

The largest n number in an electron configuration is the **valence shell**.

Bi:

Br:

Orbital diagrams

Subshell	Max # e^-	# Orbitals
s		1
p		
d		
f		

Recall, an orbital is a ...

If an s subshell contains a single orbital, how many orbitals are in a p subshell?

Every orbital holds a maximum of ___ electrons.

Orbital diagrams:

O:

O^{2-}:

Na:

Na^+: