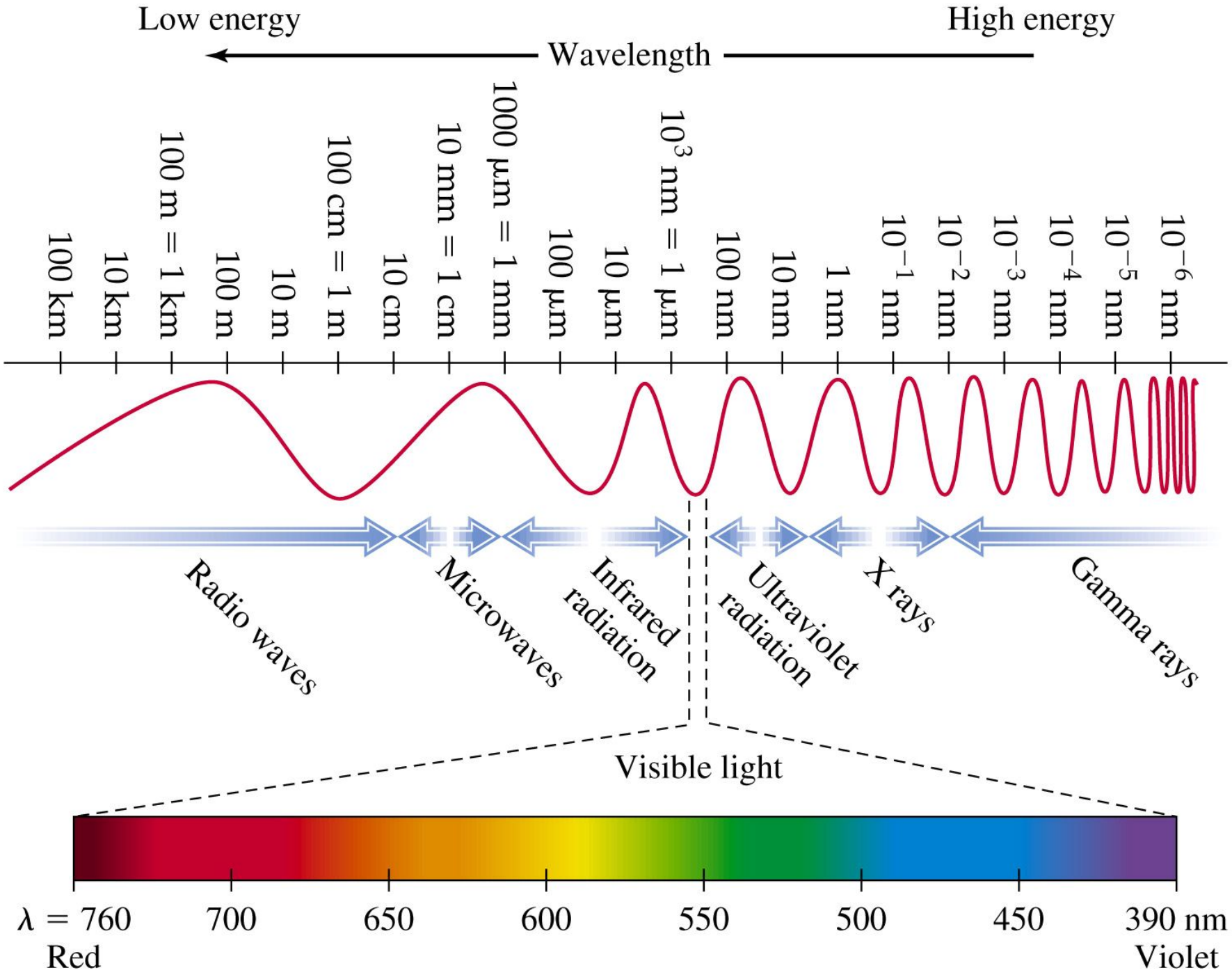
Modern Atomic Theory and the Periodic Table

Chapter 10

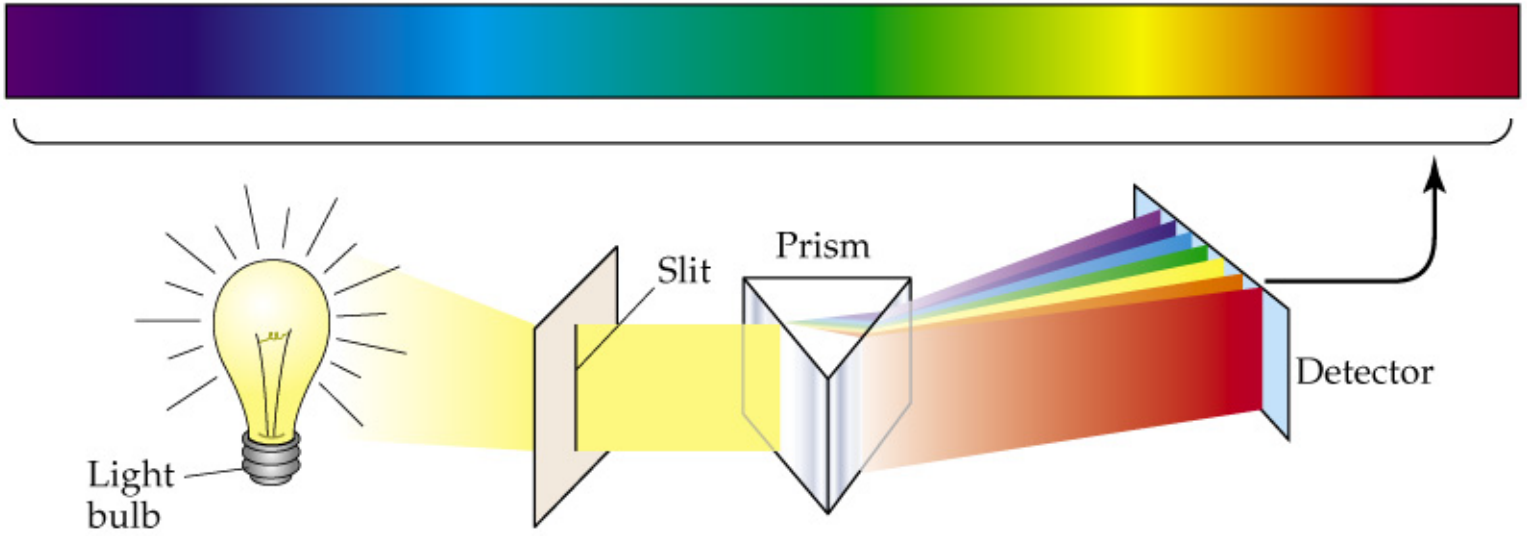

Low energy
High energy
Wavelength
100 km
10 km
100 m = 1 km
100 m
10 m
100 cm = 1 m
10 cm
10 mm = 1 cm
1000 μm = 1 mm
100 μm
10 μm
10^3 nm = 1 μm
100 nm
10 nm
1 nm
10^{-1} nm
10^{-2} nm
10^{-3} nm
10^{-4} nm
10^{-5} nm
10^{-6} nm
Radio waves
Microwaves
Infrared radiation
Ultraviolet radiation
X rays
Gamma rays
Visible light
λ = 760
Red
700
650
600
550
500
450
390 nm
Violet

Experiment 1

- Add an elemental gas to a cathode ray tube and get ----- colors
  - Hydrogen (H_2) purple blue
  - Neon (Ne) red orange
  - Helium (He) yellow pink
  - Argon (Ar) lavender
  - Xenon (Xe) blue

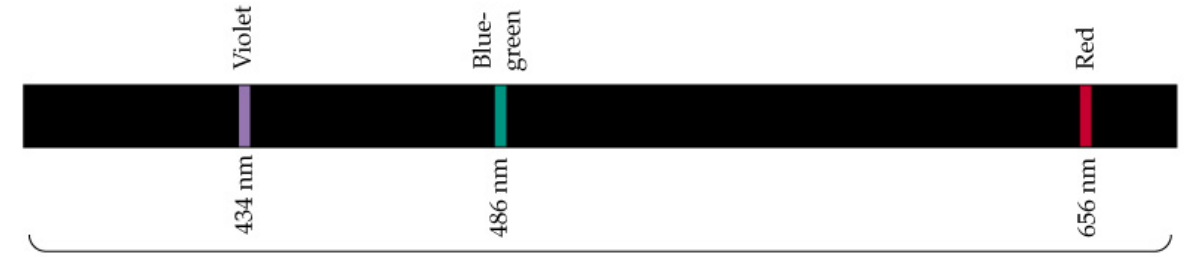
Experiment 2

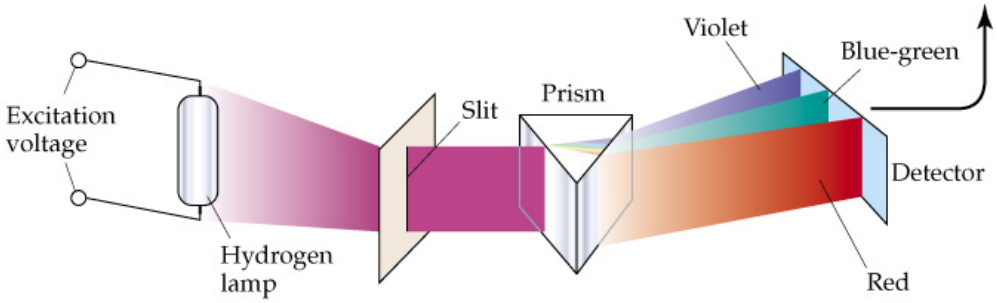
- Shine white light through a prism -- rainbow
- A prism separates light of different wavelength, each color represents a different wavelength.



