

Ch04

Flavors of the Atom

Not every atom is the same.

Differences between ions, elements, and isotopes.

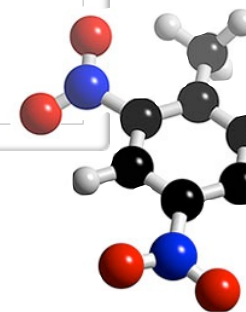


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Flavors of the Atom



Organizing the Elements

- ▶ Chemical Symbols
- ▶ Periodicity

▶ The Periodic Table

- ▶ The First Periodic Table
- ▶ Metals & Non-metals
 - ▶ Metallic Properties
- ▶ Common Ions, Predicting Charge
- ▶ Representative Elements
- ▶ Periods, Groups & Families
 - ▶ Group Numbers
 - ▶ Family Names
- ▶ Official Class Periodic Table

1 H								2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca							

▶ Pieces of the atom

– electrons, protons, neutrons

- ▶ Ions differ in electron count
- ▶ Elements have different proton counts
- ▶ Isotopes differ in total mass (because they differ in number of neutrons)
 - ▶ Isotopic Notation

¹⁷₈O

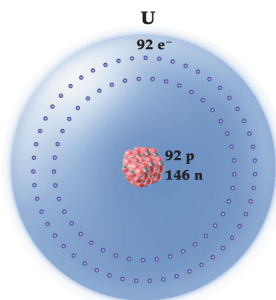
▶ Regions of the atom

- ▶ Electron Shells
 - ▶ Finding Electron Shells
 - ▶ Valence Electrons
 - ▶ Lewis Symbols



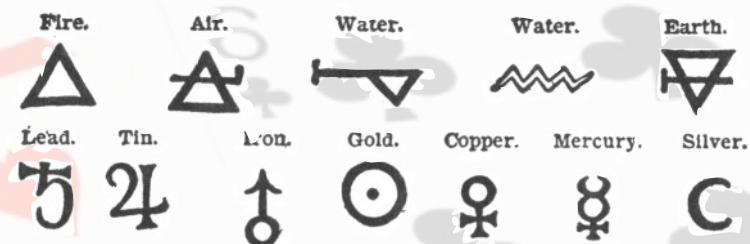
▶ Trends

- ▶ in Size
- ▶ in Ionization Energy



Organizing the Elements

- ▶ Finding new pure substances with useful and interesting properties made chemistry a valuable science.
- ▶ As chemists sought out more pure substances and documented their properties they explored how those substances could be made or decomposed.
- ▶ They quickly realized that every substance they discovered could be decomposed into one of a handful of unique substances that could not themselves be decomposed.
- ▶ They called those handful of cornerstone substances elements.
- ▶ Between the early 1700's and mid 1800's chemists sought out and found over 50 of those essential substances.
- ▶ As we found more and more elements we needed to organize them.
- ▶ So we started by making flash cards.
- ▶ We gave each element a symbol.



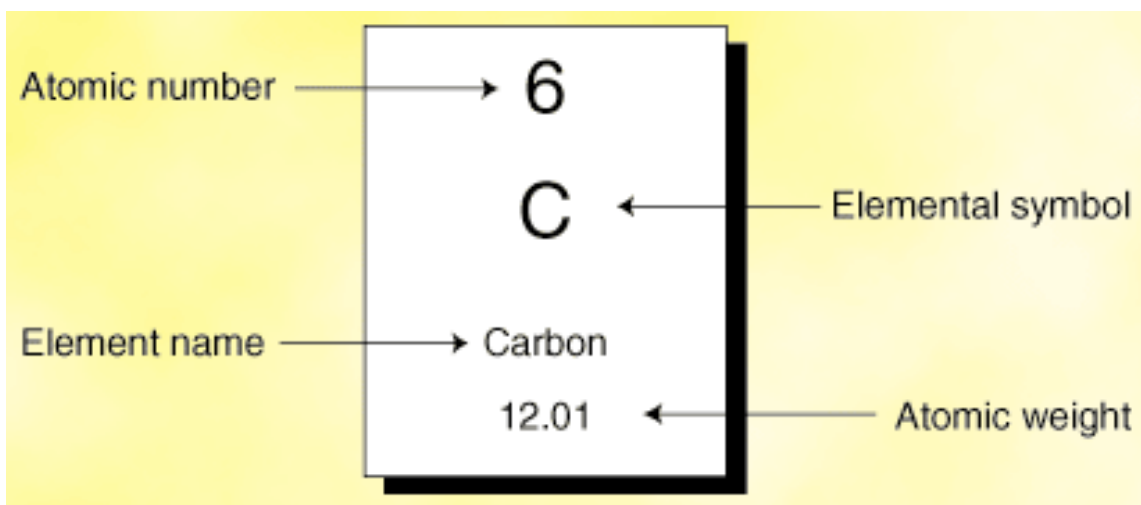
Symbols for 18 Elements

Hydrogen (H)
 Helium (He)
 Lithium (Li)
 Beryllium (Be)
 Boron (B)
 Carbon (C)
 Nitrogen (N)
 Oxygen (O)
 Fluorine (F)

Neon (Ne)
 Sodium (Na)
 (latin: **Natrium**)
 Magnesium (Mg)
 Aluminum (Al)
 Silicon (Si)
 Phosphorus (P)
 Sulfur (S)
 Chlorine (Cl)
 Argon (Ar)

For the next exam:
 Know the name and symbol of the
 first 18 elements.

Organizing the Elements



Symbols have 1, 2 or 3 letters. If 1 letter is used, it is capitalized. If 2 or 3 letters are used, only the first is capitalized.

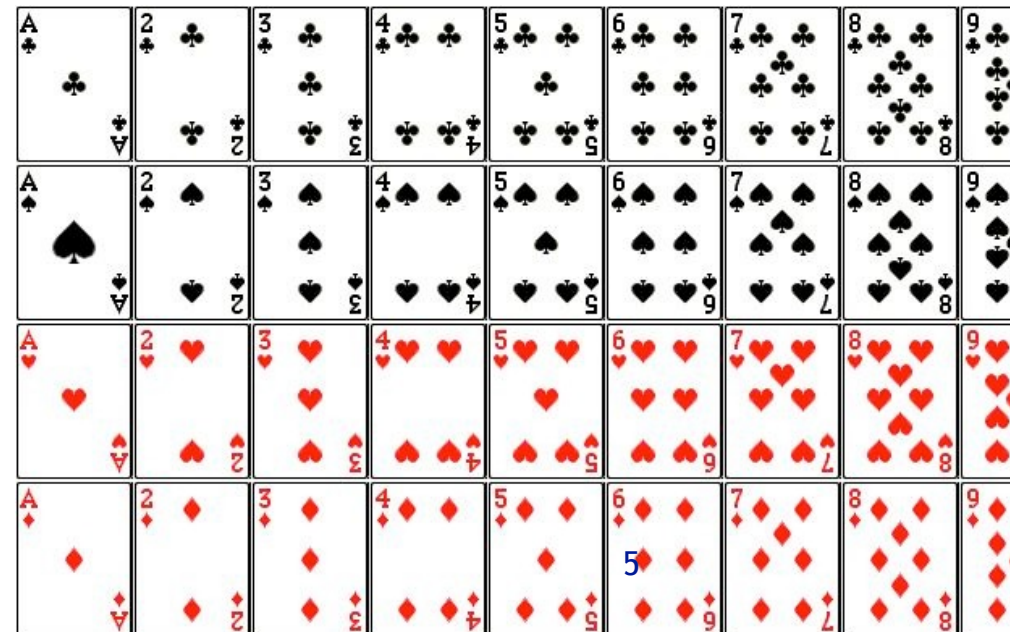
- ▶ We started by making flash cards.
- ▶ We gave each element a symbol.
- ▶ Then we lined them up by increasing weight, just like you might organize a poker hand.
- ▶ We gave each element a serial number (atomic number), to indicate it's place in the sequence of increasing weight.



Periodicity

Atomic number	1	2	3	4	—	9	10	11	12	—	17	18	19	20	—
Symbol	H	He	Li	Be	—	F	Ne	Na	Mg	—	Cl	Ar	K	Ca	—
	Nonreactive gas		Soft, reactive metal		Nonreactive gas		Soft, reactive metal		Nonreactive gas		Soft, reactive metal				

- ▶ We lined up all the cards by weight. From lightest to heaviest.
- ▶ Then we looked at their chemical and physical properties and saw a repeating pattern.
- ▶ Periodically, the same property shows up again and again and again.
- ▶ So instead of making it one really long line, we wrapped our set of cards so that those periodic trends lined up.



Periodicity

1 H	2 He	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	19 K	20 Ca
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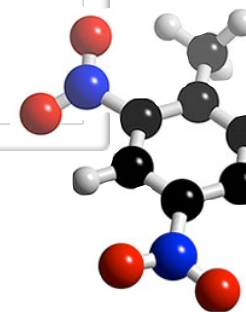
Elements with similar properties recur in a regular pattern.

- ▶ We lined up all the cards by weight. From lightest to heaviest.
- ▶ Then we looked at their chemical and physical properties and saw a repeating pattern.
- ▶ Periodically, the same property shows up again and again and again.
- ▶ So instead of making it one really long line, we wrapped our set of cards so that those periodic trends lined up.

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3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
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19 K	20 Ca						

Elements with similar properties fall into columns.

Flavors of the Atom



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- Periodicity

→ The Periodic Table

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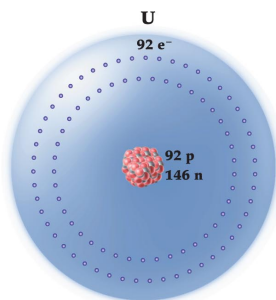
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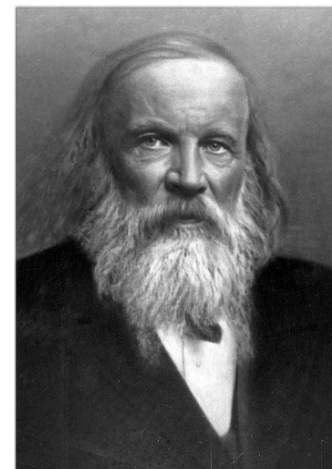


► Trends

- in Size
- in Ionization Energy



Periodic Table



- ▶ Dmitri Ivanovich Mendeleev, a Russian chemistry teacher, is credited for producing the first periodic table in 1871.
- ▶ There were about 50 elements in his first table.
- ▶ Periodic law predicted elements that weren't yet known, so Mendeleev left holes in his periodic table – to leave room for when they were discovered.

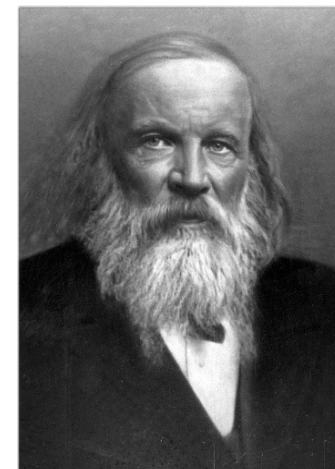


I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Tl 204	Pb 207	Bi 209					
			Th 232		U 238				

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Periodic Table



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

		Ti = 50	Zr = 90	? = 180.
		V = 51	Nb = 94	Ta = 182.
		Cr = 52	Mo = 96	W = 186.
		Mn = 55	Rh = 104,4	Pt = 197,1.
		Fe = 56	Ru = 104,4	Ir = 198.
		Ni = 59	Pd = 106,8	Os = 199.
		Cu = 63,4	Ag = 108	Hg = 200.
H = 1				
Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
B = 11	Al = 27,1	? = 68	U = 116	At = 197?
C = 12	Si = 28	? = 70	Sn = 118	
N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
O = 16	S = 32	Se = 79,4	Te = 128?	
F = 19	Cl = 35,5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133
		Ca = 40	Sr = 87,6	Ba = 137
			Pb = 207.	
		? = 45	Ce = 92	
		?Er = 56	La = 94	
		?Yt = 60	Di = 95	
		?In = 75,6	Th = 118?	

Д. Менделѣевъ

- As we added more elements the table grew.
- To make it more manageable, we cut out the lanthanide and actinide cards and set them in a separate table.



