1-1-4. The periodic properties of elements

The stable filled electron configuration

$$1s^2 \mid 2s^2\ 2p^6 \mid 3s^2\ 3p^6 \mid 4s^2\ 3d^{10}\ 4p^6 \mid 5s^2\ 4d^{10}\ 5p^6 \mid 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6 \mid \cdots$$

He　Ne　Ar　Kr　Xe　Rn

Inert element or inert gas

At the periodic table

Alkali element : one more electron on the closed shell.

Alkaline earth element : two more electrons on the closed shell.

Transition elements : have the outmost electron on the 3d, 4d or 5d subshells.

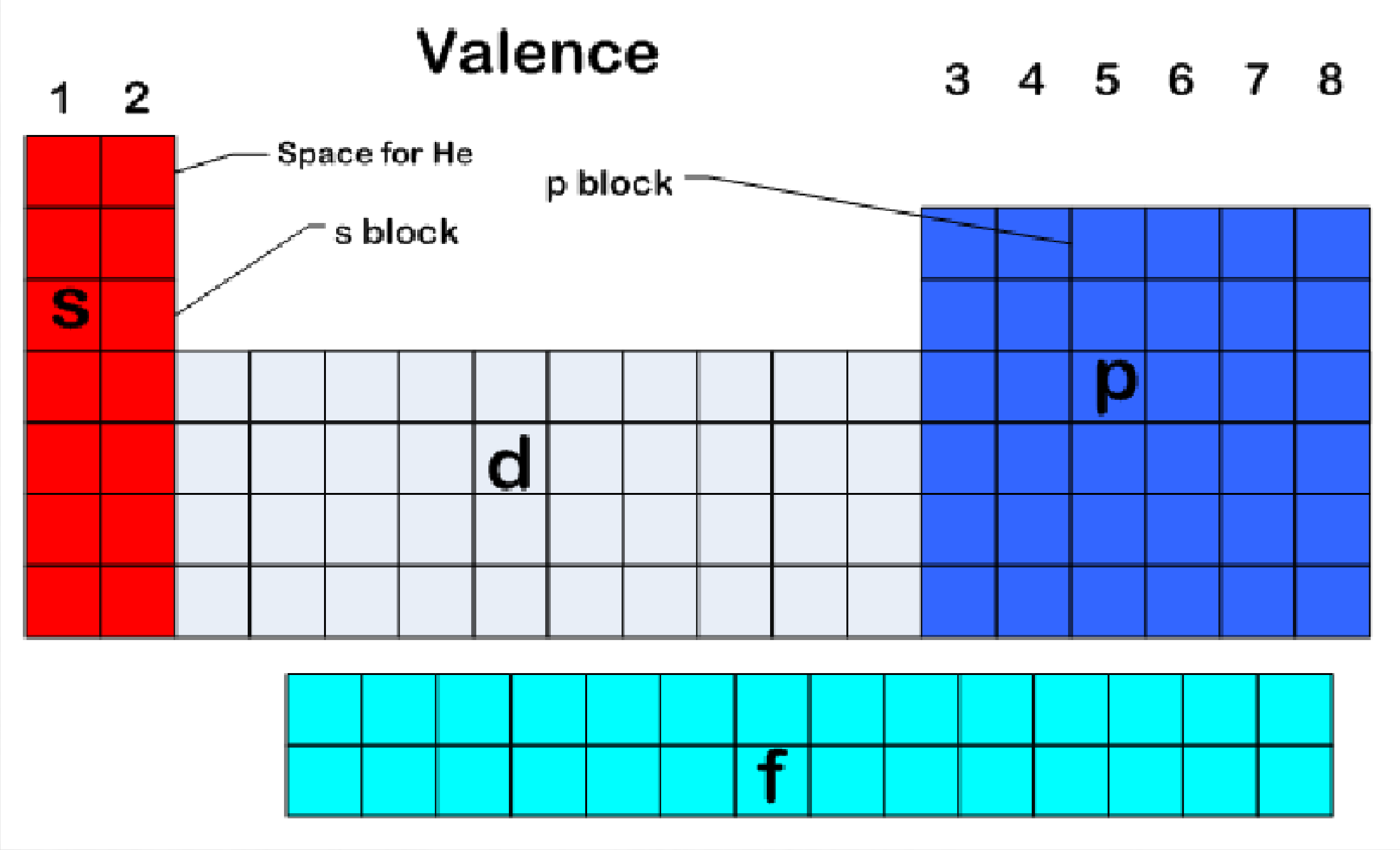
Lanthanide and actinide elements: have the outmost electron on the 4f and 5f subshell.