Experiment 3

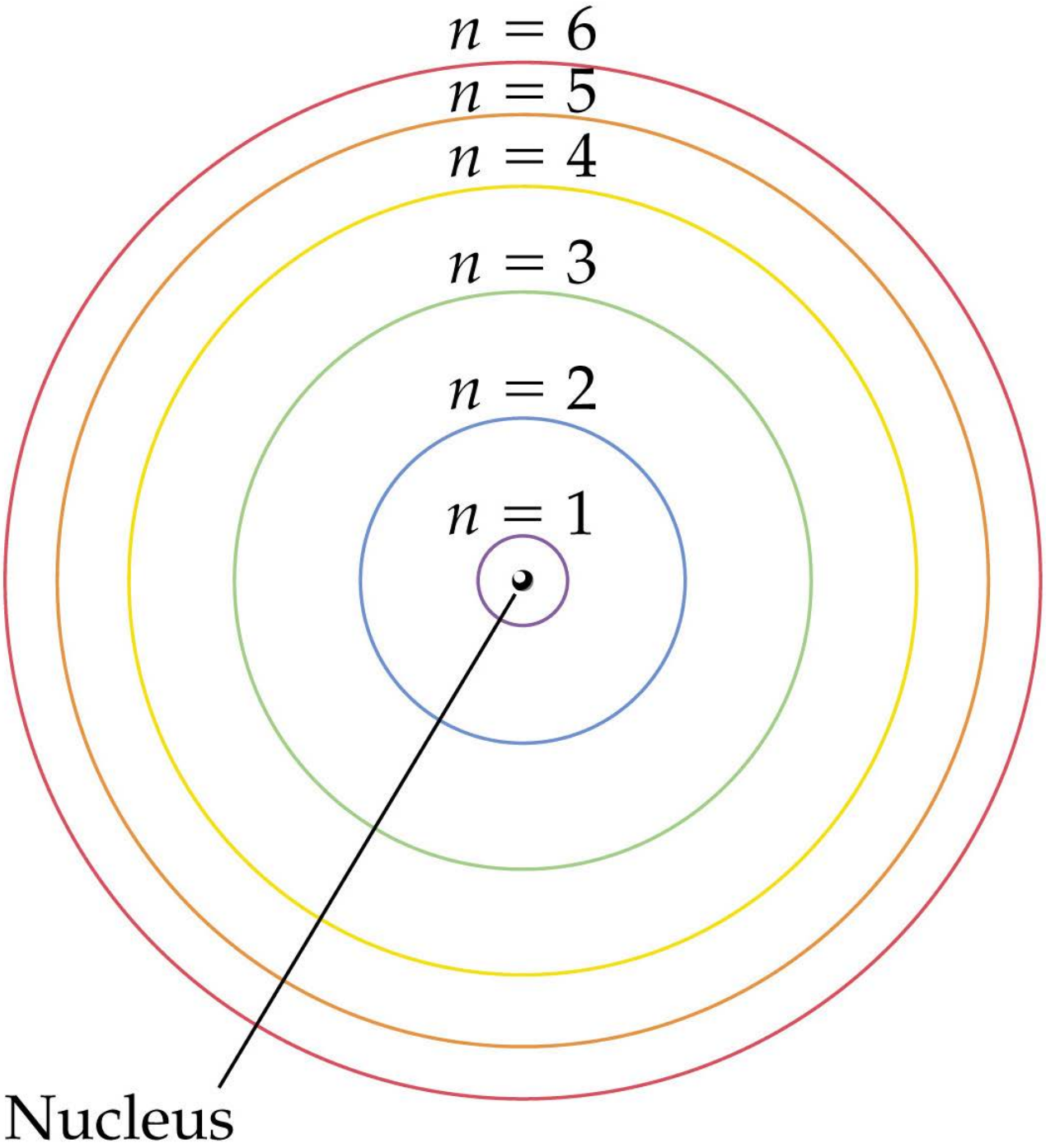
- Shine the colored light from our gas discharge tubes through a prism ⟶ get distinct bands of color (light).
- http://jersey.uoregon.edu/vlab/elements/Elements.html