The 118 Known Elements

1
IA
1A

2
IIA
2A

3
IIIB
3B

4
IVB
4B

5
VB
5B

6
VIB
6B

7
VIIB
7B

8
VIII
8

9
VIII
8

10
VIII
8

11
IB
1B

12
IIB
2B

13
IIIA
3A

14
IVA
4A

15
VA
5A

16
VIA
6A

17
VIIA
7A

18
VIIIA
8A

1
H
Hydrogen
1.008

3
Li
Lithium
6.941

11
Na
Sodium
22.990

19
K
Potassium
39.098

37
Rb
Rubidium
84.468

55
Cs
Cesium
132.905

87
Fr
Francium
223.020

4
Be
Beryllium
9.012

12
Mg
Magnesium
24.305

20
Ca
Calcium
40.078

38
Sr
Strontium
87.62

56
Ba
Barium
137.327

88
Ra
Radium
226.025

5
B
Boron
10.811

13
Al
Aluminum
26.982

21
Sc
Scandium
44.956

29
Cu
Copper
63.546

37
Ag
Silver
107.868

45
Au
Gold
196.967

63
Eu
Europium
151.966

65
Tb
Terbium
158.925

67
Ho
Holmium
164.930

69
Tm
Thulium
168.934

71
Lu
Lutetium
174.967

6
C
Carbon
12.011

14
Si
Silicon
28.086

22
Ti
Titanium
47.88

30
Zn
Zinc
65.39

38
Cd
Cadmium
112.411

46
Pd
Palladium
106.42

54
Xe
Xenon
131.29

72
Hf
Hafnium
178.49

80
Hg
Mercury
200.59

88
Ra
Radium
226.025

7
N
Nitrogen
14.007

15
P
Phosphorus
30.974

23
V
Vanadium
50.942

31
Ga
Gallium
69.732

39
Y
Yttrium
88.906

47
Ag
Silver
107.868

55
Au
Gold
196.967

63
Eu
Europium
151.966

65
Tb
Terbium
158.925

67
Ho
Holmium
164.930

69
Tm
Thulium
168.934

71
Lu
Lutetium
174.967

8
O
Oxygen
15.999

16
S
Sulfur
32.066

24
Cr
Chromium
51.996

32
Ge
Germanium
72.61

40
Zr
Zirconium
91.224

48
Cd
Cadmium
112.411

56
Ba
Barium
137.327

64
Gd
Gadolinium
157.25

66
Dy
Dysprosium
162.50

68
Er
Erbium
167.26

70
Yb
Ytterbium
173.04

72
Hf
Hafnium
178.49

80
Hg
Mercury
200.59

88
Ra
Radium
226.025

9
F
Fluorine
18.998

17
Cl
Chlorine
35.453

25
Mn
Manganese
54.938

33
As
Arsenic
74.922

41
Nb
Niobium
92.906

49
In
Indium
114.818

57
La
Lanthanum
138.906

65
Tb
Terbium
158.925

73
Ta
Tantalum
180.948

81
Tl
Thallium
204.383

89
Ac
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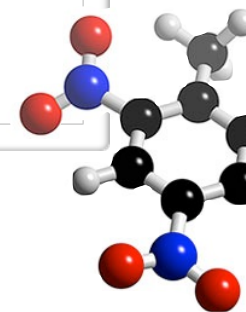
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Flavors of the Atom



► Organizing the Elements

- Chemical Symbols
- Periodicity

► The Periodic Table

- The First Periodic Table



Metals & Non-metals

- Metallic Properties
- Common Ions, Predicting Charge
- Representative Elements
- Periods, Groups & Families
 - Group Numbers
 - Family Names
- Official Class Periodic Table

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

► Pieces of the atom

— electrons, protons, neutrons

- Ions differ in electron count
- Elements have different proton counts
- Isotopes differ in total mass (because they differ in number of neutrons)

- Isotopic Notation

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► Regions of the atom

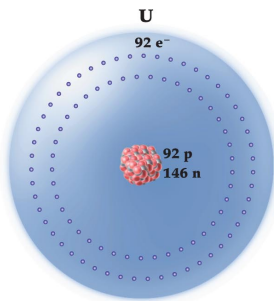
► Electron Shells

- Finding Electron Shells
- Valence Electrons
- Lewis Symbols



► Trends

- in Size
- in Ionization Energy



Metallic Character

- ▶ Most elements are metals (shiny, malleable, ductile, good conductors)
- ▶ Some are non-metals (dull, brittle, not-ductile, poor conductors)
- ▶ Seven are metalloids (kinda shiny, somewhat malleable, sorta ductile, semi-conductors)

Metals Metalloids Nonmetals

1A 1 2A 2

1 H 2 He

2 3 Li 4 Be

3 11 Na 12 Mg

4 19 K 20 Ca

5 37 Rb 38 Sr

6 55 Cs 56 Ba

7 87 Fr 88 Ra

3B 4B 5B 6B 7B 8B 9 10 11B 12B

13 14 15 16 17 18

5 6 7 8 9 10

13 14 15 16 17 18

31 32 33 34 35 36

49 50 51 52 53 54

81 82 83 84 85 86

113 114 115 116 117 118

Strontium Chromium Gold Copper Lead

Silicon Arsenic Carbon

Sulfur

Bromine

Iodine

Lanthanides

Actinides

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Periodic Table

- ▶ We call each horizontal row a **period**.
- ▶ We call each vertical column a **family** or **group**.
- ▶ We divide sections of the table into the **representative elements**, the **transition metals** and the **inner transition metals**.

Periodic Table of the Elements

Representative
(main-group)
elements

1 IA	2 IIA
1 H 1.0079	
3 Li 6.941	4 Be 9.012
11 Na 22.990	12 Mg 24.305
19 K 39.098	20 Ca 40.078
37 Rb 85.468	38 Sr 87.62
55 Cs 132.905	56 Ba 137.327
87 Fr 223	88 Ra 226.025

Element symbol coloring

● **H** Gas

● **Li** Solid

● **Br** Liquid

● **Tc** Not found in nature

} at 25°C and 1 atm pressure

Representative
(main-group)
elements

13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.905	54 Xe 131.29
81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222

Transition metals

3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB
21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39
39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411
57 La 138.906	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm 145	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.5
71 Lu 174.967	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59
89 Ac 227.028	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251
	101 Db 261	102 Sg 262	103 Bh 263	104 Hs 265	105 Mt 266	106 Uun 269	107 Uuu 272	108 Uub 277	

Lanthanides (rare earths)

58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm 145	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
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Actinides

90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262
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Periodic Table

- Some families (groups) are important enough to have unique names.

Group	Name
1A	Alkali metals
2A	Alkaline earth metals
6A	Chalcogens
7A	Halogens
8A	Noble gases (or rare gases)

Periodic Table of the Elements

Representative
(main-group)
elements

1 IA	2 IIA
1 H 1.0079	
3 Li 6.941	4 Be 9.012
11 Na 22.990	12 Mg 24.305
19 K 39.098	20 Ca 40.078
37 Rb 85.468	38 Sr 87.62
55 Cs 132.905	56 Ba 137.327
87 Fr 223	88 Ra 226.025

Element symbol coloring

● **H** Gas

● **Li** Solid

● **Br** Liquid

● **Tc** Not found in nature

} at 25°C and 1 atm pressure

Transition metals

3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB
21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn
39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf

Representative
(main-group)
elements

13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.905	54 Xe 131.29
81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222

Periodic Table

- Some families (groups) are important enough to have unique names.

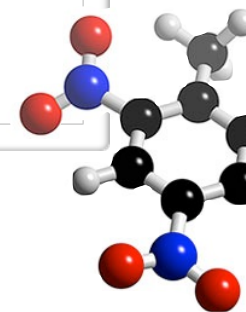
Group	Name
1A	Alkali metals
2A	Alkaline earth metals
6A	Chalcogens
7A	Halogens
8A	Noble gases (or rare gases)

Alkali metals												Noble gases																	
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Many Ionic Charges are Predictable

1A												7A				8A	
H ⁺	2A											3A	4A	5A	6A	H ⁻	Noble Gases
Li ⁺														N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺	Transition metals										Al ³⁺			S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺													Se ²⁻	Br ⁻		
Rb ⁺	Sr ²⁺													Te ²⁻	I ⁻		
Cs ⁺	Ba ²⁺																

Flavors of the Atom



► Organizing the Elements

- Chemical Symbols
- Periodicity

► The Periodic Table

- The First Periodic Table
- Metals & Non-metals
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- Common Ions, Predicting Charge
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► Pieces of the atom

— electrons, protons, neutrons

- Ions differ in electron count
- Elements have different proton counts
- Isotopes differ in total mass (because they differ in number of neutrons)
 - Isotopic Notation

¹⁷₈O

► Regions of the atom

- Electron Shells
 - Finding Electron Shells
 - Valence Electrons
 - Lewis Symbols

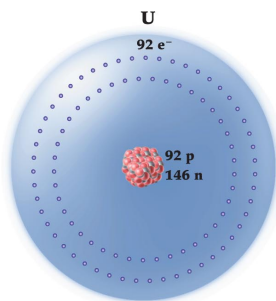


► Properties

- Predicting Trends



➔ Official Class Periodic Table



Official Class Periodic Table

Unless directed otherwise, use only this table for all classwork.

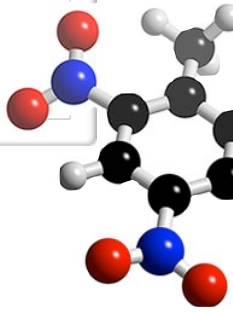
This table will be provided with all exams.

This table is printed in the front cover of your text book and is available as a pop-up in mastering chemistry.

This table is printed in the front cover of your text book and is available as a pop-up in mastering chemistry.

1 IA	2											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H 1.01 hydrogen																	2 He 4.00 helium
3 Li 6.94 lithium	4 Be 9.01 beryllium											5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.18 neon
11 Na 22.99 sodium	12 Mg 24.31 magnesium	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.07 sulfur	17 Cl 35.45 chlorine	18 Ar 39.95 argon
19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.88 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.69 nickel	29 Cu 63.55 copper	30 Zn 65.39 zinc	31 Ga 69.72 gallium	32 Ge 72.61 germanium	33 As 74.92 arsenic	34 Se 78.96 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.94 molybdenum	43 Tc (99) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.42 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.71 tin	51 Sb 121.75 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.29 xenon
55 Cs 132.91 cesium	56 Ba 137.33 barium	57 La 138.91 lanthanum	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.2 osmium	77 Ir 192.22 iridium	78 Pt 195.08 platinum	79 Au 196.97 gold	80 Hg 200.59 mercury	81 Tl 204.38 thallium	82 Pb 207.2 lead	83 Bi 208.98 bismuth	84 Po (209) polonium	85 At (210) astatine	86 Rn (222) radon
87 Fr (223) francium	88 Ra (226) radium	89 Ac (227) actinium	104 Rf (261) rutherfordium	105 Db (262) dubnium	106 Sg (263) seaborgium	107 Bh (262) bohrium	108 Hs (265) hassium	109 Mt (266) meitnerium	110 Ds (281) darmstadtium	111 Rg (280) roentgenium	112 Cn (285) copernicium	113 — (284)	114 Fl (289) flerovium	115 — (288)	116 Lv (292) livermorium	117* — (294)	118 — (294)

Flavors of the Atom



► Organizing the Elements

- Chemical Symbols
- Periodicity

► The Periodic Table

- The First Periodic Table
- Metals & Non-metals
 - Metallic Properties
- Common Ions, Predicting Charge
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► Pieces of the atom

– electrons, protons, neutrons

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► Elements have different proton counts

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► Isotopic Notation

¹⁷₈O

► Regions of the atom

► Electron Shells

► Finding Electron Shells

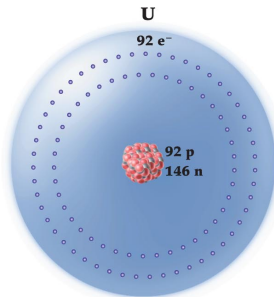
► Valence Electrons

► Lewis Symbols



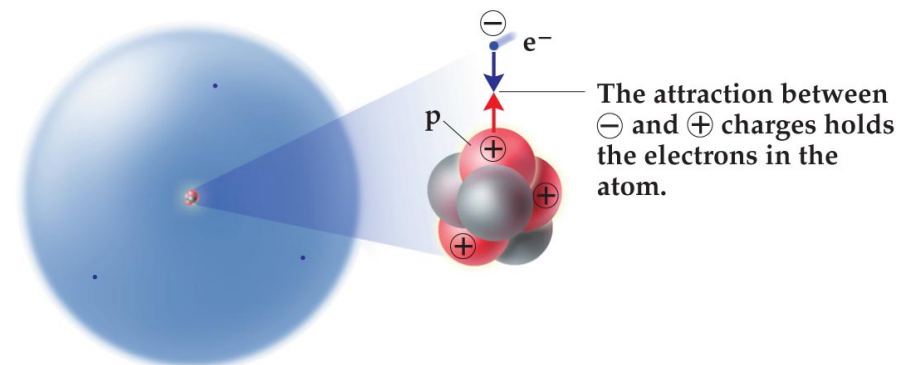
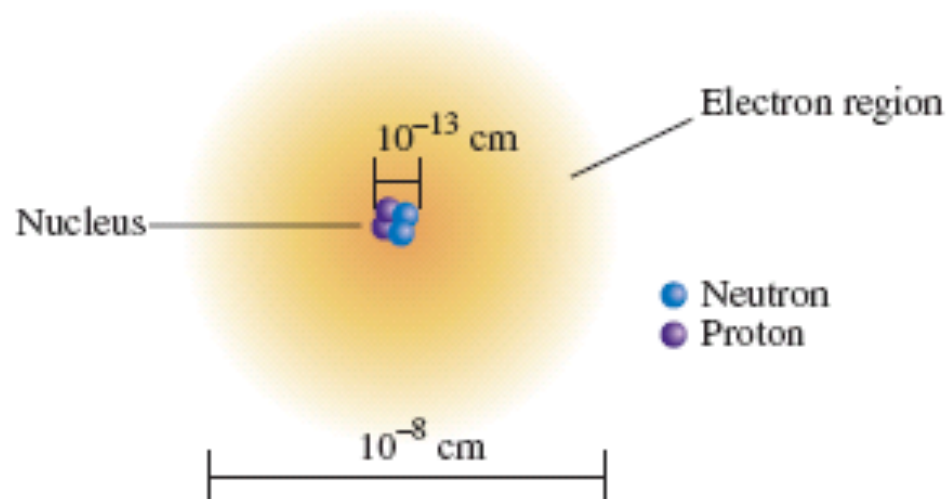
► Properties

► Predicting Trends



Pieces of the Atom

- ▶ Atoms are the smallest particle of an element that can enter into a chemical reaction.
- ▶ Protons and neutrons make up the dense, positive nucleus.
- ▶ Electrons occupy the empty space outside the nucleus.
- ▶ A neutral atom contains the same number of electrons and protons.



