

Chapter Eight

The Periodic Table

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
138.905	140.12	140.908	144.24	144.913	150.36	151.964	157.25	158.925	162.50	164.930	167.259	168.934	173.054	174.967
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lrutherfordium
227.033	232.038	231.036	238.029	237.048	244.064	243.061	247.065	247.067	251.077	252.083	257.105	258.10	259.108	262

Alkali Metals Alkaline Earths Transition Metals Rare Metals Semimetals Nonmetals Halogens Noble Gases Lanthanides Actinides

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The Modern Periodic Table

- Representative Elements: (main group elements)
 - Incomplete s or p shell determine elemental properties
- Transition metals – d orbitals also play a role in bonding

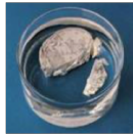
1 1A H	2 2A He											13 3A B	14 4A C	15 5A N	16 6A O	17 7A F	18 8A Ne
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	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	57 La	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	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	(113)	114	(115)	116	(117)	(118)

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

Some Groups in the Periodic Table

Alkali Metals

- Group 1A
- +1 charge
- Highly reactive



Alkali Earth Metals

- Group 2A
- +2 charge
- Reactive



Halogens

- Group 7A
- -1 charge
- Highly reactive if single atoms
- Diatomic molecules



Metalloids

- Some characteristics of metals, some of nonmetals
- semiconductors



Periodic Table of the Elements

Legend:

- Alkali metals
- Alkaline earth metals
- Transition metals
- Post-transition metals
- Metals
- Other nonmetals
- Nonmetals
- Unknown properties

Legend:

- Atomic number
- Element symbol
- Element name
- Atomic weight

Transition metals

- Center of table
- Varying (+) charge
- Use Roman numerals

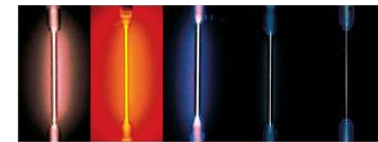


Lanthanides & Actinides

- Bottom of table
- Very reactive
- + charge
- Often radioactive

Noble Gases

- Group 8A
- + charge (if charged)
- Inert (least reactive)



Valence and Core Electrons

Valence electrons:

- Highest energy shell (largest principle quantum #, n)
- Furthest from nucleus
- Outermost electrons
- Available for bonding
 - Determine the behavior of the atom

Core electrons

- Located on the inside in inner shells.
- Principal quantum number is lower

Example

Oxygen, O

$Z = 8$

valence electrons

$e^- = 6$

Core electrons

$e^- = 2$

Valence e⁻

$1s^2 2s^2 2p^4$

TABLE 8.1

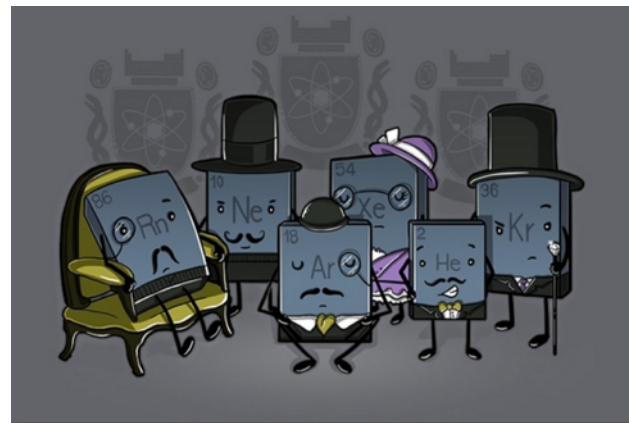
Electron Configurations of Group 1A and Group 2A Elements

Group 1A		Group 2A	
Li	[He]2s ¹	Be	[He]2s ²
Na	[Ne]3s ¹	Mg	[Ne]3s ²
K	[Ar]4s ¹	Ca	[Ar]4s ²
Rb	[Kr]5s ¹	Sr	[Kr]5s ²
Cs	[Xe]6s ¹	Ba	[Xe]6s ²
Fr	[Rn]7s ¹	Ra	[Rn]7s ²