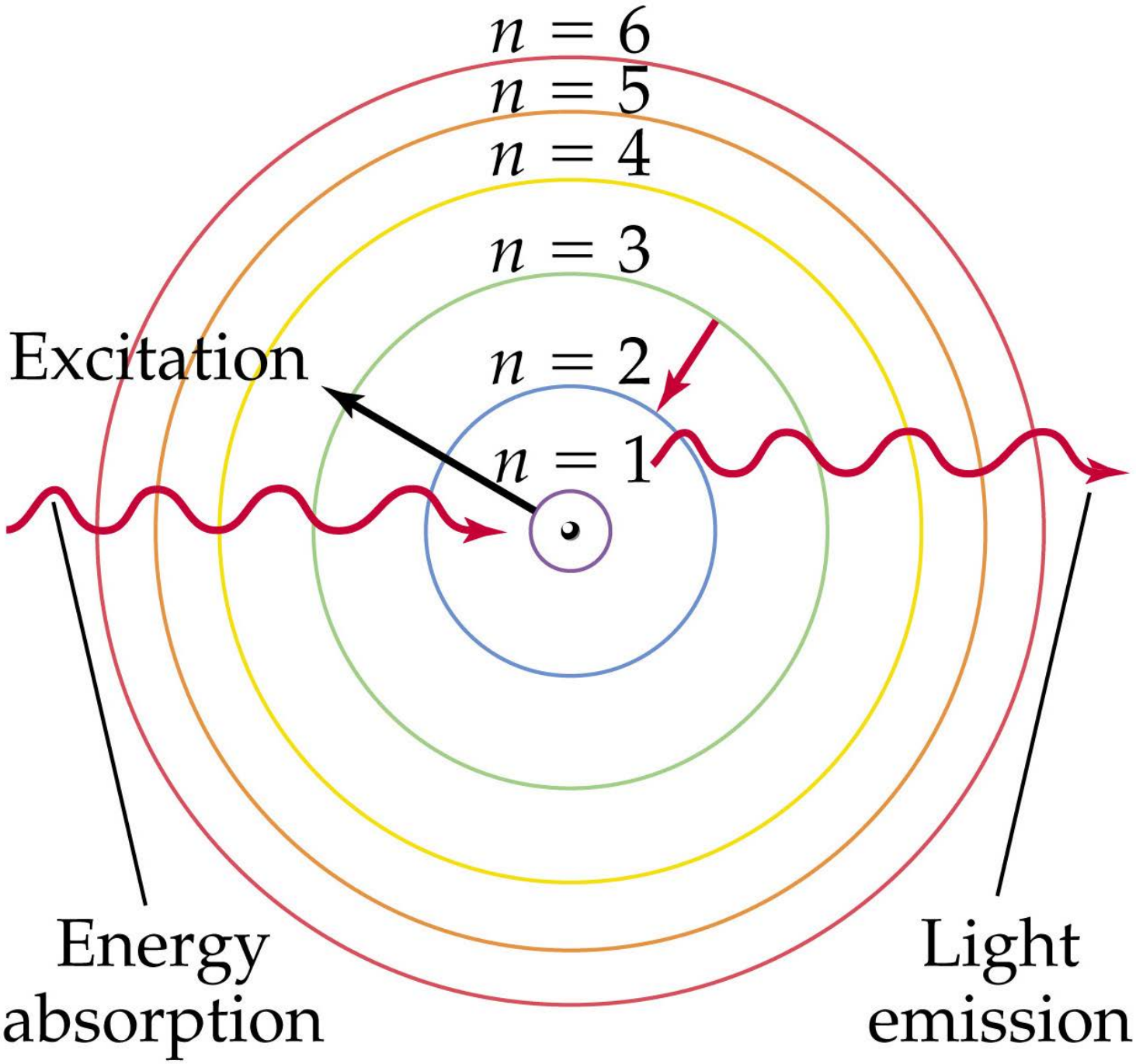


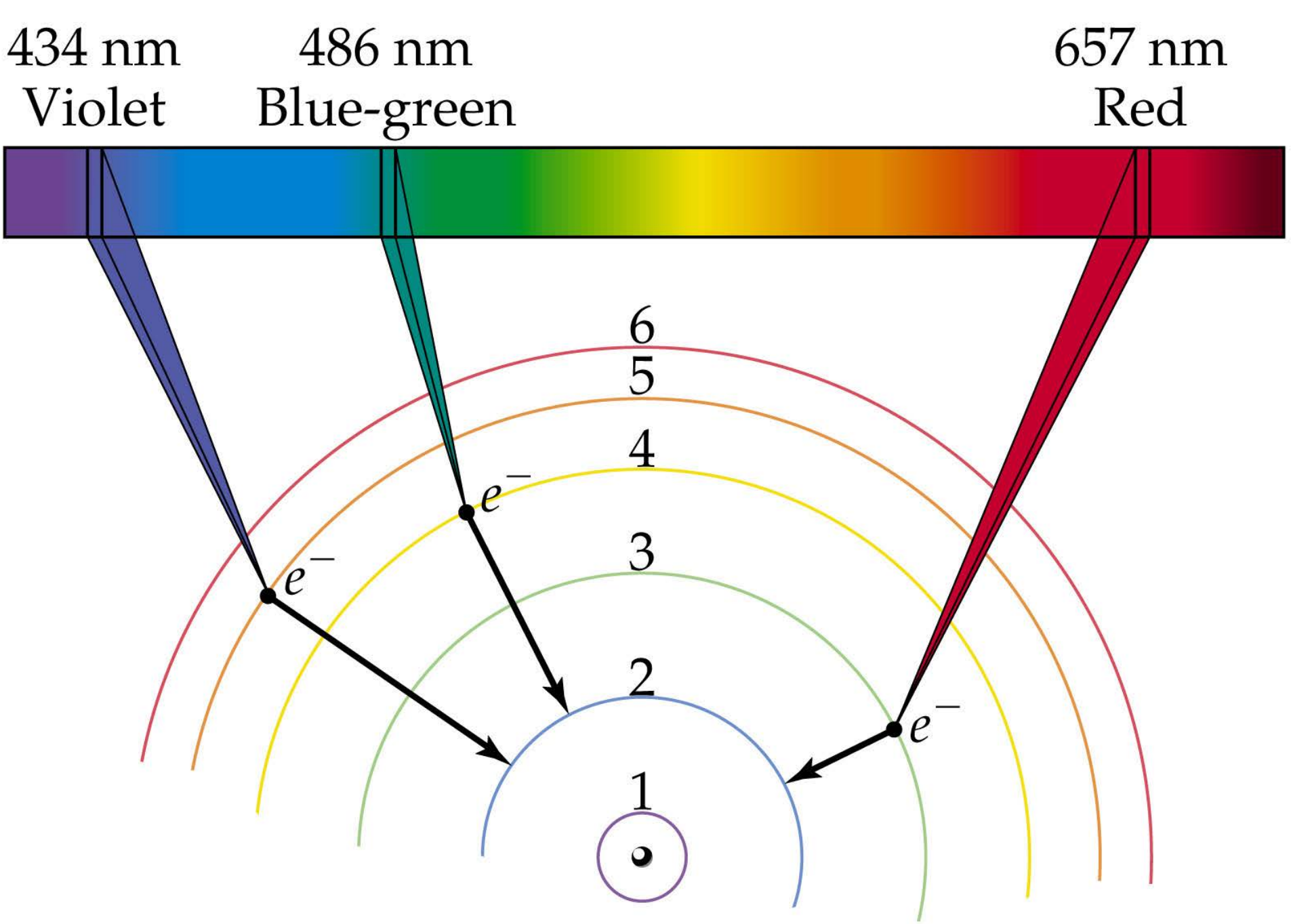


Bohr model of the atom

- Electrons orbit the nucleus like little planets (planetary model) each with its own energy. Electrons can move from one energy level to another by absorbing or releasing energy.
- *Energy is released as radiant energy or light.*

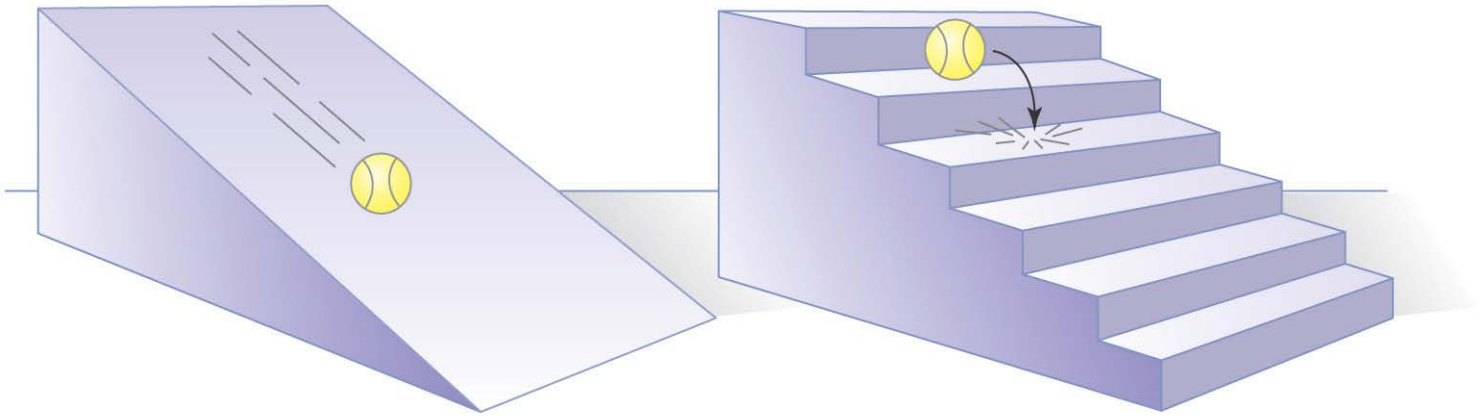

$n = 6$
$n = 5$
$n = 4$
$n = 3$
$n = 2$
$n = 1$
Nucleus


$n = 6$
$n = 5$
$n = 4$
$n = 3$
$n = 2$
$n = 1$
Excitation
Energy absorption
Light emission


434 nm
Violet
486 nm
Blue-green
657 nm
Red
6
5
4
3
2
1
e⁻
e⁻
e⁻

Quantum of energy

- the smallest quantity of energy that can be emitted (or absorbed) in the form of electromagnetic radiation.



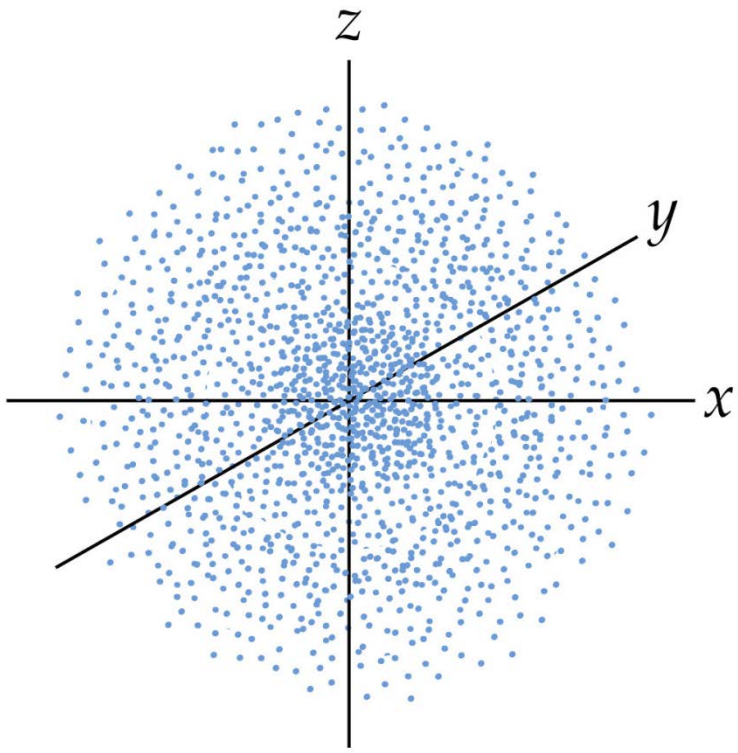
Schrodinger's quantum mechanical model of the atom

- $E\psi = H\psi$

- ψ is the wave function or orbital
- ψ^2 (probability function) represents the probability of finding an electron at any given position in an atom.

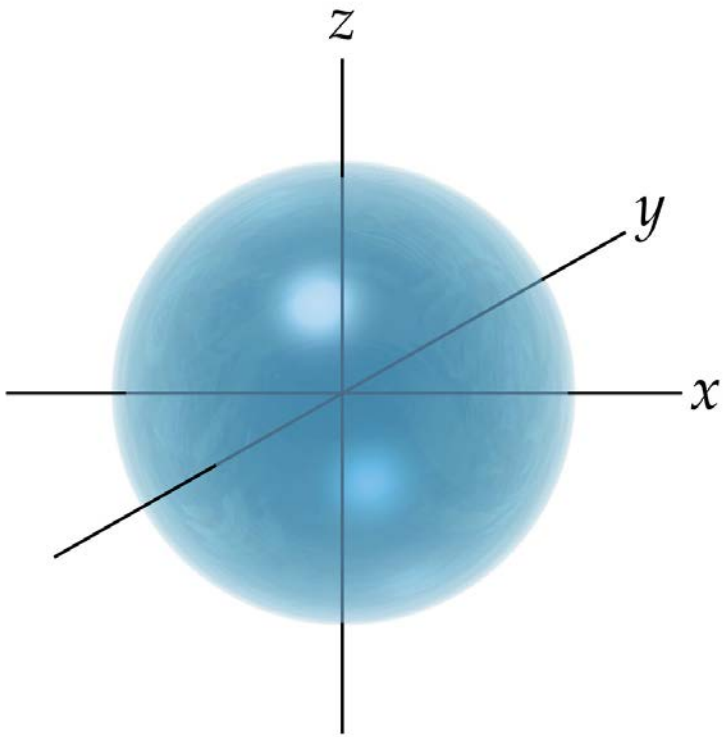
s orbitals

- spherical in shape



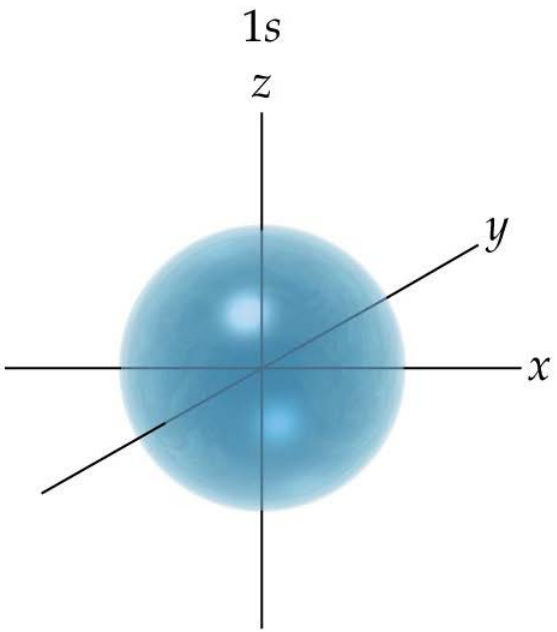
(a)

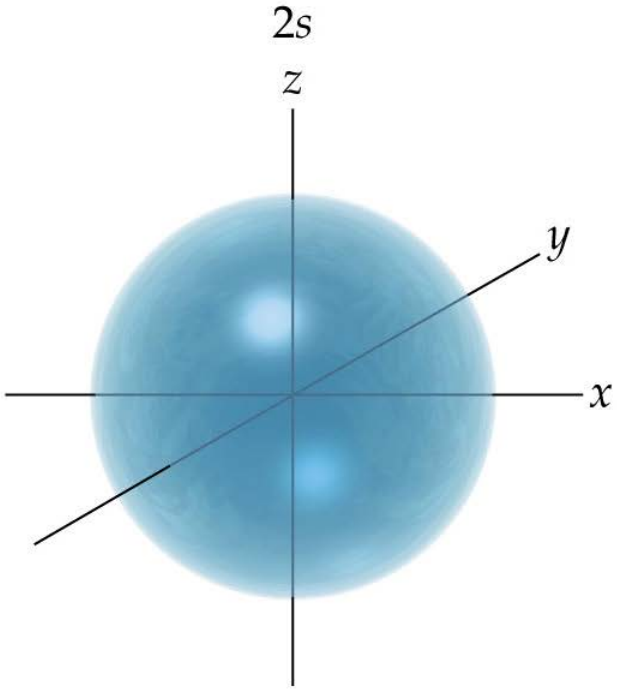
Electron density map



(b)