Ions

- ▶ JJ Thomson explained Michael Faraday's observations about some atoms being charged with his plumb pudding model (theory).

- ▶ Cations are formed by removing an electron from the atom.

- ▶ Leaving more protons than electrons and a net positive charge.

- ▶ The difference between Al atom and Al^{3+} ion is the number of electrons.

- ▶ The ion has very different properties than the atom.

▶ Do not confuse them.

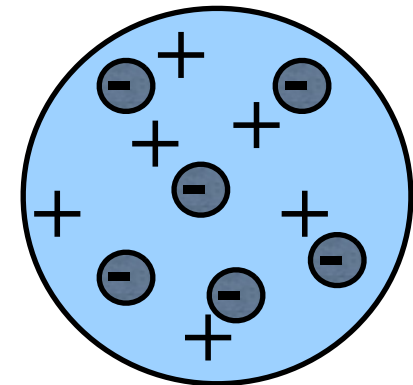
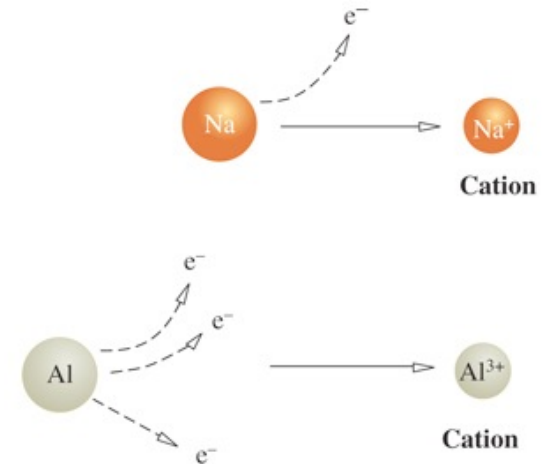
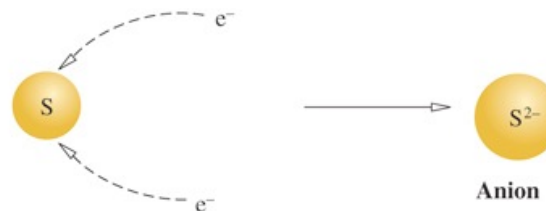
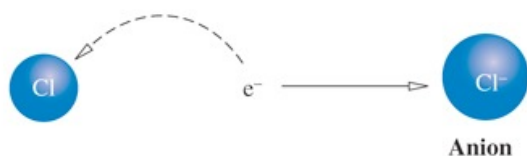
- ▶ Anions are formed by adding an electron to an atom.

- ▶ Leaving more electrons than protons and a net negative charge.

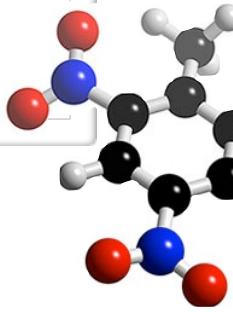
- ▶ The difference between S atom and S^{2-} ion is the number of electrons.

- ▶ The ion has very different properties than the atom.

▶ Do not confuse them.



Flavors of the Atom



► Organizing the Elements

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► Isotopic Notation

¹⁷₈O

► Regions of the atom

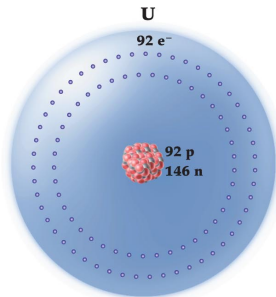
- Electron Shells

- Finding Electron Shells
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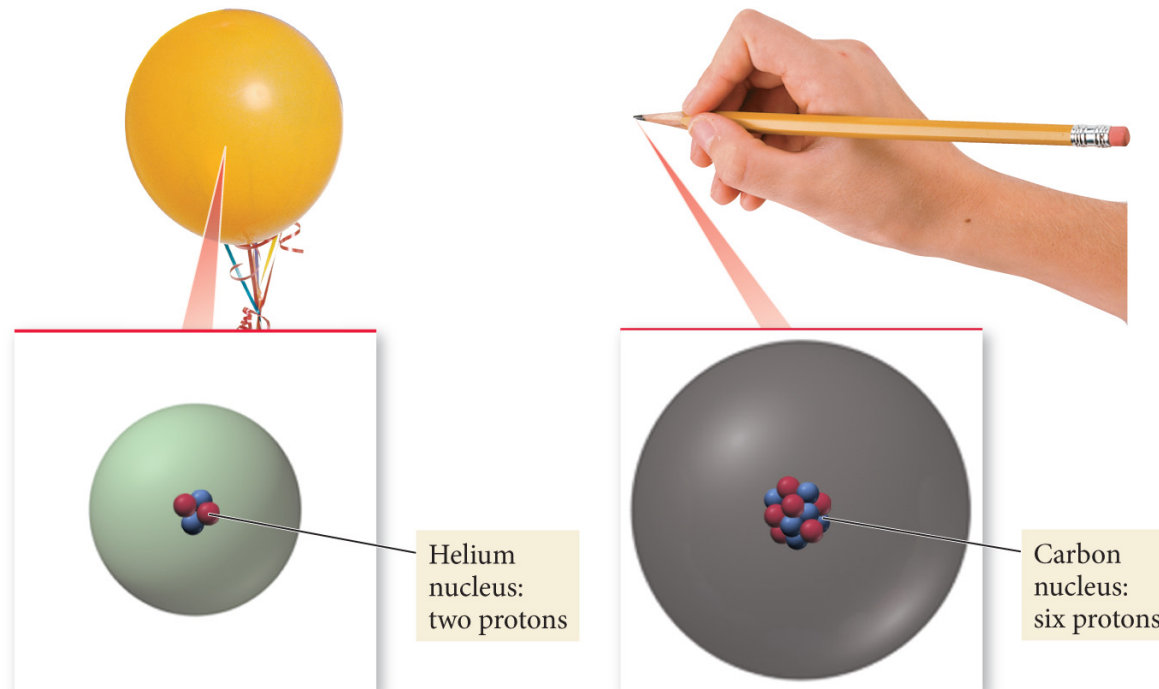
► Properties

- Predicting Trends



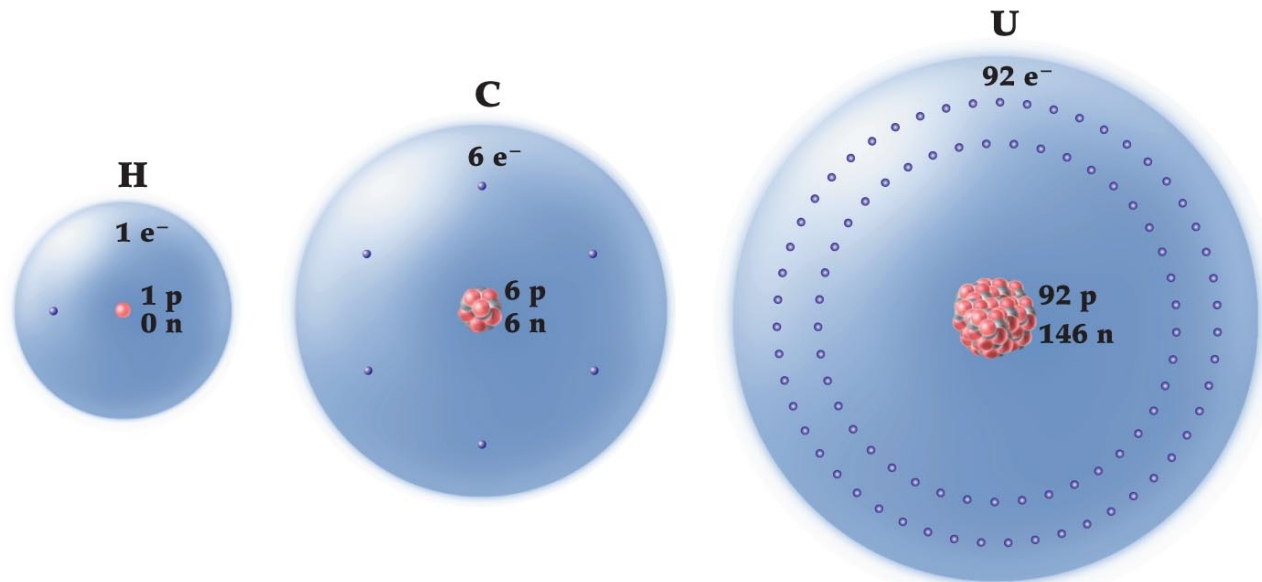
Elements differ in Protons

- ▶ If all atoms are made up of protons, neutrons, and electrons – what makes one element different from another?
- ▶ Elements differ by the number of protons.
- ▶ Carbon atoms have six protons. Helium atoms have two protons. **Always.**



Elements differ in Protons

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Elements differ in Protons

- ▶ The “serial number” in the periodic table is the atomic number.
- ▶ The **atomic number** equals the number of protons for that element.

4

Be

beryllium

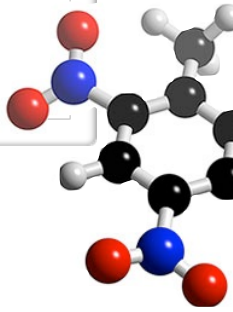
Atomic number (Z)

Chemical symbol

Name

1 H hydrogen																	2 He helium																												
3 Li lithium	4 Be beryllium																	5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon																						
11 Na sodium	12 Mg magnesium																	13 Al aluminum	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon																						
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton																												
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon																												
55 Cs cesium	56 Ba barium	57 La lanthanum	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon																												
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<table><tr><td>58 Ce cerium</td><td>59 Pr praseodymium</td><td>60 Nd neodymium</td><td>61 Pm promethium</td><td>62 Sm samarium</td><td>63 Eu europium</td><td>64 Gd gadolinium</td><td>65 Tb terbium</td><td>66 Dy dysprosium</td><td>67 Ho holmium</td><td>68 Er erbium</td><td>69 Tm thulium</td><td>70 Yb ytterbium</td><td>71 Lu lutetium</td></tr><tr><td>90 Th thorium</td><td>91 Pa protactinium</td><td>92 U uranium</td><td>93 Np neptunium</td><td>94 Pu plutonium</td><td>95 Am americium</td><td>96 Cm curium</td><td>97 Bk berkelium</td><td>98 Cf californium</td><td>99 Es einsteinium</td><td>100 Fm fermium</td><td>101 Md mendelevium</td><td>102 No nobelium</td><td>103 Lr lawrencium</td></tr></table>																		58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium
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Flavors of the Atom



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Isotopes differ in total mass (because they differ in number of neutrons)

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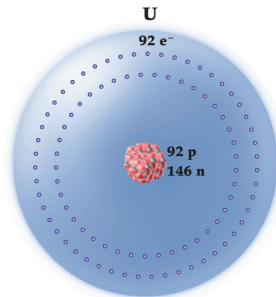
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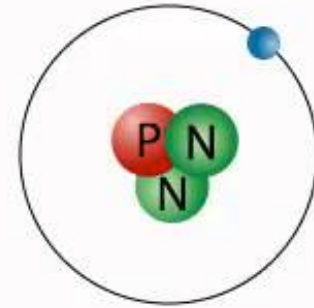
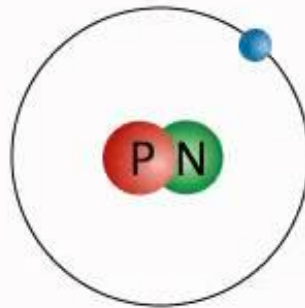
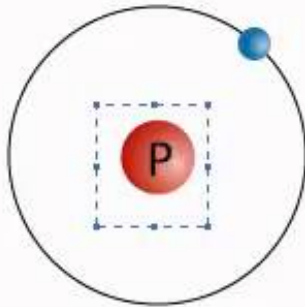
► Properties

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Isotopes differ in Mass

- ▶ All atoms of the same element, have the same number of protons.
- ▶ But may not have the same weight.
- ▶ Some hydrogen atoms weigh twice as much as other hydrogen atoms.
- ▶ The difference is in the **number of neutrons**.
- ▶ Atoms of the same element but different masses are called **isotopes**.