Effect of Valence Electrons on Elements

Octet Rule:

- Elements most stable with 8 valence electrons ($2s + 6p$)
- Noble gases have 8 valence electrons
 - No e^- want to be added or removed
 - Why they are so unreactive
- Main group elements form ions to become isoelectronic with the noble gases
 - Same electron configuration
- He & H follow duet rule
 - $2 e^-$; too small for $8e^-$



Main Group elements – gain or lose s & $p e^-$ to get 8
Transition metals – all form cations – remove e^- from s orbital before d orbital (ie $4s e^-$ lost before $3d e^-$)

Periodic Properties in Main Group Elements

Table of Pauling Electronegativity Values																	
IA												VIIIA					
1	2											5	6	7	8	9	10
H	He											B	C	N	O	F	Ne
2.1												2.0	2.5	3.0	3.5	4.0	
3	4											13	14	15	16	17	18
Li	Be											Al	Si	P	S	Cl	Ar
1.0	1.5											1.5	1.8	2.1	2.5	3.0	
11	12	IIIB	IVB	VB	VIB	VIIIB	VIII			IB	IIB						
Na	Mg																
0.9	1.2																
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
0.8	1.0	1.3	1.5	1.6	1.6	1.5	1.8	1.8	1.8	1.9	1.6	1.6	1.8	2.0	2.4	2.8	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.2	2.2	2.2	1.9	1.8	1.8	1.8	1.9	2.1	2.5	
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
0.7	0.9											1.8	1.9	1.9	2.0	2.2	
87	88	89	104	105	106	107	108	109	110	111	112			114		116	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									
0.7	0.9																
Lanthanides		58	59	60	61	62	63	64	65	66	67	68	69	70	71		
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
Actinides		90	91	92	93	94	95	96	97	98	99	100	101	102	103		
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

Trends in the Periodic Table

Effective Nuclear Charge (Z_{eff})

- The attractive force felt by an electron in an atom
- Takes into account two things:
 - The actual nuclear charge (Z)
 - The repulsive effects of the other electrons (referred to as **shielding** effects)
 - Most shielding is due to core electrons
- Depends on size of nucleus & energy level

Francium:
Valence electrons
experience low Z_{eff}

Periodic Table of the Elements

The table shows elements color-coded by groups: Alkali metals (yellow), Alkaline earth metals (orange), Transition metals (green), Post-transition metals (light green), Metalloids (purple), Nonmetals (blue), and Noble gases (pink). Element symbols and atomic numbers are provided for each element.

Fluorine:
Valence electrons
experience high Z_{eff}

Trends in the Periodic Table

When looking at trends, consider 3 things:

- Amount of positive charge in nucleus (Z)
- Distance of the electron from the nucleus (Energy level)
- Number of other electrons between the electron in question and the nucleus (Shielding)



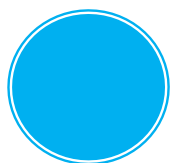
Lithium

- 3 protons
- 2nd energy level
- 2 core electrons

Fluorine



- 9 protons
- 2nd energy level
- 2 core electrons



Rubidium

- 37 protons
- 5th energy level
- 36 core electrons

Iodine



- 53 protons
- 5th energy level
- 46 core electrons

Atomic Radius

Atomic radius increases from top to bottom in a group/column

- Electrons are shielded from nucleus
- Previous shells blocks attraction
- Effective nuclear charge decreases
- Large size difference between shells



Atomic radius decreases from left to right across a row/period

- Little shielding as all electrons in same shell
- Effective nuclear charge higher as protons added
- Electrons pulled closer to nucleus