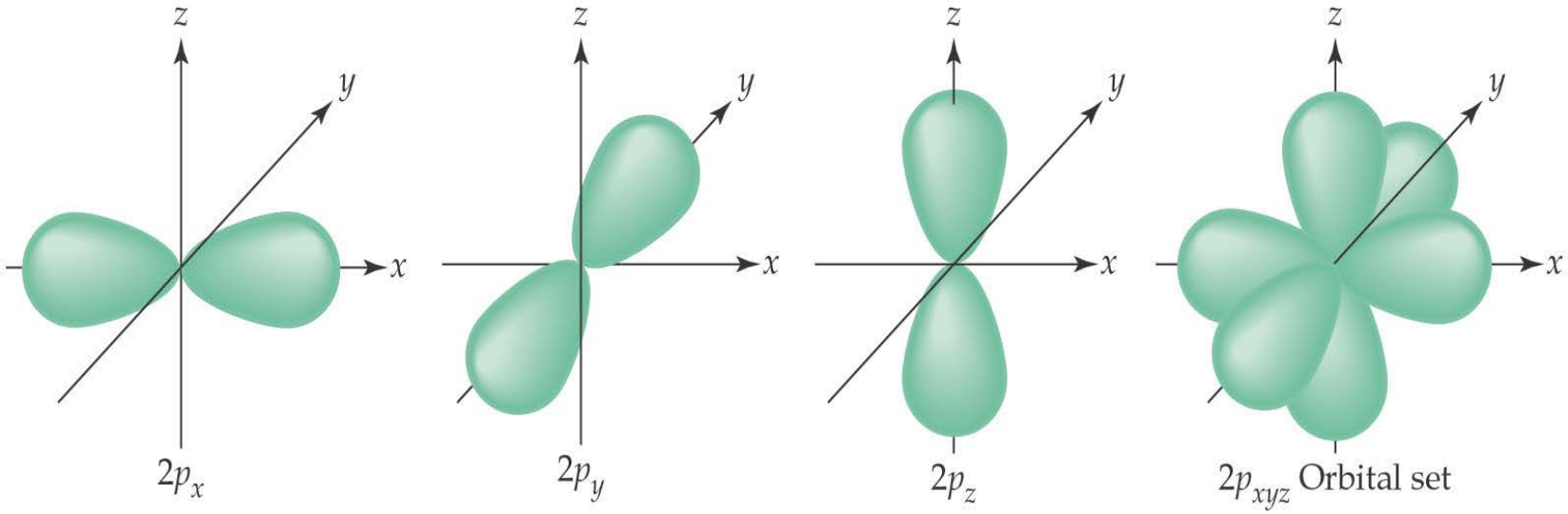
Representation of volume of orbital


1s
z
y
x

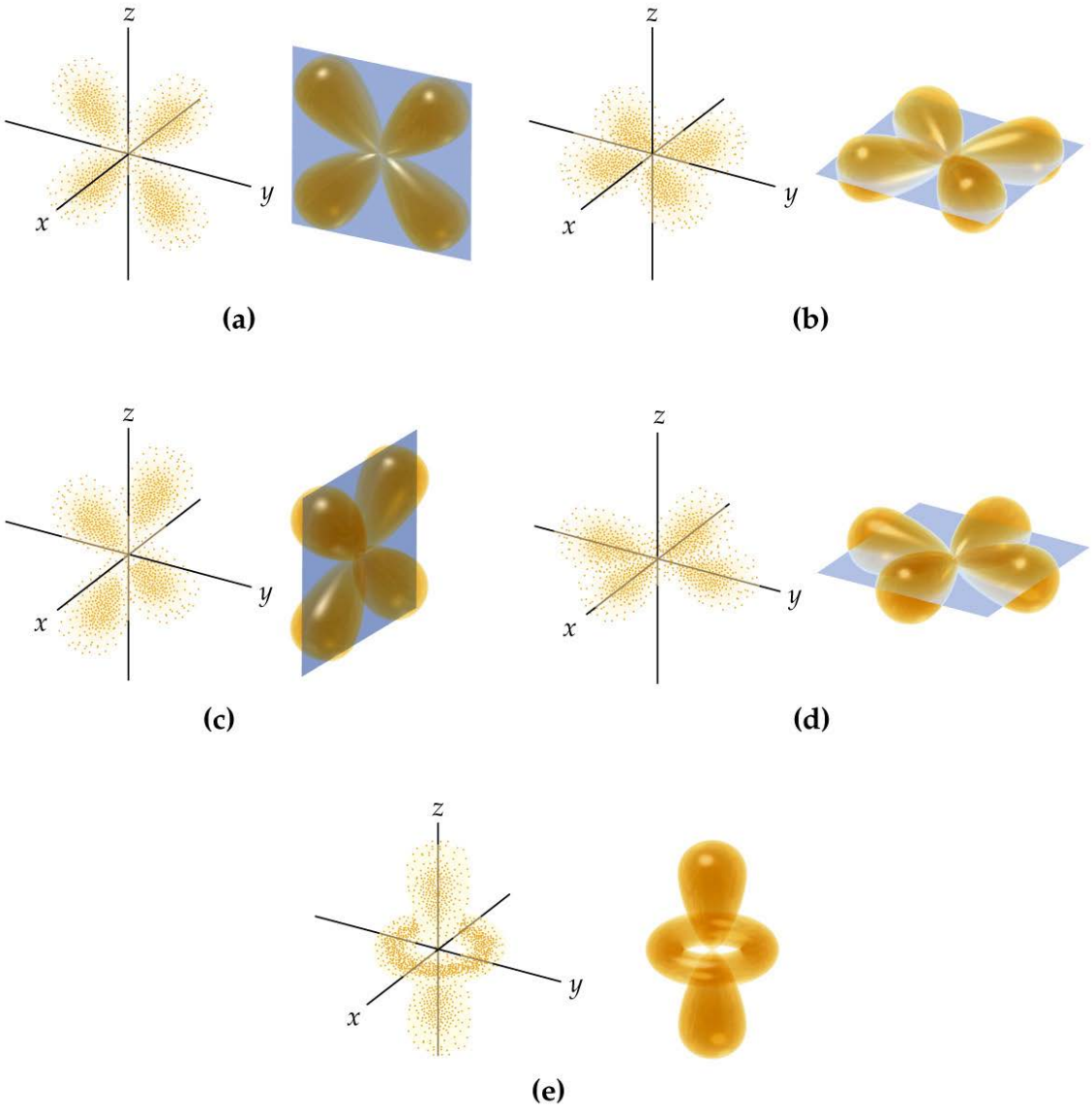

2s
z
y
x

p orbitals

- dumbbell shaped
- three different spatial orientations



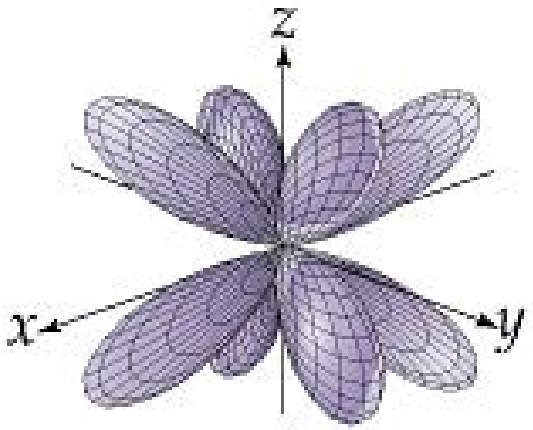
d orbitals



f orbitals

Complex shapes

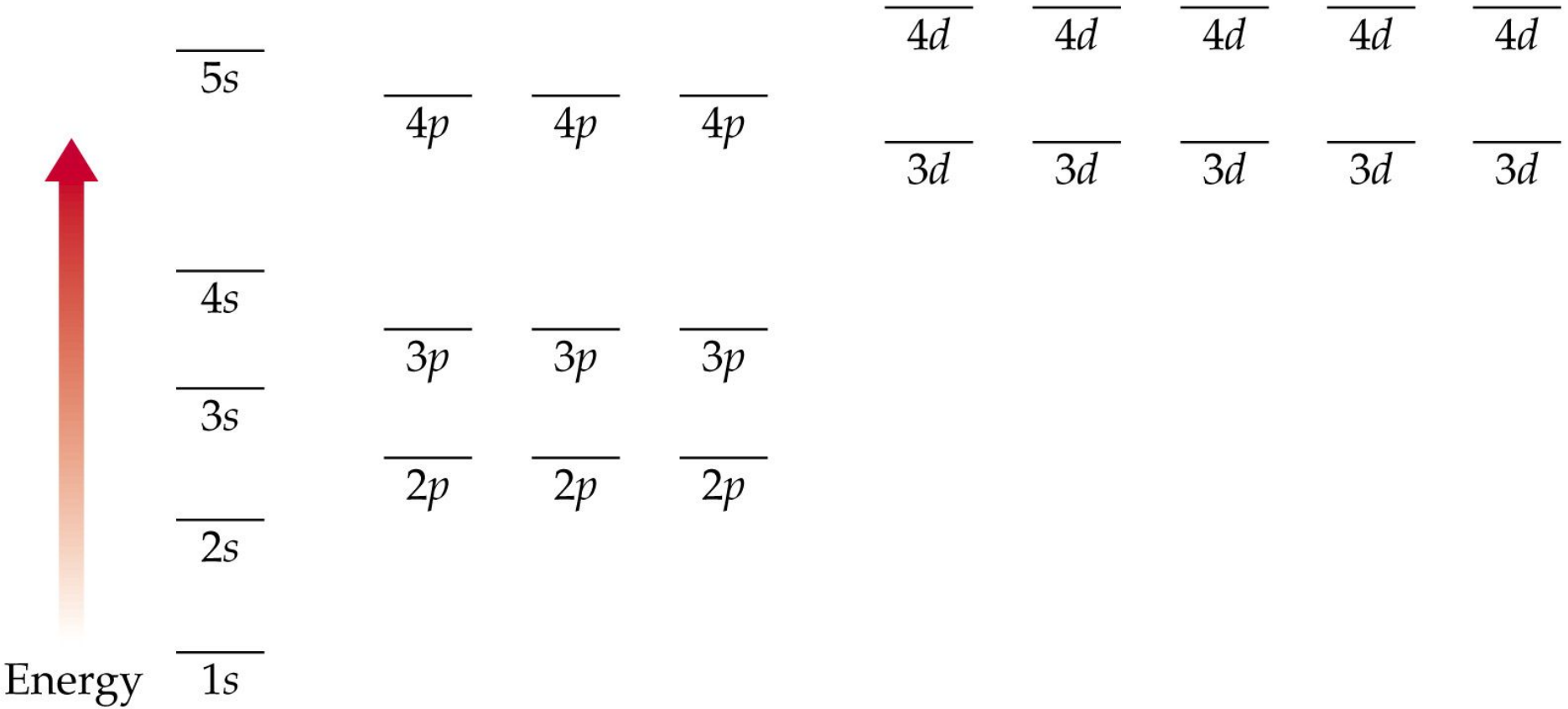
7 different orientations

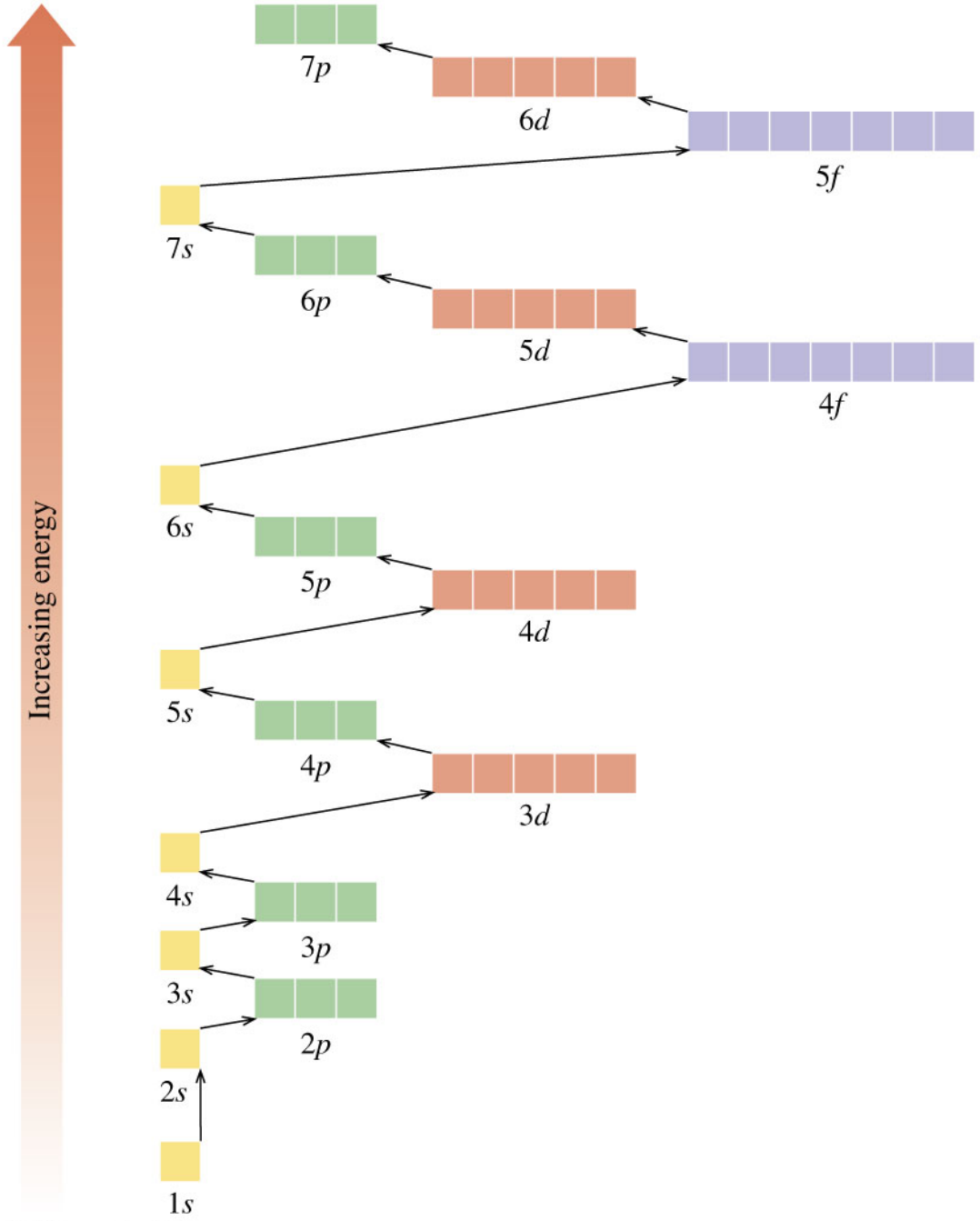


fxyz
(f)

Shell	# of subshells	Letters specifying subshells
$n = 4$	4	s p d f
$n = 3$	3	s p d
$n = 2$	2	s p
$n = 1$	1	s

Energy ordering of orbitals for multi-electron atoms



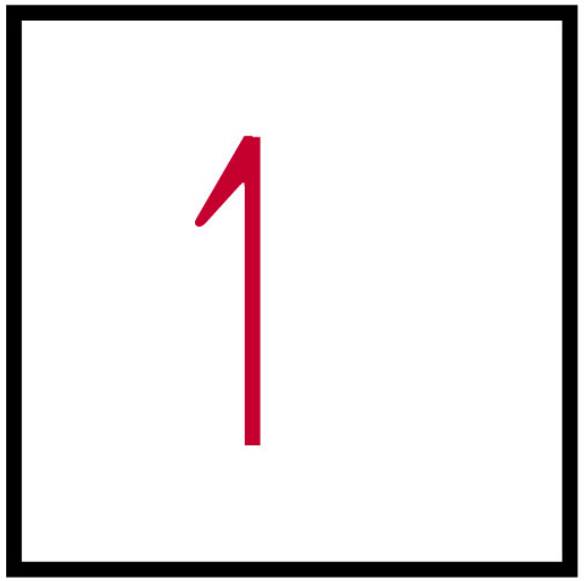


Electronic configuration of the atoms