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- ▶ Atoms of the same element but different masses are called **isotopes**.
- ▶ Isotopes are defined by their number of neutrons.
- ▶ We use isotopic notation to describe different isotopes.

Mass number
(sum of protons and
neutrons in the nucleus)

Atomic number
(number of protons
in the nucleus)

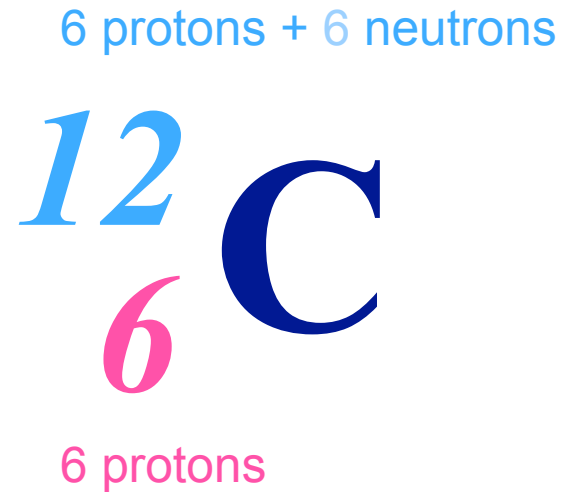


← Symbol of element

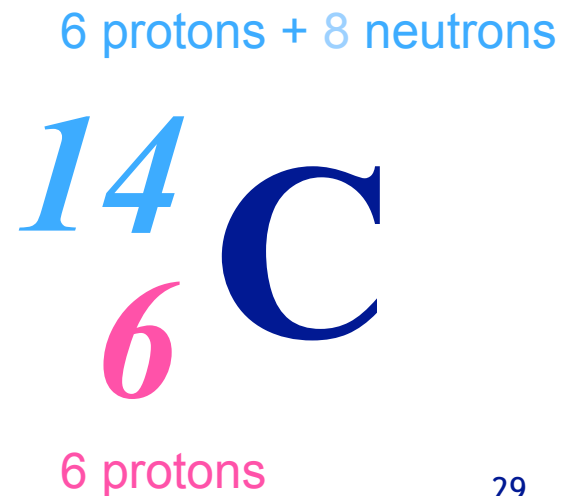
Isotopes differ in Mass



- ▶ What would the symbol be for the Carbon-12 isotope?



- ▶ What would the symbol be for the Carbon-14 isotope?

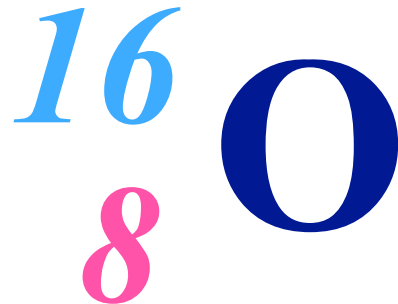


Isotopes differ in Mass



- ▶ Oxygen has three isotopes...

8 protons + 8 neutrons



8 protons

8 protons + 9 neutrons



8 protons

8 protons + 10 neutrons



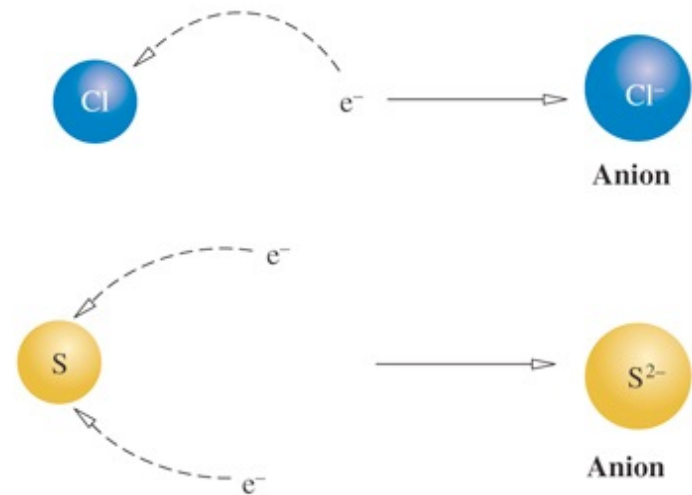
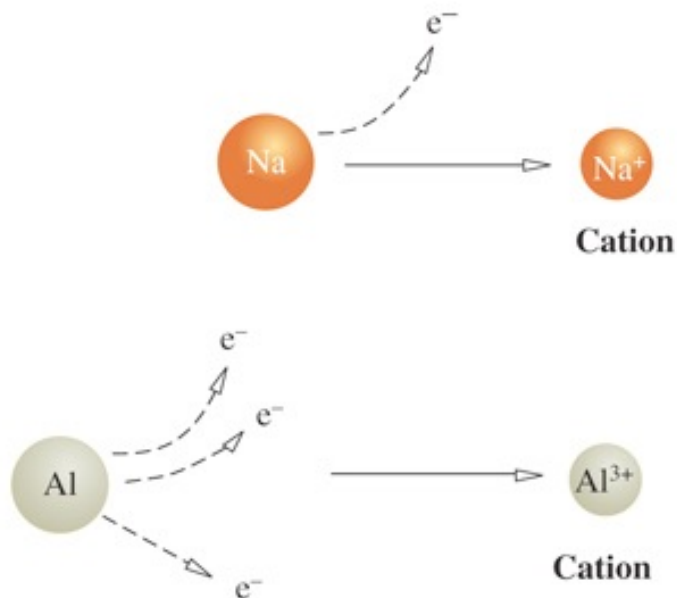
8 protons

Examples of Isotopes

<u>Element</u>	<u>Protons</u>	<u>Electrons</u>	<u>Neutrons</u>	<u>Symbol</u>
Hydrogen	1	1	0	
Hydrogen	1	1	1	
Hydrogen	1	1	2	
Uranium	92	92	143	
Uranium	92	92	146	
Chlorine	17	17	18	
Chlorine	17	17	20	

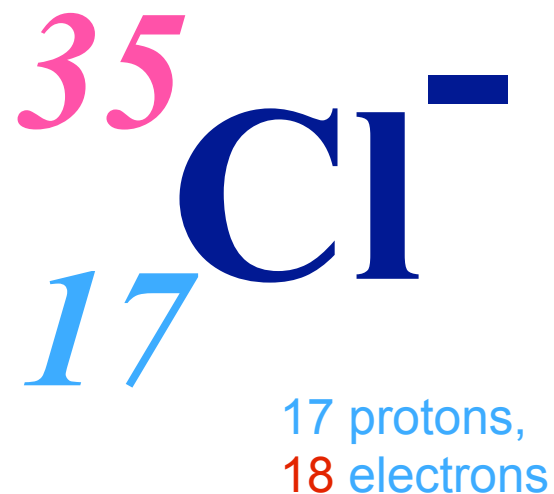
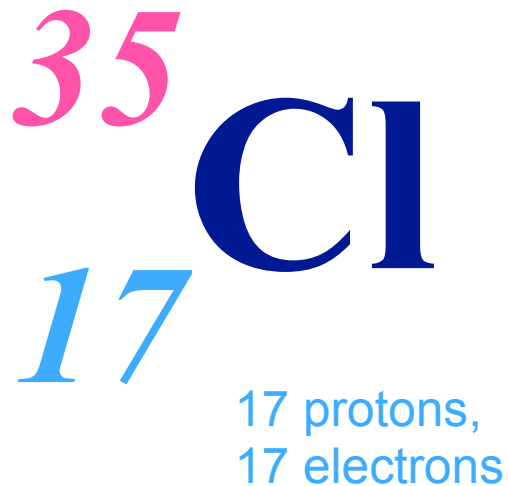
Ions differ in Electrons

- ▶ For a neutral atom, the number of protons equals the number of electrons.
- ▶ For a cation, there are less electrons than protons.
- ▶ For an anion, there are more electrons than protons.



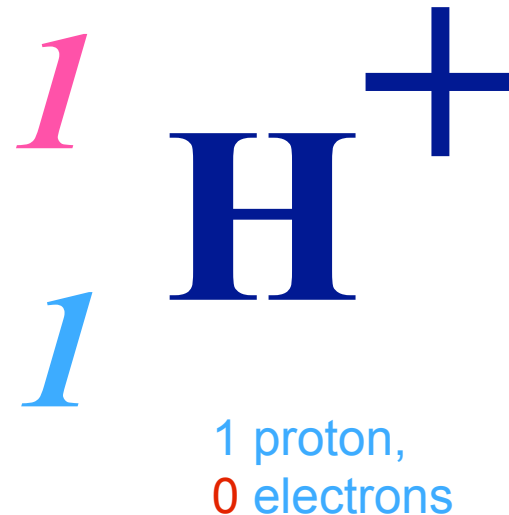
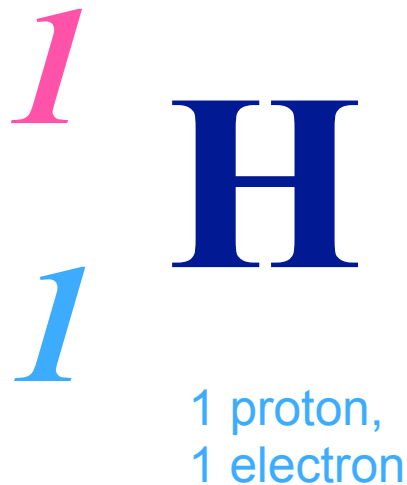
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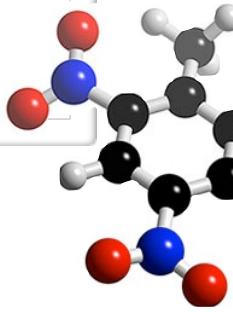


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Flavors of the Atom



► Organizing the Elements

- Chemical Symbols
- Periodicity

► The Periodic Table

- The First Periodic Table
- Metals & Non-metals
 - Metallic Properties
- Common Ions, Predicting Charge
- Representative Elements
- Periods, Groups & Families
 - Group Numbers
 - Family Names
- Official Class Periodic Table

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

► Pieces of the atom

— electrons, protons, neutrons

- Ions differ in electron count
- Elements have different proton counts
- Isotopes differ in total mass (because they differ in number of neutrons)

► Isotopic Notation

¹⁷₈O

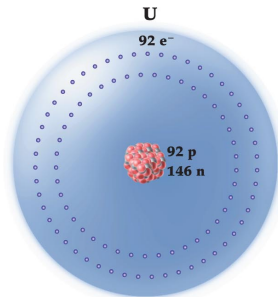
Regions of the atom

- Electron Shells
 - Finding Electron Shells
 - Valence Electrons
 - Lewis Symbols