- **Periodic Trends**

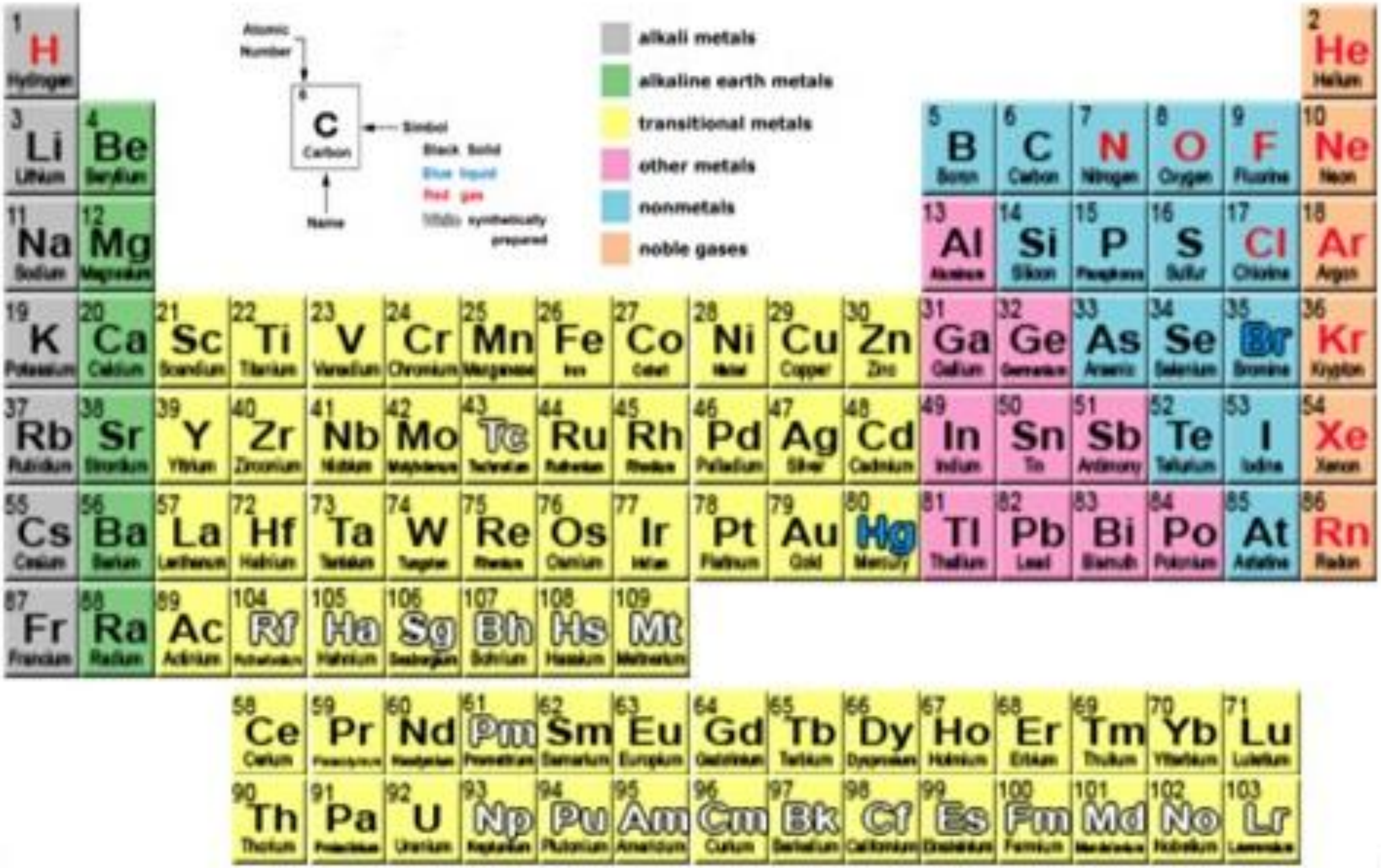
The historical **periodic table was an arrangement of the known elements ranked by either increasing mass or atomic number** such that chemically similar elements were grouped together. As experimental techniques improved and the arrangement was refined, a host of physical and chemical properties were found to fall in cyclic patterns when the elements were arranged by atomic number. The name ‘periodic’ comes from the mathematical term for a repeating function.