- Rules for filling orbitals

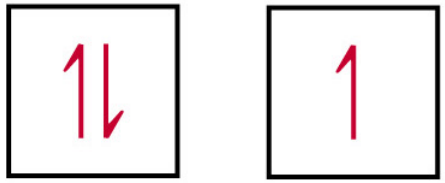
- 1. Lowest energy orbitals are filled first.
- 2. Only 2 electrons (of different spin) allowed in each orbital.
- 3. When sublevels are filling, fill each orbital with 1 electron of same spin and then pair openly when necessary

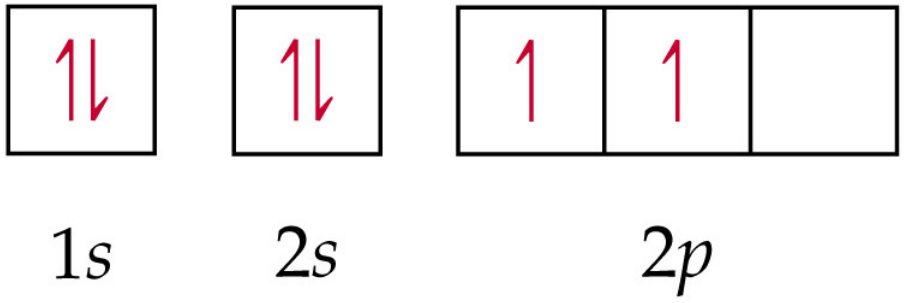
H

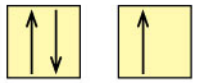
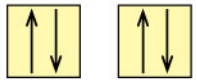
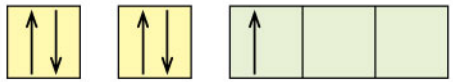
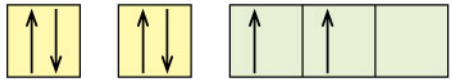
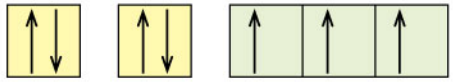
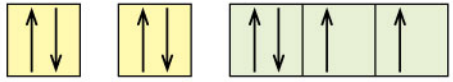
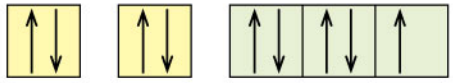
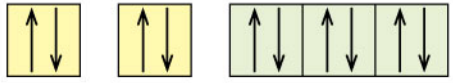