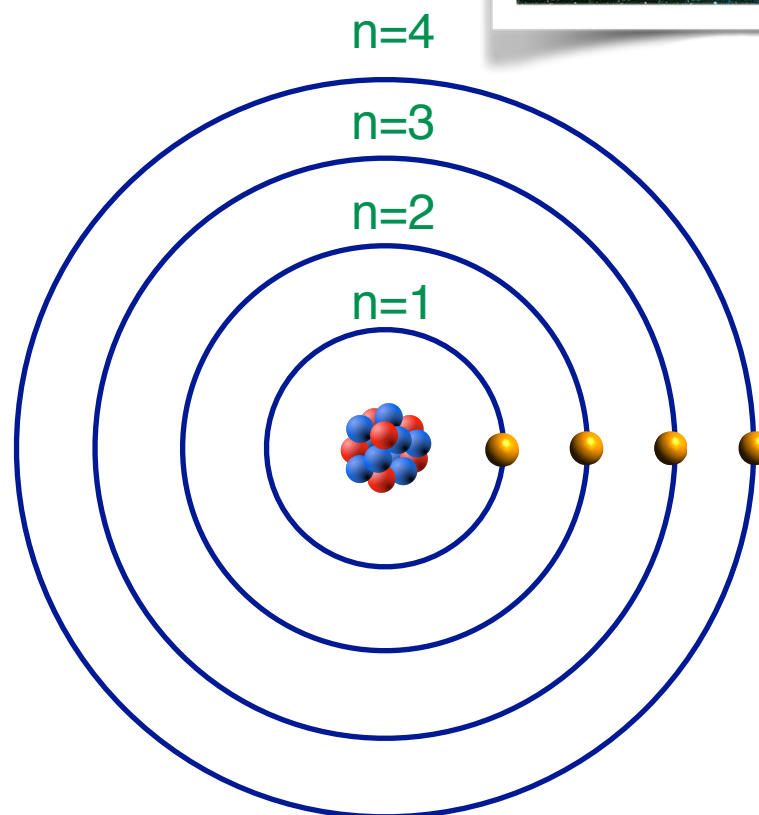
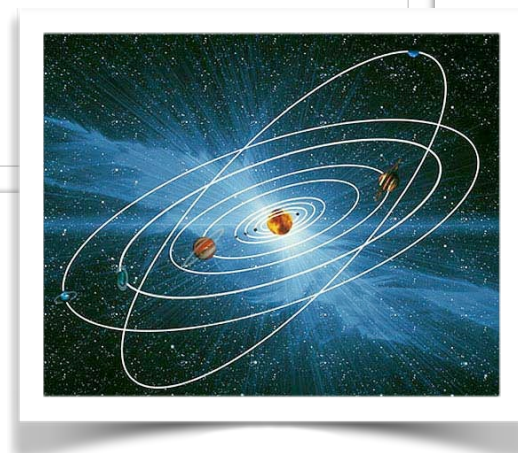
► Trends

- in Size
- in Ionization Energy



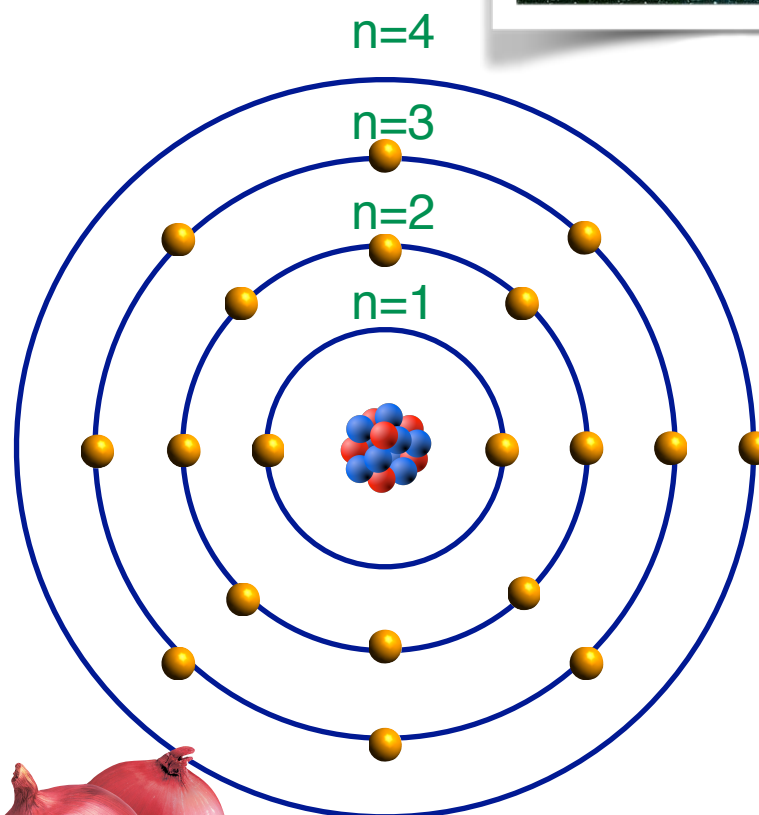
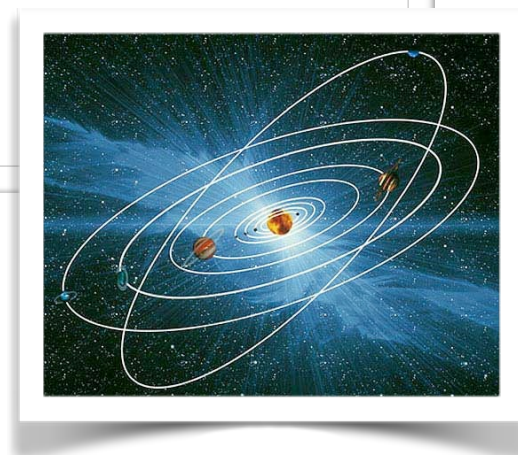
Electronic Structure

- ▶ Electrons exist at certain distances from the nucleus.
 - ▶ Similar to the way planets exist in discrete orbits around the sun.
 - ▶ The full story is more complex, but this is a good first approximation.
- ▶ The orbits are numbered, we indicate the orbit number with the variable n .
- ▶ n is the **principle quantum number**.
 - ▶ The closest orbit to the nucleus is $n=1$.
 - ▶ The next farther out is $n=2$.
 - ▶ ... and so on.
- ▶ The electrons closer to nucleus have less energy.
 - ▶ Like a ball at the bottom of a hill has less energy.
- ▶ Electrons prefer to be in the lowest orbital (closest to the nucleus).



Electronic Structure

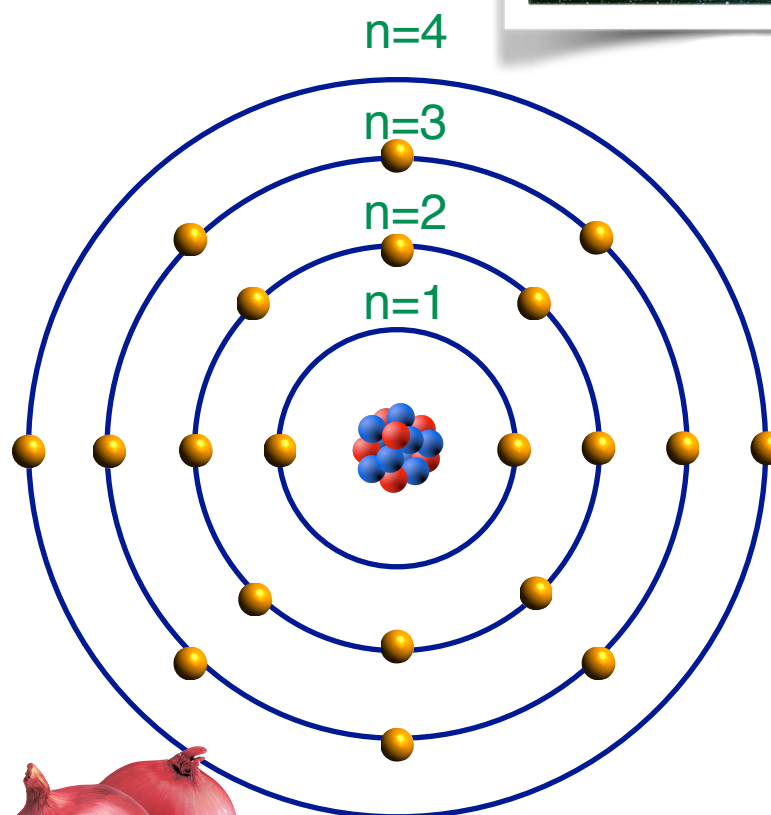
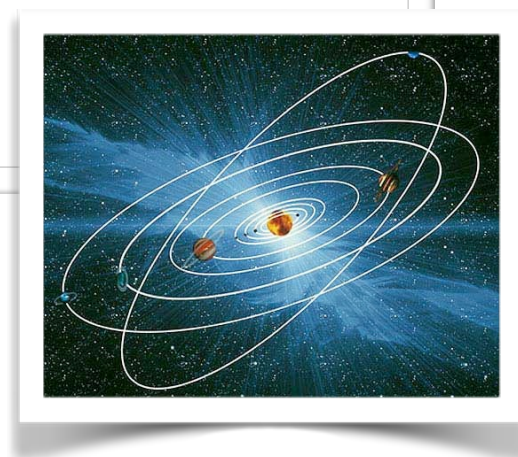
- ▶ More than one electron can orbit at each level.
- ▶ There is a maximum number of electrons that can orbit at each level.
- ▶ This creates layers or shells of electrons around the nucleus,
 - ▶ Two electrons can orbit at $n=1$
 - ▶ This is the $n=1$ shell.
 - ▶ Eight electrons can orbit at $n=2$.
 - ▶ This is the $n=2$ shell.
 - ▶ Eight electrons can orbit at $n=3$.
 - ▶ This is the $n=3$ shell.
 - ▶ At $n=4$ the shells get larger and some complicated things happen that we won't get into in this class.
 - ▶ But $n=4$ can hold at least two electrons.
 - ▶ You are responsible for knowing the capacity of each of the shells 1-3.



Electronic Structure

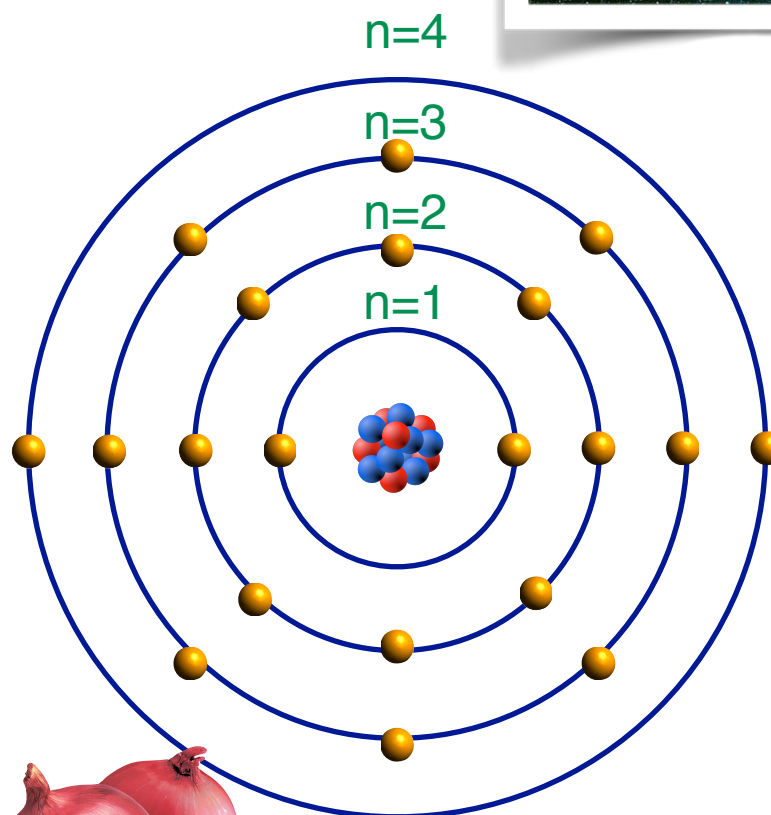
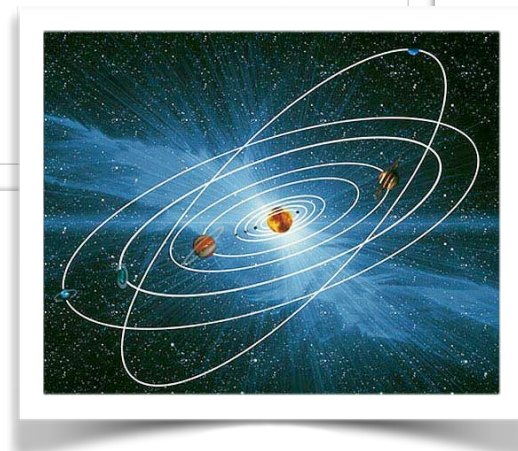
- ▶ Since electrons prefer to fill electron shells at lowest number possible n number, if you know how many electrons an atom has, you can predict it's electronic structure.
- ▶ Helium has two, both electrons are in $n=1$
 - ▶ Electronic structure 2
- ▶ Carbon has six, two in $n=1$ and four in $n=2$
 - ▶ Electronic structure 2, 4
- ▶ Chlorine has 17
 - ▶ 2, 8, 7
- ▶ Calcium has 20
 - ▶ 2, 8, 8, 2

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Electronic Structure

- ▶ The outermost shell is the one other atoms will “see” when they bump into an atom.
- ▶ That shell is the most important part of the atom's electronic structure.
- ▶ The outermost shell of the atom is its **valence shell**.
- ▶ The rest of the electrons are **core electrons**.
- ▶ An atom will have 1-8 electrons in its valence shell. This is the octet rule.