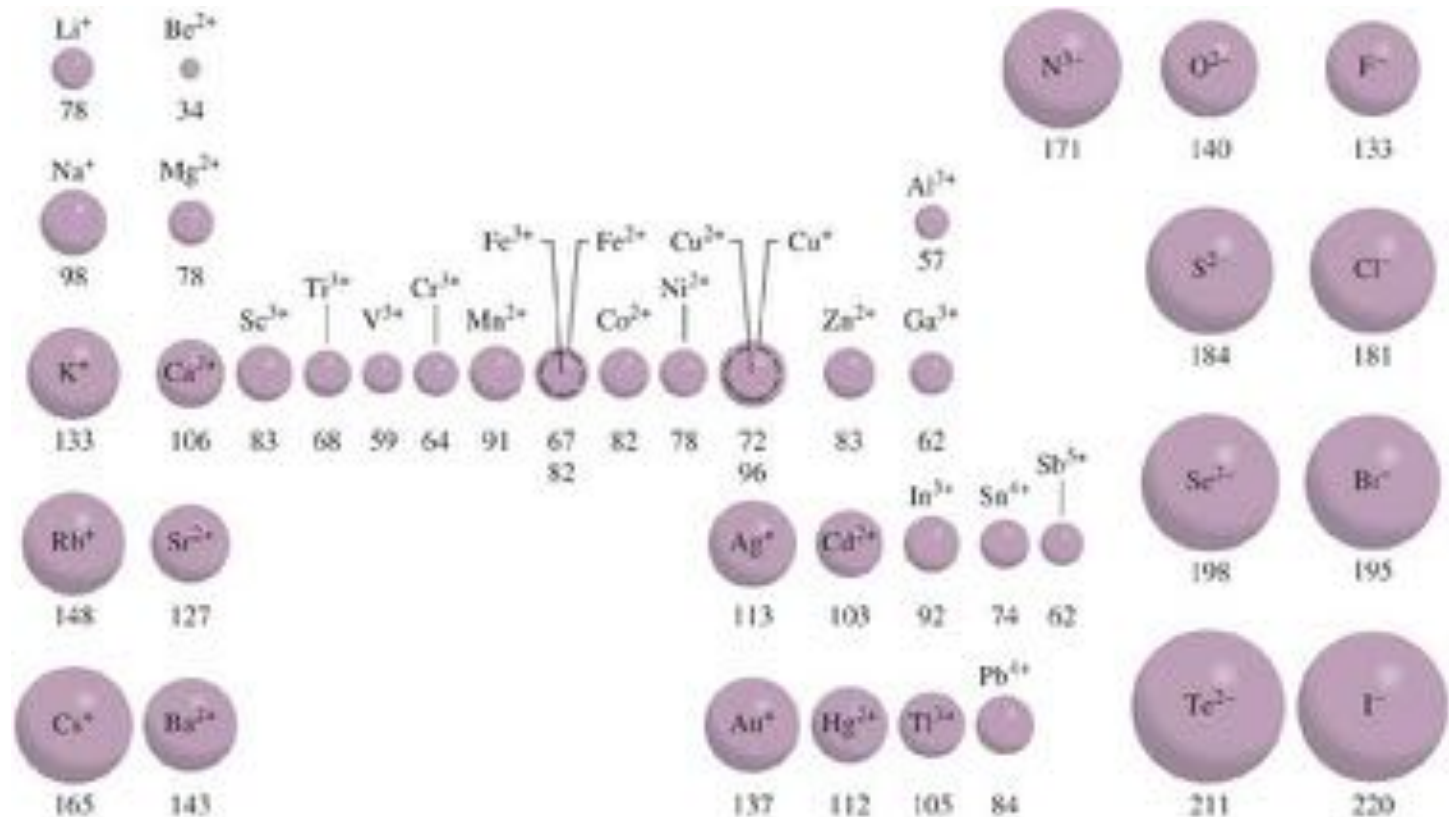
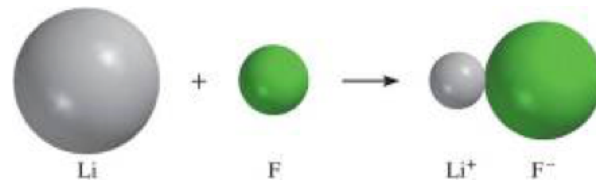
Ionic Radius