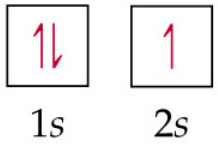
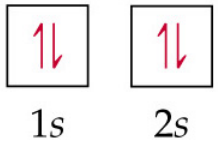
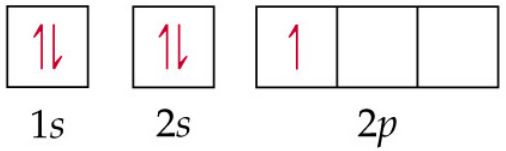
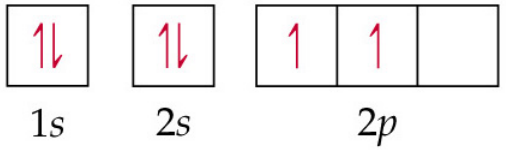
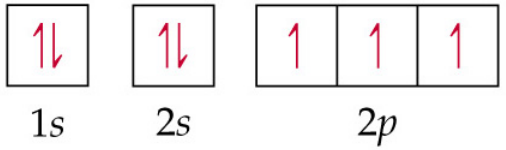
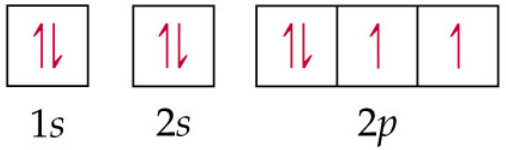
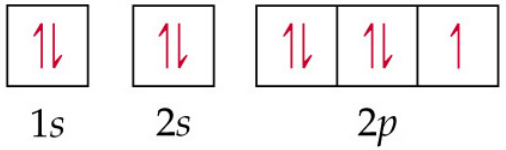
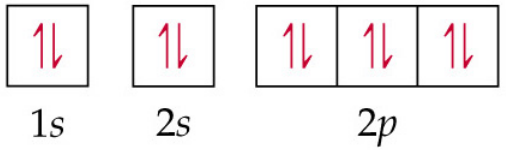
$1s$

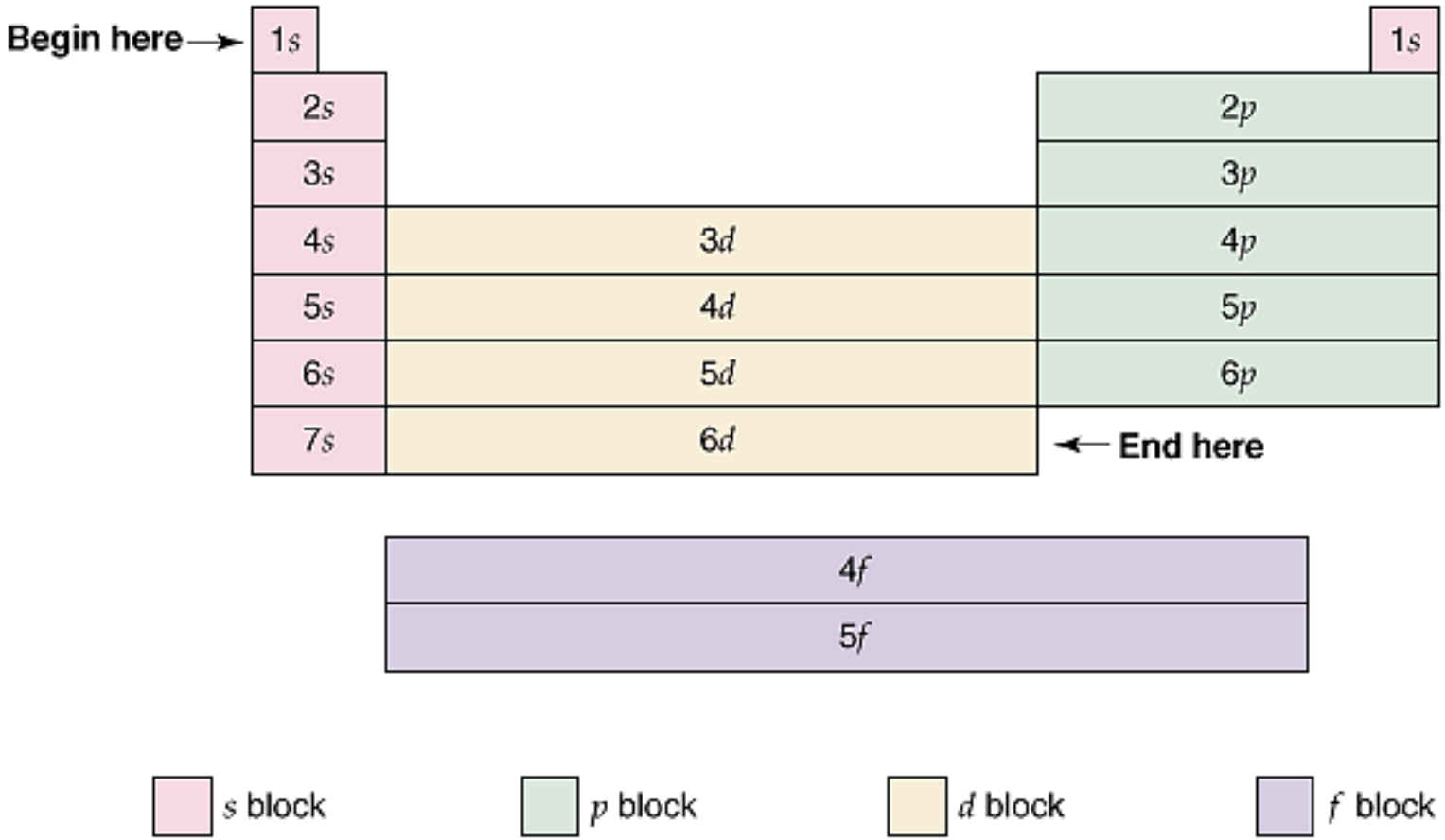
	Electron configuration	Orbital diagram
He	$1s^2$	

Electron configuration		Orbital diagram
Li	$1s^2 2s^1$	

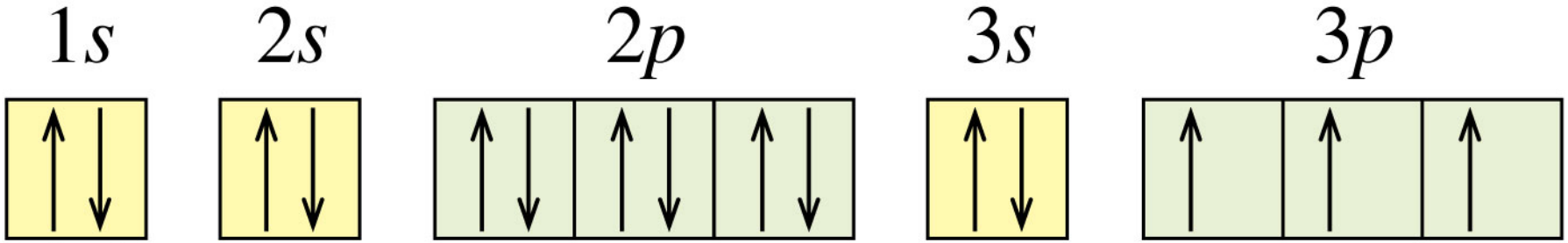
Electron configuration		Orbital diagram
C	$1s^2 2s^2 2p^2$	

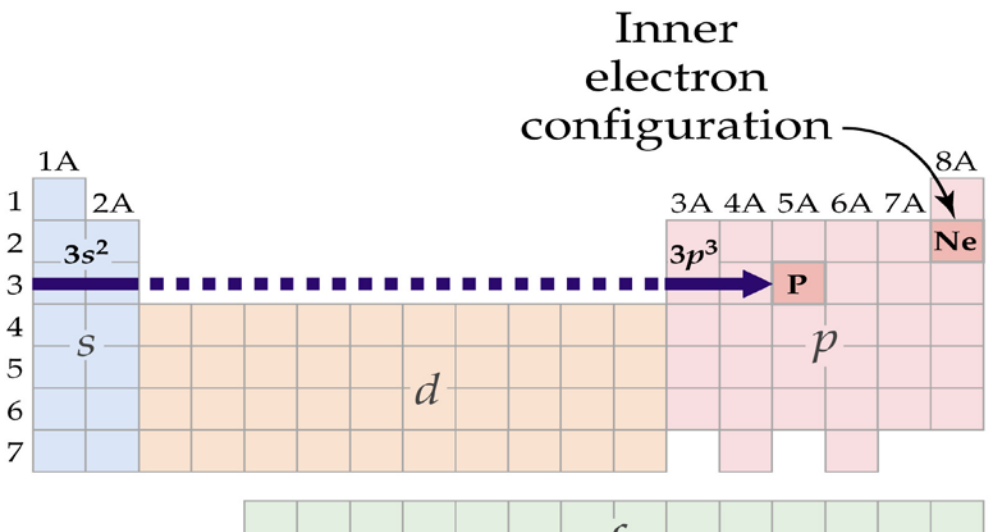
Atomic Number	Element	Orbital Diagram	Electron Configuration	Abbreviated Electron Configuration
3	Li		$1s^2 2s^1$	$[He]2s^1$
4	Be		$1s^2 2s^2$	$[He]2s^2$
5	B		$1s^2 2s^2 2p^1$	$[He]2s^2 2p^1$
6	C		$1s^2 2s^2 2p^2$	$[He]2s^2 2p^2$
7	N		$1s^2 2s^2 2p^3$	$[He]2s^2 2p^3$
8	O		$1s^2 2s^2 2p^4$	$[He]2s^2 2p^4$
9	F		$1s^2 2s^2 2p^5$	$[He]2s^2 2p^5$
10	Ne		$1s^2 2s^2 2p^6$	$[He]2s^2 2p^6$

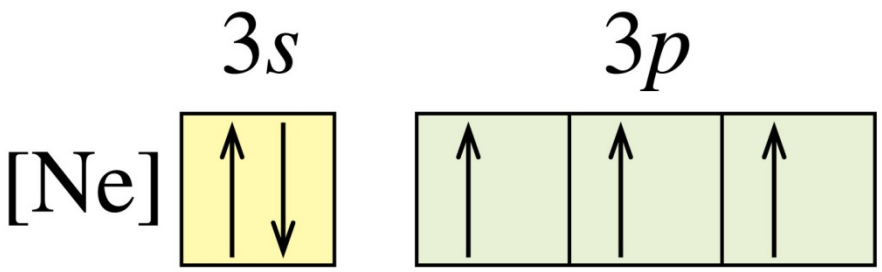
Symbol (#e⁻)	Electron configuration	Orbital diagram
Li (3)	$1s^2 2s^1$	
Be (4)	$1s^2 2s^2$	
B (5)	$1s^2 2s^2 2p^1$	
C (6)	$1s^2 2s^2 2p^2$	
N (7)	$1s^2 2s^2 2p^3$	
O (8)	$1s^2 2s^2 2p^4$	
F (9)	$1s^2 2s^2 2p^5$	
Ne (10)	$1s^2 2s^2 2p^6$	