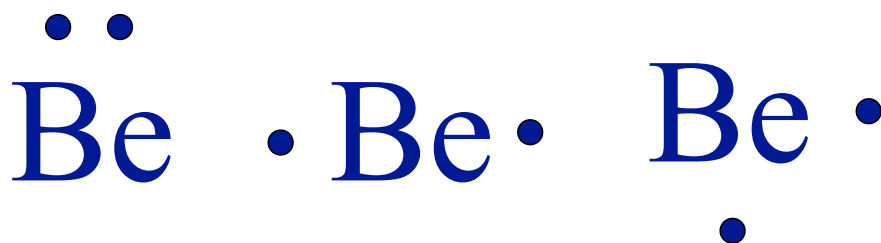


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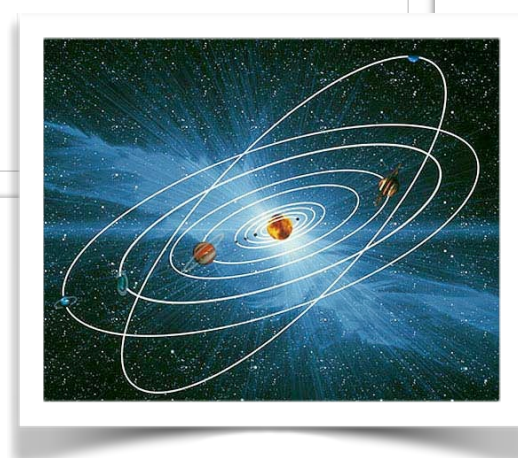
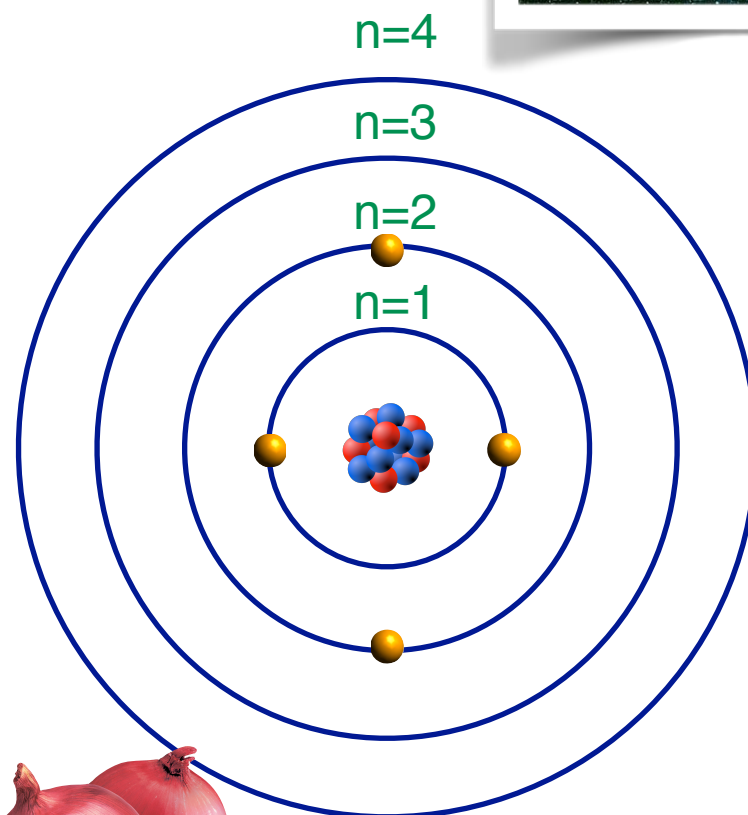
Electronic Structure

- ▶ As we start to understand chemical bonding, we will use Lewis symbols to indicate the number of electrons in an atoms valence shell.
- ▶ A Lewis symbol starts with the symbol of the element, and adds to it the valence electrons in sets of two on each of the four sides of that symbol.
 - ▶ It does not matter which side, as long as you have 1-8 dots in sets of (at most) two.



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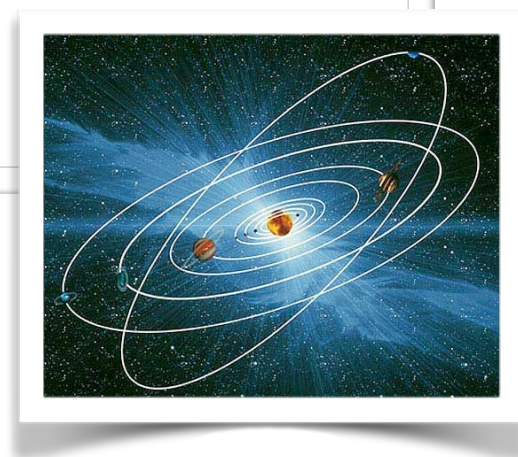
Be



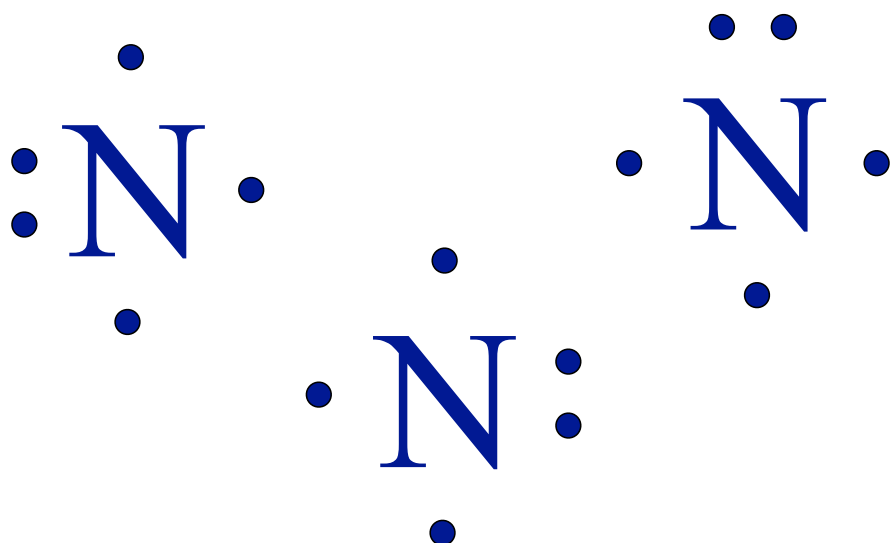
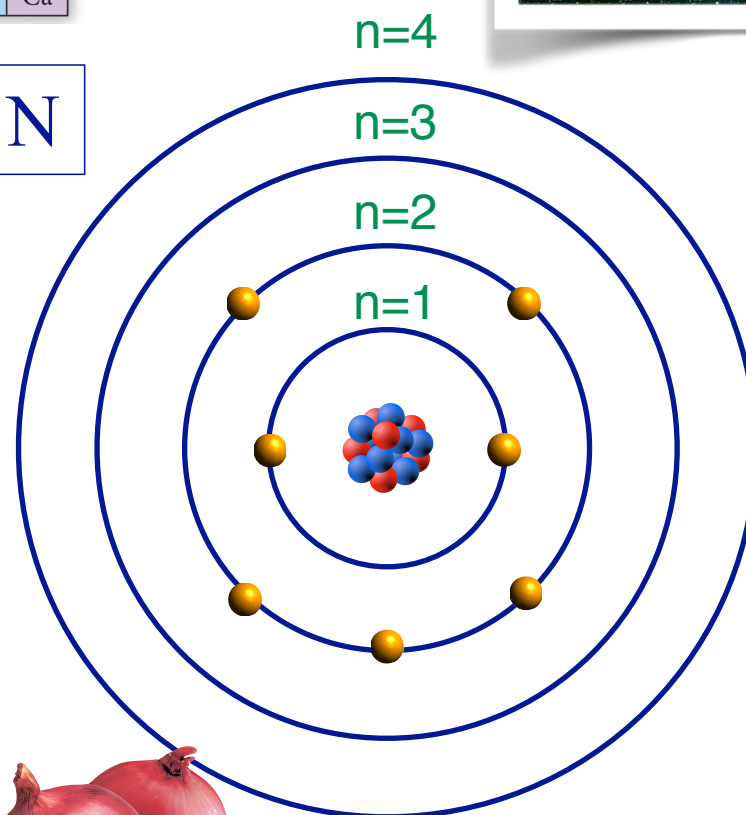
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N



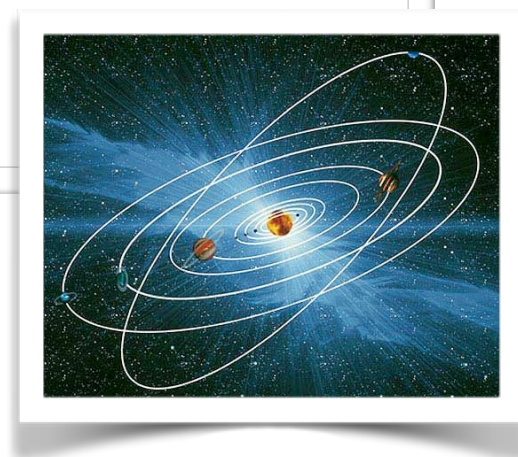
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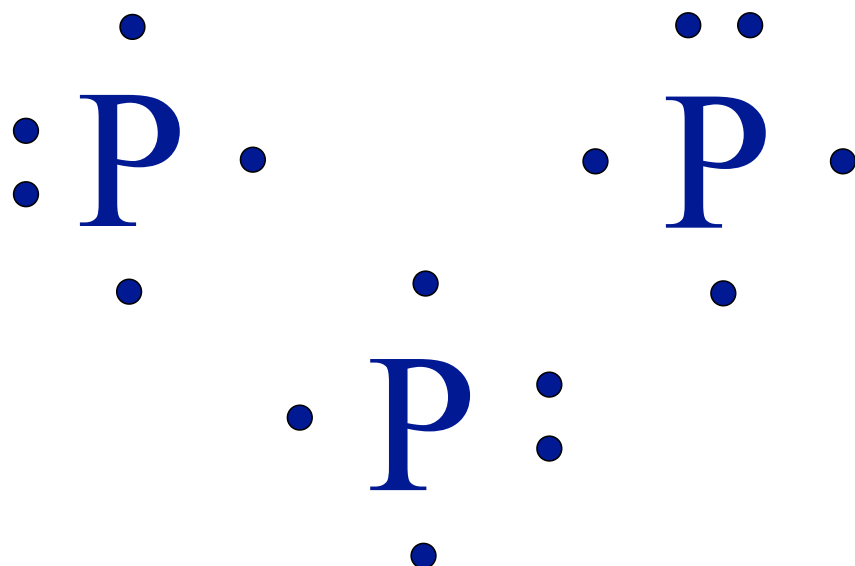
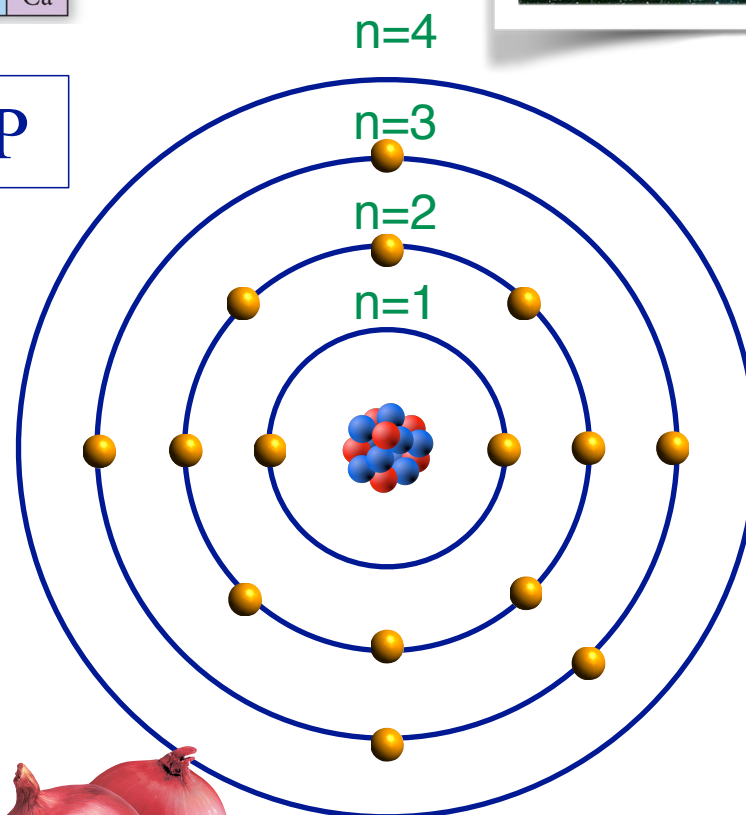
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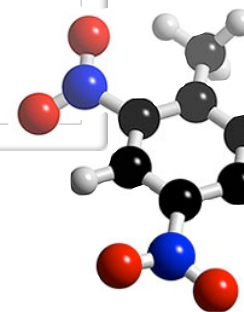
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P