•Low effective nuclear charge •High effective nuclear charge

•More electrons •Fewer electrons

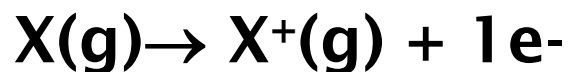
•More repulsion •Less repulsion





Ionization Energy

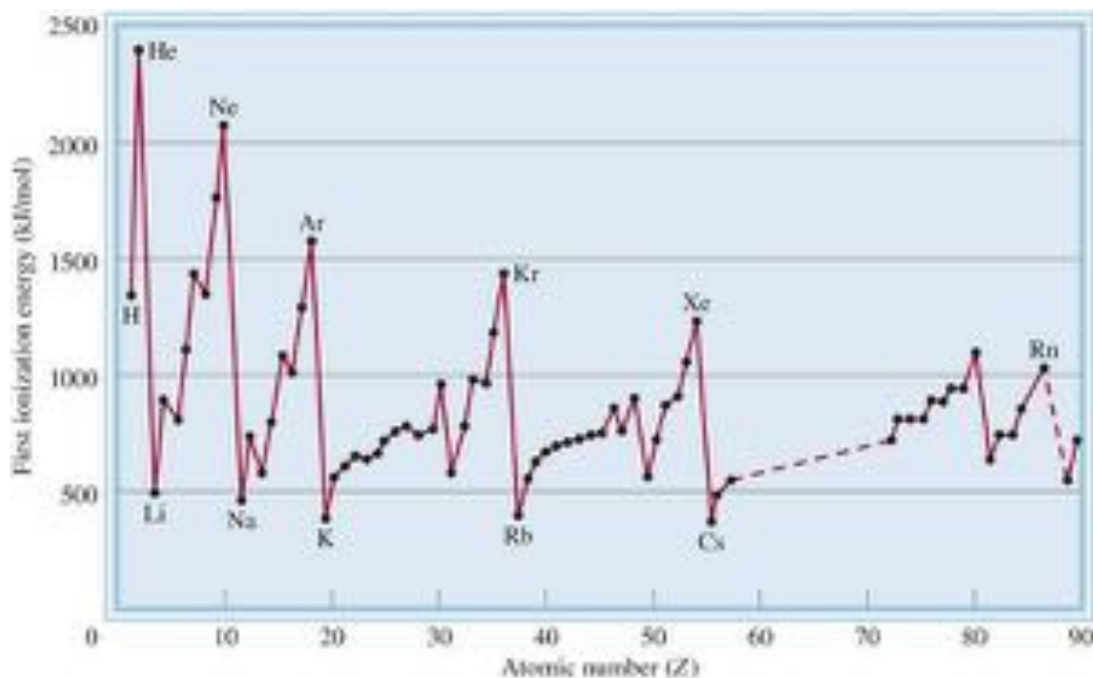
Energy needed to remove an e⁻ from a gaseous atom or ion