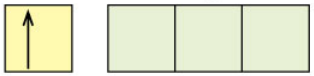
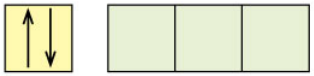
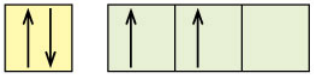
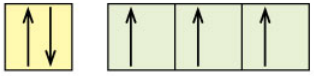
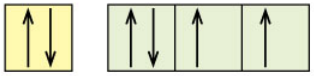
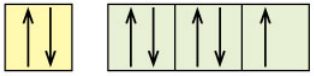
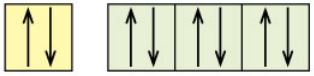

Begin here
1s
2s
3s
4s
5s
6s
7s
3d
4d
5d
6d
1s
2p
3p
4p
5p
6p
End here
4f
5f
s block
p block
d block
f block

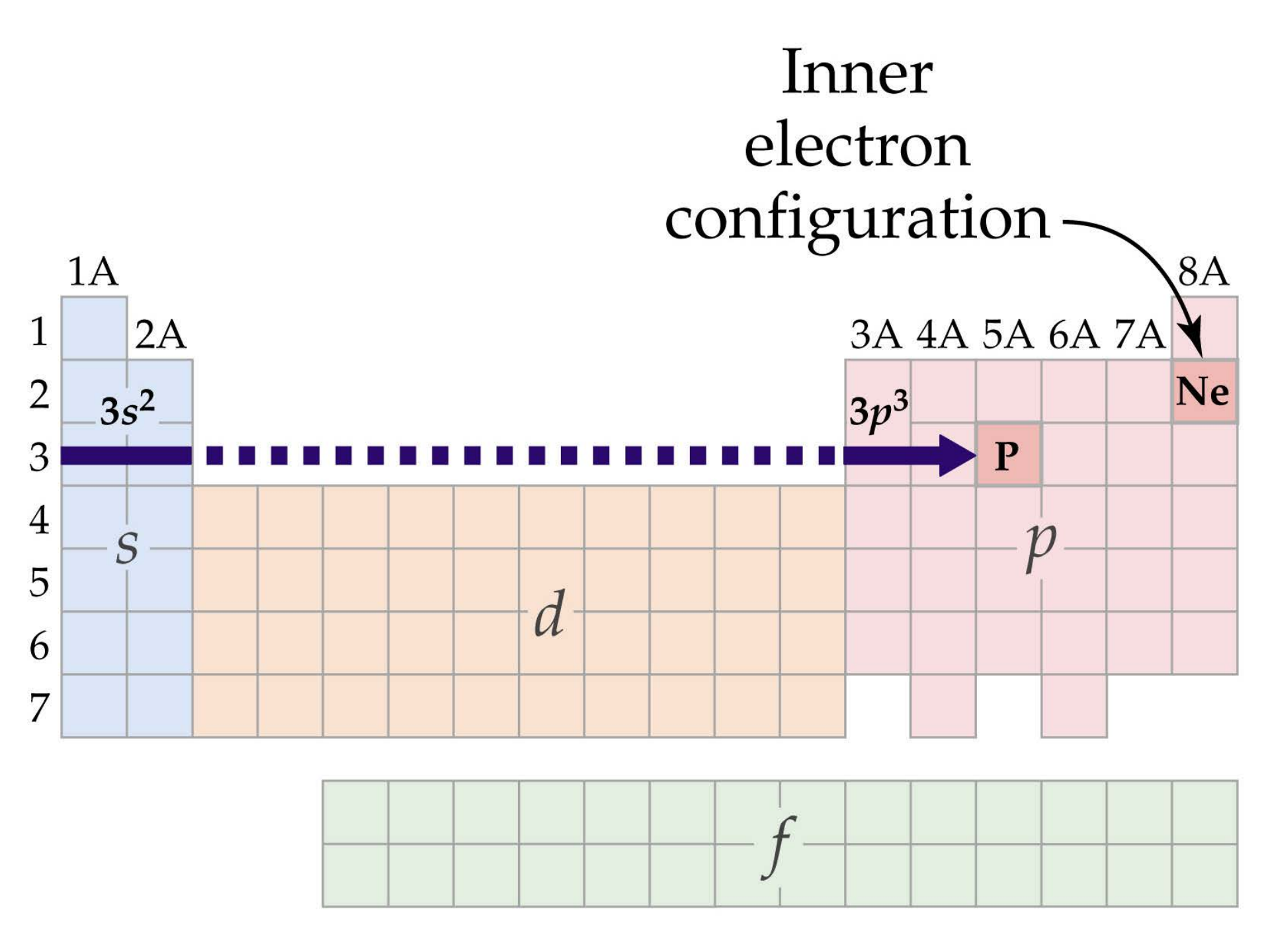
Phosphorous







Atomic Number	Element	Orbital Diagram (3*s* and 3*p* orbitals only)	Electron Configuration	Abbreviated Electron Configuration
		3*s* 3*p*		
11	Na	[Ne] 	$1s^2 2s^2 2p^6 3s^1$	[Ne]$3s^1$
12	Mg	[Ne] 	$1s^2 2s^2 2p^6 3s^2$	[Ne]$3s^2$
13	Al	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^1$	[Ne]$3s^2 3p^1$
14	Si	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^2$	[Ne]$3s^2 3p^2$
15	P	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^3$	[Ne]$3s^2 3p^3$
16	S	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^4$	[Ne]$3s^2 3p^4$
17	Cl	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^5$	[Ne]$3s^2 3p^5$
18	Ar	[Ne] 	$1s^2 2s^2 2p^6 3s^2 3p^6$	[Ne]$3s^2 3p^6$