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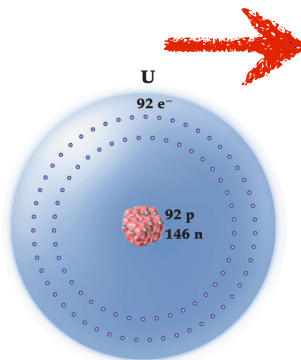
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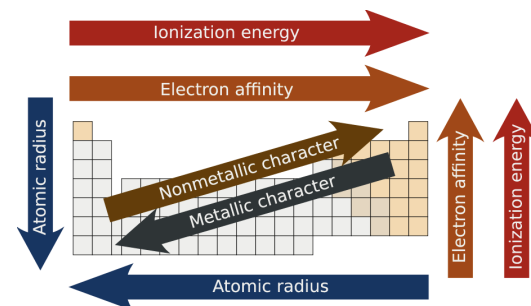
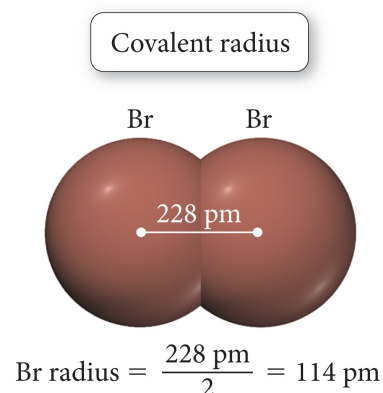
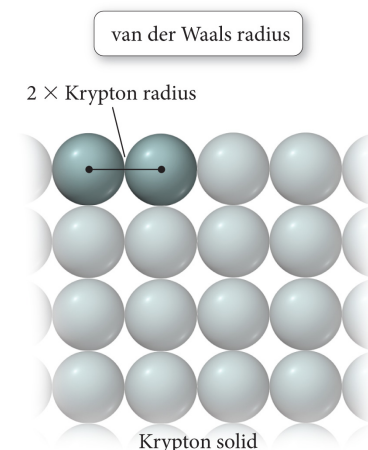
Trends

- in Size
- in Ionization Energy



The size of Atoms

- ▶ The electron cloud of an atom defines its size.
- ▶ How do you measure the size of a cloud?
 - ▶ The edges of a cloud are uncertain.
- ▶ We measure the distance between two adjacent atoms.
 - ▶ Atomic size is measured by packing atoms close together, finding the distance between adjacent nuclei, and dividing that number by 2.
 - ▶ Atoms can be packed densely by capturing them in solid form or capturing them in another compound that is a solid.
 - ▶ These atoms are not bonded, their electron orbitals don't mix.
 - ▶ We describe the atomic size we get from this process as the **nonbonding atomic radius** or **van der Waals radius**.
 - ▶ For metals this involves analyzing metallic crystals (atoms held together with metallic bonds).
 - ▶ For non-metals, we look at a large number of compounds that contain the element.
 - ▶ We look at the average bond length between atoms.
 - ▶ There is overlap between the electron orbitals.
 - ▶ We describe the atomic radius found from covalently bonded compounds as the **bonding atomic radius** or **covalent radius**.
 - ▶ Which atomic radius we use depends on the context.
 - ▶ When we say **atomic radius**, we more often mean bonding atomic radius.
 - ▶ We can determine the relative atomic radius of two elements by their position in the periodic table.

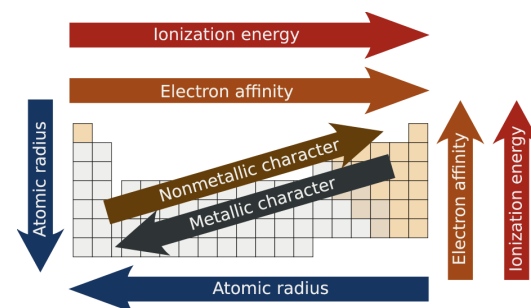
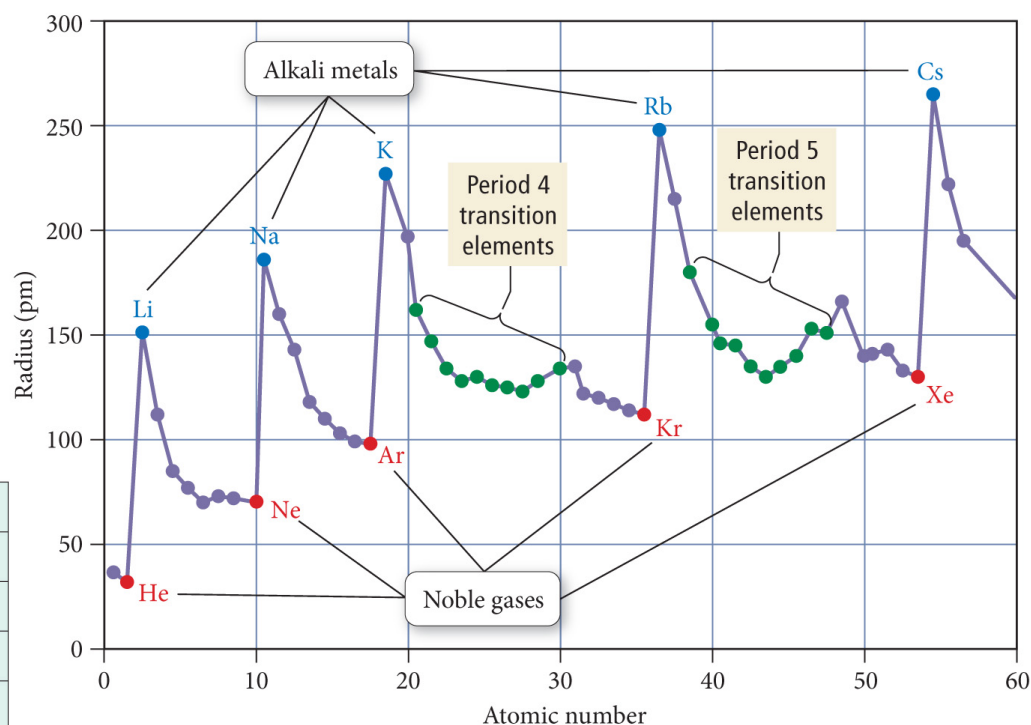


Relative Atomic Radius

- ▶ In general, as we move **across** the periodic table left to right the atomic radius **decreases**.
- ▶ Transition metals of the same period are *roughly* the same size.
- ▶ In general, as we move **down** the periodic table the atomic radius **increases**.

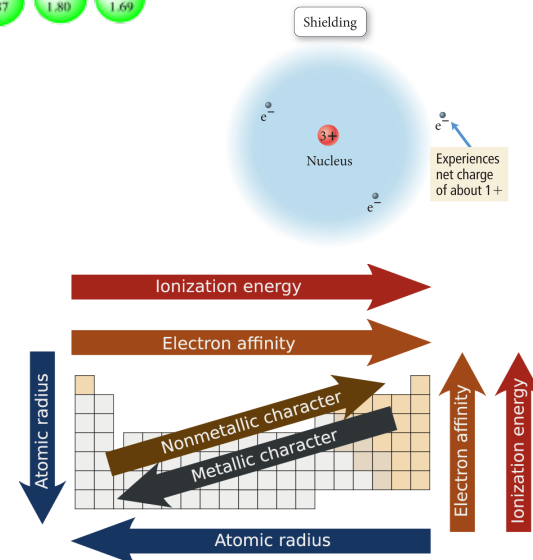
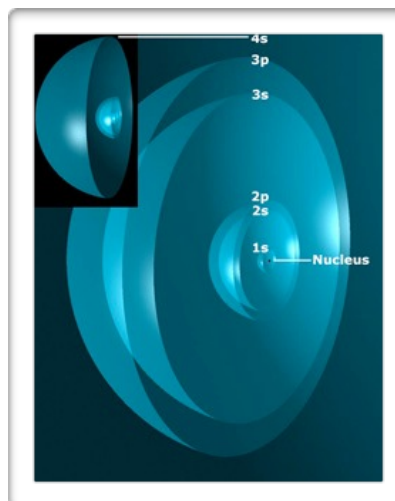
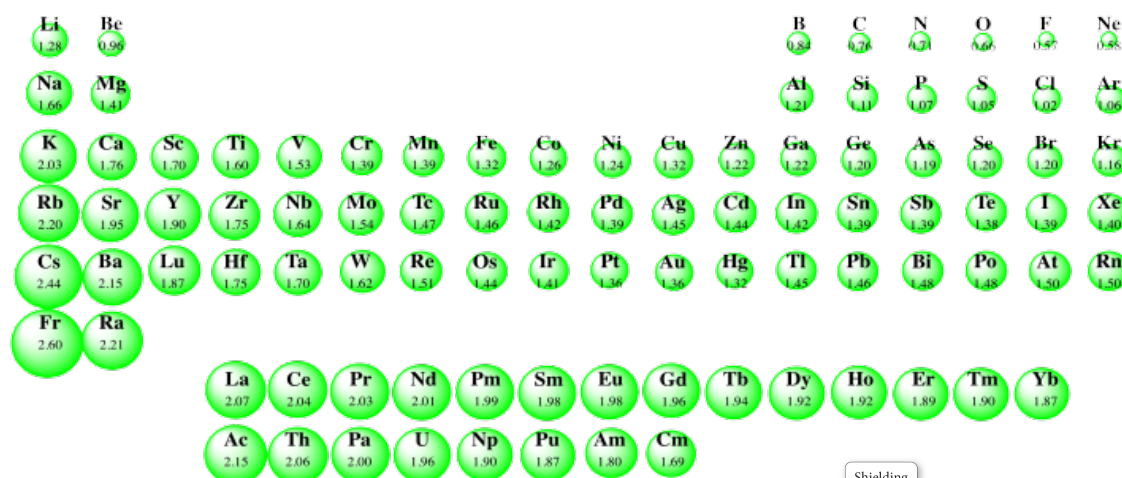
1A 1	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
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19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	113	114	115	116		118

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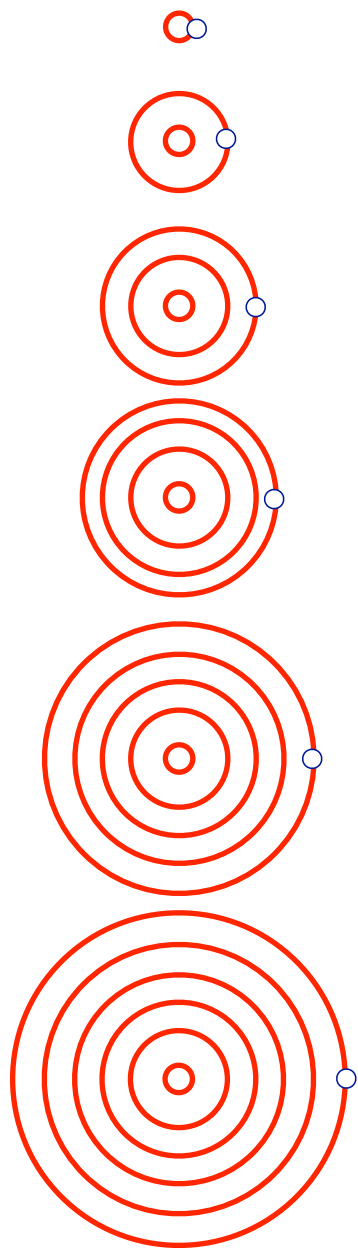
Atomic Size Increases as we go Down

- ▶ Atomic Radius increases as we move down the periodic table because each period represents a new electron shell.
 - ▶ Each shell shields the previous shell from the nuclear charge reducing the pull of electrons to the nucleus.
 - ▶ The electrons in the inner shells repulse the electrons on the outer shells, pushing them farther from the nucleus.
- ▶ Each period corresponds to an increase in the principle quantum number n , which describes the size of that shell.
- ▶ As we add a larger shell, a new layer to the atom, it gets bigger.



Atomic radii increase
down a group.