Endothermic Process

Decreases top to bottom: Bigger atom = more shielding

Increases from left to right: Atoms want to gain electrons



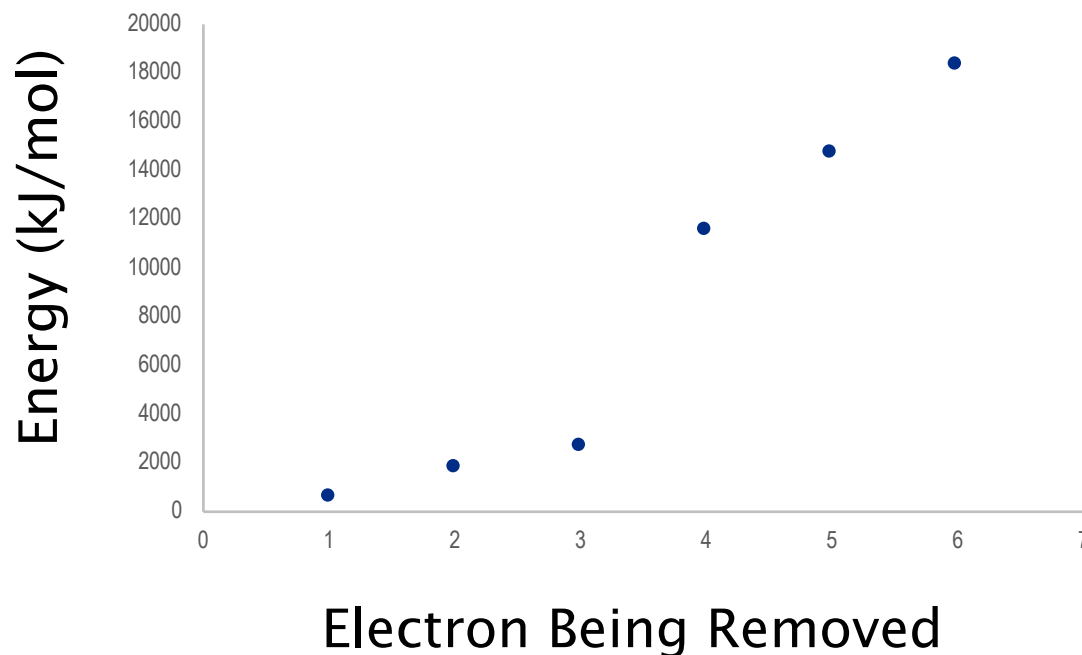
Ionization Energy con't

3rd ionization energy > 2nd > 1st:

- takes less energy to remove the first electron
- 2nd , 3rd , 4th , etc. electrons are held more strongly

Very large jump once all valence e⁻ have been removed

Ionization Energies of Aluminum



Elemental Ionization Energies

TABLE 8.2 The Ionization Energies (kJ/mol) of the First 20 Elements

Z	Element	First	Second	Third	Fourth	Fifth	Sixth
1	H	1,312					
2	He	2,373	5,251				
3	Li	520	7,300	11,815			
4	Be	899	1,757	14,850	21,005		
5	B	801	2,430	3,660	25,000	32,820	
6	C	1,086	2,350	4,620	6,220	38,000	47,261
7	N	1,400	2,860	4,580	7,500	9,400	53,000
8	O	1,314	3,390	5,300	7,470	11,000	13,000
9	F	1,680	3,370	6,050	8,400	11,000	15,200
10	Ne	2,080	3,950	6,120	9,370	12,200	15,000
11	Na	495.9	4,560	6,900	9,540	13,400	16,600
12	Mg	738.1	1,450	7,730	10,500	13,600	18,000
13	Al	577.9	1,820	2,750	11,600	14,800	18,400
14	Si	786.3	1,580	3,230	4,360	16,000	20,000
15	P	1,012	1,904	2,910	4,960	6,240	21,000
16	S	999.5	2,250	3,360	4,660	6,990	8,500
17	Cl	1,251	2,297	3,820	5,160	6,540	9,300
18	Ar	1,521	2,666	3,900	5,770	7,240	8,800
19	K	418.7	3,052	4,410	5,900	8,000	9,600
20	Ca	589.5	1,145	4,900	6,500	8,100	11,000

Electron Affinity

Energy released when an e^- is added to a gaseous atom



- Decreases top to bottom
- Increases left to right
- Fluorine at top right
 - small atom
 - limited shielding
 - nucleus relatively large compared to overall size

Exothermic Process

1A	2A	3A	4A	5A	6A	7A	8A
H							He
73							< 0
Li	Be	B	C	N	O	F	Ne
60	≤ 0	27	122	0	141	328	< 0
Na	Mg	Al	Si	P	S	Cl	Ar
53	≤ 0	44	134	72	200	349	< 0
K	Ca	Ga	Ge	As	Se	Br	Kr
48	2.4	29	118	77	195	325	< 0
Rb	Sr	In	Sn	Sb	Te	I	Xe
47	4.7	29	121	101	190	295	< 0
Cs	Ba	Tl	Pb	Bi	Po	At	Rn
45	14	30	110	110	?	?	< 0

2nd electron affinities lower: Ion is already negative – doesn't want to add more negative charges

Electronegativity: measure of attraction for e^- in a chemical bond
 – follows similar trend; F has greatest electronegativity