Inner
electron
configuration
1A
8A
1
2A
3A 4A 5A 6A 7A
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3
4
5
6
7
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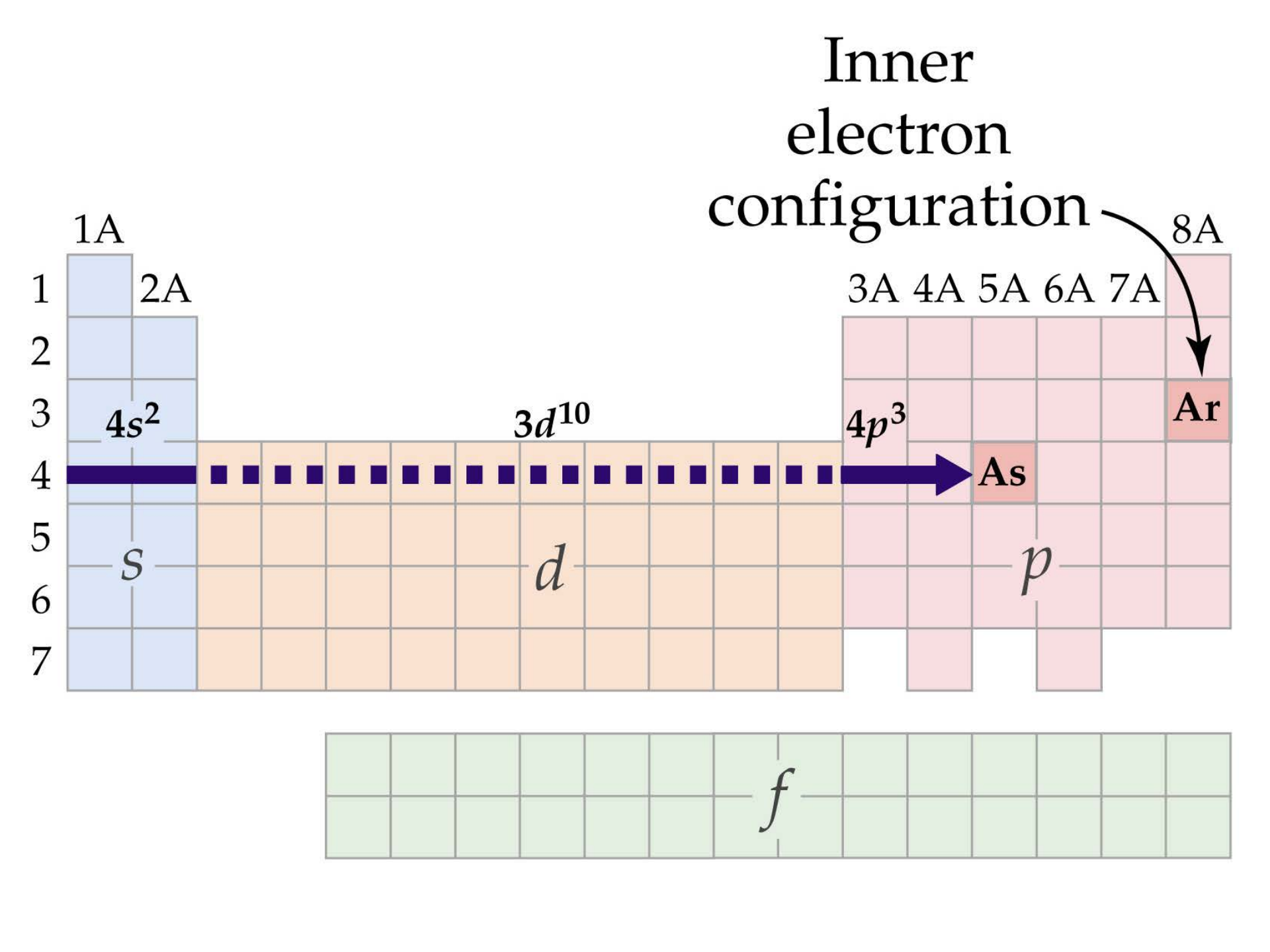
$3p^3$
Ne
P
s
d
p
f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8A
1
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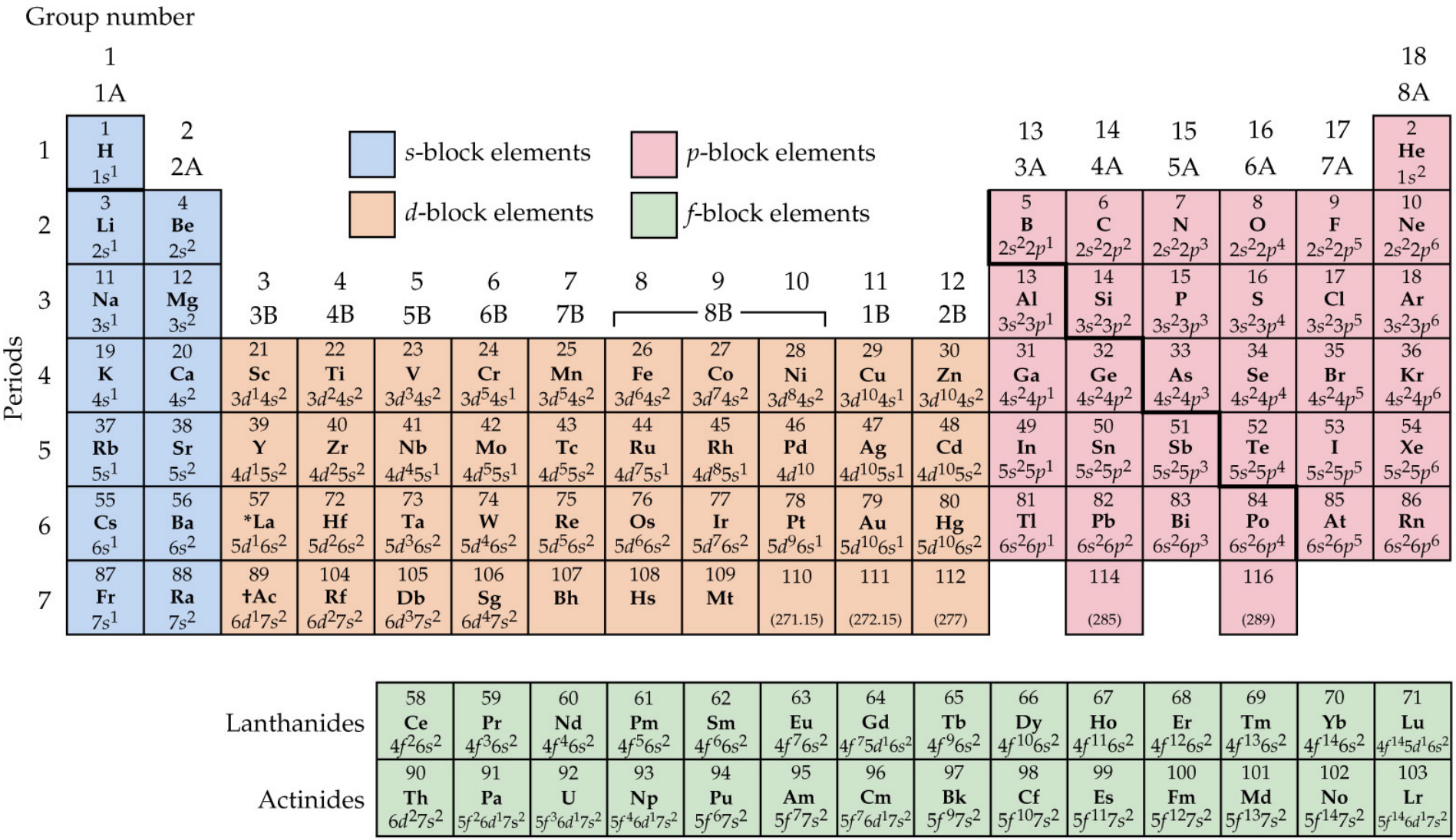
2
3
4
5
6
7
$4s^2$
$3d^{10}$
$4p^3$
Ar
As
s
d
p
f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1
1A
18
8A
Periods
s-block elements
p-block elements
d-block elements
f-block elements
2
2A
13
3A
14
4A
15
5A
16
6A
17
7A
3
3B
4
4B
5
5B
6
6B
7
7B
8
9
8B
10
11
1B
12
2B
1 H 1s1
2 He 1s2
3 Li 2s1
4 Be 2s2
5 B 2s22p1
6 C 2s22p2
7 N 2s22p3
8 O 2s22p4
9 F 2s22p5
10 Ne 2s22p6
11 Na 3s1
12 Mg 3s2
13 Al 3s23p1
14 Si 3s23p2
15 P 3s23p3
16 S 3s23p4
17 Cl 3s23p5
18 Ar 3s23p6
19 K 4s1
20 Ca 4s2
21 Sc 3d14s2
22 Ti 3d24s2
23 V 3d34s2
24 Cr 3d54s1
25 Mn 3d54s2
26 Fe 3d64s2
27 Co 3d74s2
28 Ni 3d84s2
29 Cu 3d104s1
30 Zn 3d104s2
31 Ga 4s24p1
32 Ge 4s24p2
33 As 4s24p3
34 Se 4s24p4
35 Br 4s24p5
36 Kr 4s24p6
37 Rb 5s1
38 Sr 5s2
39 Y 4d15s2
40 Zr 4d25s2
41 Nb 4d45s1
42 Mo 4d55s1
43 Tc 4d55s2
44 Ru 4d75s1
45 Rh 4d85s1
46 Pd 4d10
47 Ag 4d105s1
48 Cd 4d105s2
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50 Sn 5s25p2
51 Sb 5s25p3
52 Te 5s25p4
53 I 5s25p5
54 Xe 5s25p6
55 Cs 6s1
56 Ba 6s2
57 *La 5d16s2
72 Hf 5d26s2
73 Ta 5d36s2
74 W 5d46s2
75 Re 5d56s2
76 Os 5d66s2
77 Ir 5d76s2
78 Pt 5d96s1
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82 Pb 6s26p2
83 Bi 6s26p3
84 Po 6s26p4
85 At 6s26p5
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106 Sg 6d47s2
107 Bh
108 Hs
109 Mt
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112 (277)
114 (285)
116 (289)
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59 Pr 4f36s2
60 Nd 4f46s2
61 Pm 4f56s2
62 Sm 4f66s2
63 Eu 4f76s2
64 Gd 4f75d16s2
65 Tb 4f96s2
66 Dy 4f106s2
67 Ho 4f116s2
68 Er 4f126s2
69 Tm 4f136s2
70 Yb 4f146s2
71 Lu 4f145d16s2
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90 Th 6d27s2
91 Pa 5f26d17s2
92 U 5f36d17s2
93 Np 5f46d17s2
94 Pu 5f67s2
95 Am 5f77s2
96 Cm 5f76d17s2
97 Bk 5f97s2
98 Cf 5f107s2
99 Es 5f117s2
100 Fm 5f127s2
101 Md 5f137s2
102 No 5f147s2
103 Lr 5f146d17s2

Descriptive Chemistry

- Alkali Metals
- Alkaline Earths
- Aluminum
- Halogens
- Nobel Gases

Mendeleev's Original Periodic Table

H = 1							
Li = 7	Be = 9.4		B = 11	C = 12	N = 14	O = 16	F = 19
Na = 23	Mg = 24		Al = 27.3	Si = 28	P = 31	S = 32	Cl = 35.5
K = 39	Ca = 40	?, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn	? = 68	? = 72	As = 75	Se = 78	Br = 80

Gallium (eka-aluminum)

	Mendeleev's predicted properties	Actual properties
Atomic mass	About 68 amu	69.72 amu
Melting point	Low	29.8 °C
Density	5.9 g/cm^3	5.90 g/cm^3
Formula of oxide	X_2O_3	Ga_2O_3
Formula of chloride	XCl_3	$GaCl_3$

Germanium (eka-silicon)

	Mendeleev's predicted properties	Actual properties
Atomic mass	About 72 amu	72.64 amu
Density	5.5 g/cm^3	5.35 g/cm^3
Formula of oxide	XO_2	GeO_2
Formula of chloride	XCl_4	$GeCl_4$

Reactions of the Alkali Metals with Water

Lithium

Sodium

Potassium

TABLE 8.2 Properties of the Alkali Metals*

Element	Electron Configuration	Atomic Radius (pm)	IE_1 (kJ/mol)	Density at 25 °C (g/cm^3)	Melting Point (°C)
Li	$[He]\,2s^1$	152	520	0.535	181
Na	$[Ne]\,3s^1$	186	496	0.968	102
K	$[Ar]\,4s^1$	227	419	0.856	98
Rb	$[Kr]\,5s^1$	248	403	1.532	39
Cs	$[Xe]\,6s^1$	265	376	1.879	29

TABLE 8.3 Properites of the Halogens*

Element	Electron Configuration	Atomic Radius (pm)	EA (kJ/mol)	Melting Point (°C)	Boiling Point (°C)	Density of Liquid (g/cm^3)
F	$[He]\,2s^2 2p^5$	72	−328	−219	−188	1.51
Cl	$[Ne]\,3s^2 3p^5$	99	−349	−101	−34	2.03
Br	$[Ar]\,4s^2 4p^5$	114	−325	−7	59	3.19
I	$[Kr]\,5s^2 4p^5$	133	−295	114	184	3.96

TABLE 8.4 Properites of the Noble Gases*

Element	Electron Configuration	Atomic Radius (pm)**	IE_1 (kJ/mol)	Boiling Point (K)	Density of Gas (g/L at STP)
He	$1s^2$	32	2372	4.2	0.18
Ne	$[He]\,2s^2 2p^6$	70	2081	27.1	0.90
Ar	$[Ne]\,3s^2 3p^6$	98	1521	87.3	1.78
Kr	$[Ar]\,4s^2 4p^6$	112	1351	119.9	3.74
Xe	$[Kr]\,5s^2 5p^6$	130	1170	165.1	5.86

*Radon is omitted because it is radioactive.

**Since only the heavier noble gases form compounds, covalent radii for the smaller noble gases are estimated.