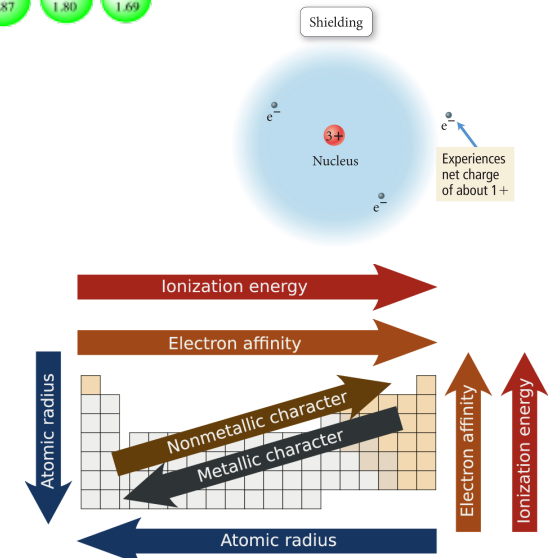
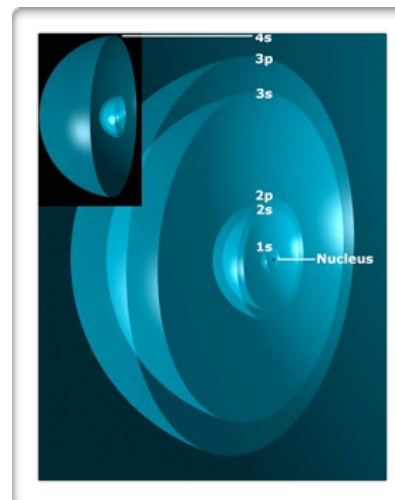
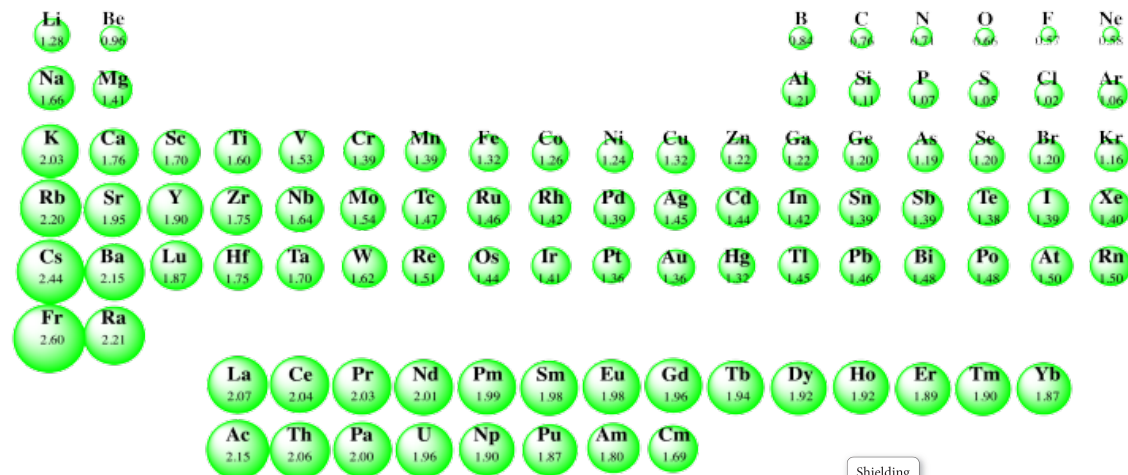
For each step down a group, electrons enter
the next higher energy level.



IA	IIA	IIIA	IVA	VA	VIA	VIIA	Noble gases
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca	Ga	Ge	As	Se	Br	Kr
Rb	Sr	In	Sn	Sb	Te	I	Xe
Cs	Ba	Tl	Pb	Bi	Po	At	Rn

Atom Size decreases as we move Across

- ▶ Atomic Radius decreases as we move across the periodic table because the nuclear charge increases with each new row.
 - ▶ Shielding within a period is minimal.
 - ▶ Electrons have a minimal repulsion within a shell because they are in separate orbitals.
 - ▶ They fit together well.
- ▶ As the effective nuclear charge increases it nuclear attraction all electrons in that shell feel.
- ▶ It tightens the atom.
- ▶ The increased effective nuclear charge pulls all the electrons in the outer shell closer.
- ▶ It makes the atom smaller.





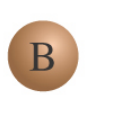







































Radii of atoms tend to decrease from left to right across a period.

Each time an electron is added, a proton is also added to the nucleus.

This increase in positive nuclear charge pulls all electrons closer to the nucleus.

For representative elements within the same period, the energy level remains constant as electrons are added.

IA	IIA	IIIA	IVA	VA	VIA	VIIA	Noble gases
 H							 He
 Li	 Be	 B	 C	 N	 O	 F	 Ne
 Na	 Mg	 Al	 Si	 P	 S	 Cl	 Ar
 K	 Ca	 Ga	 Ge	 As	 Se	 Br	 Kr
 Rb	 Sr	 In	 Sn	 Sb	 Te	 I	 Xe
 Cs	 Ba	 Tl	 Pb	 Bi	 Po	 At	 Rn

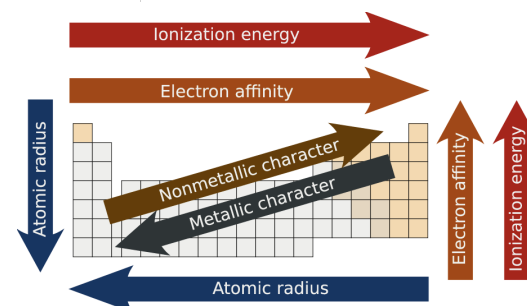
Which Atom is Larger?

- Al or Po

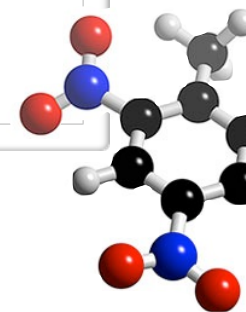
Po

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	Nonmetals														

Within the P block or within the S block, move down the periodic table has a bigger effect than moving across it. But trust this only if the distance is two or more rows or columns.



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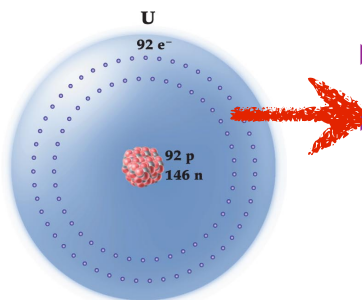
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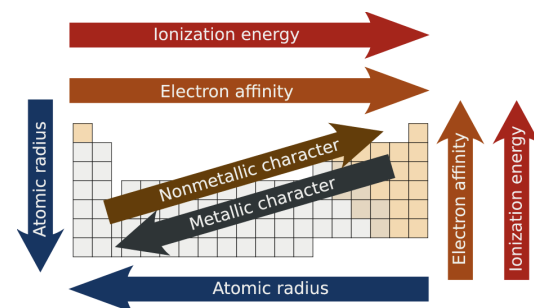
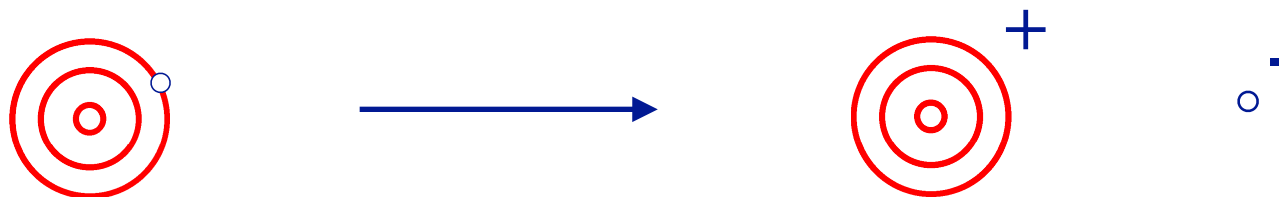


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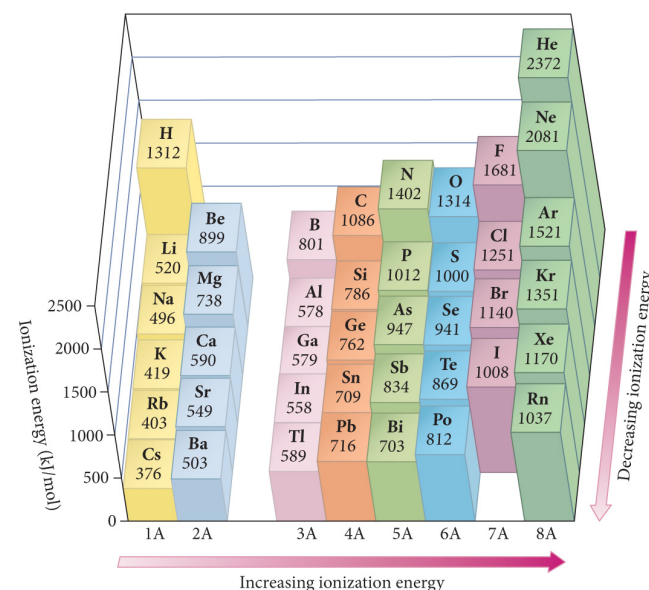
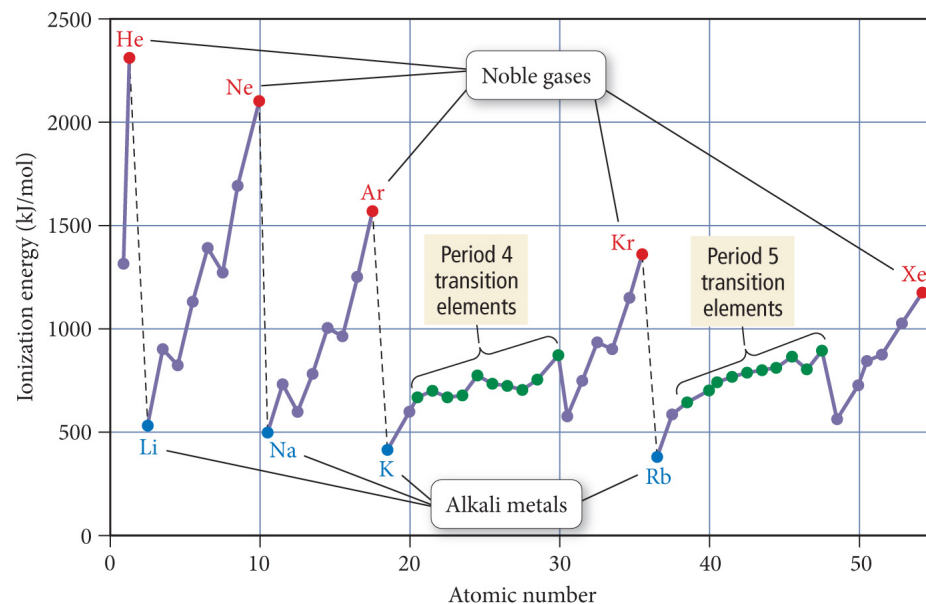


The **ionization energy** of an atom is the energy required to remove an electron from an atom.



Ionization Energy

- ▶ Ionization energy is the energy required to remove an electron from an atom or ion.
- ▶ Ionization energy gets **larger** as you move **across** the periodic table from left to right.
 - ▶ As you move across the periodic table, the effective nuclear charge increases.
 - ▶ The pull on each electron in the outermost shell increases.
 - ▶ So it's harder to remove those electrons.
- ▶ Ionization energy gets **smaller** as you move **down** the periodic table.
 - ▶ As you move down the periodic table the radius of the valence shell increases.
 - ▶ While nuclear charge increases, shielding reduces the effect of that increased nuclear charge.
 - ▶ The outer electrons are held more loosely.
 - ▶ It's easier to remove electrons from these larger shells.
- ▶ Noble gases are almost impossible to ionize.
- ▶ Of the remaining elements, **Fluorine is the king**, as you get farther from Fluorine it becomes easier to steal electrons.
- ▶ Hydrogen is an exception to the pattern.

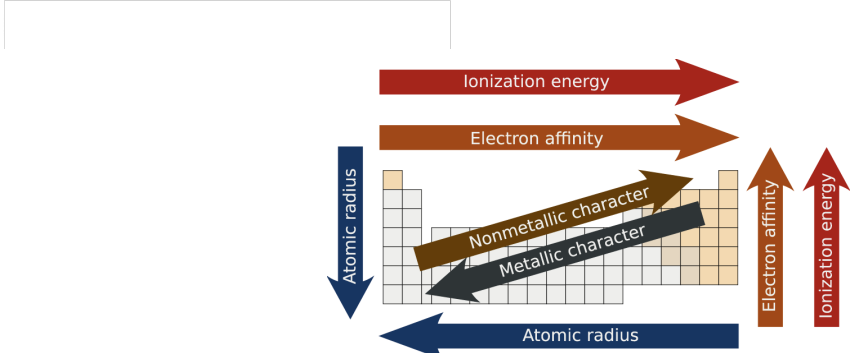


Which Element has a higher IE?

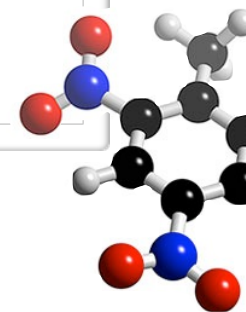
- Al or Ge

Unclear

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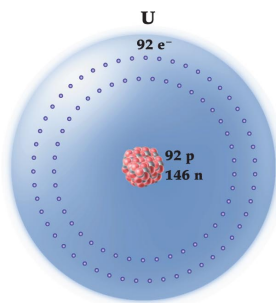
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Questions?