- **Valence**

The valence is the number of outer shell electrons. These are the electrons available to take part in chemical reactions, so it is important for us to know their number and how tightly they are attracted to the nucleus. The periodic trend for valence works well for the representative elements, which are in groups 1, 2, 13, 14, 15, 16, 17, and 18 (the ‘tall’ parts of the table). Reading left to right, the valence for each of the main groups increases from one to 8. The noble gas elements, with 8 valence electrons, are especially stable. From this information we can deduce the octet rule and the common monatomic ion charges.


Valence
1
2
3
4
5
6
7
8
Space for He
s block
p block
s
d
p
f

Periodic table of elements



Periodic table of elements

비금속원소

금속원소

전이원소

위의 것 이외는 전형원소

원자번호 → 1 H ← 원소기호, 수소 ← 원소명, 1.0 ← 원자량

[ ]내의 수치는 가장 안정적인 동위체의 질량수를 나타냄

주기 \ 족	1A	2A	3A	4A	5A	6A	7A	8	8	8	1B	2B	3B	4B	5B	6B	7B	0
1	1 H 수소 1.0																	2 He 헬륨 4.0
2	3 Li 리튬 6.9	4 Be 베릴륨 9.0											5 B 붕소 10.8	6 C 탄소 12.0	7 N 질소 14.0	8 O 산소 16.0	9 F 플루오르 19.0	10 Ne 네온 20.2
3	11 Na 나트륨 23.0	12 Mg 마그네슘 24.3											13 Al 알루미늄 27.0	14 Si 규소 28.1	15 P 인 31.0	16 S 황 32.1	17 Cl 염소 35.5	18 Ar 아르곤 39.9
4	19 K 칼륨 39.1	20 Ca 칼슘 40.1	21 Sc 스칸듐 45.0	22 Ti 티탄 47.9	23 V 바나듐 50.9	24 Cr 크롬 52.0	25 Mn 망간 54.9	26 Fe 철 55.8	27 Co 코발트 58.9	28 Ni 니켈 58.7	29 Cu 구리 63.5	30 Zn 아연 65.4	31 Ga 갈륨 69.7	32 Ge 게르마늄 72.6	33 As 비소 74.9	34 Se 셀렌 79.0	35 Br 브롬 79.9	36 Kr 크립톤 83.8
5	37 Rb 루비듐 85.5	38 Sr 스트론튬 87.6	39 Y 이트륨 88.9	40 Zr 지르코늄 91.2	41 Nb 니오브 92.9	42 Mo 몰리브덴 95.9	43 Tc 테크네튬 [97]	44 Ru 루테늄 101.1	45 Rh 로듐 102.9	46 Pd 팔라듐 106.4	47 Ag 은 107.9	48 Cd 카드뮴 112.4	49 In 인듐 114.8	50 Sn 주석 118.7	51 Sb 안티몬 121.8	52 Te 텔루르 127.6	53 J 요오드 126.9	54 Xe 크세논 131.3
6	55 Cs 세슘 132.9	56 Ba 바륨 137.3	57~71 란탄족	72 Hf 하프늄 178.5	73 Ta 탄탈 180.9	74 W 텅스텐 183.9	75 Re 레늄 186.2	76 Os 오스뮴 190.2	77 Ir 이리듐 192.2	78 Pt 백금 195.1	79 Au 금 197.0	80 Hg 수은 200.6	81 Tl 탈륨 204.4	82 Pb 납 207.2	83 Bi 비스무트 209.0	84 Po 폴로늄 [209]	85 At 아스타틴 [210]	86 Rn 라돈 [222]
7	87 Fr 프랑슘 [223]	88 Ra 라듐 226.0	89~103 악티늄족															
족의 일반명	알칼리 금속	알칼리 토류 금속	희토족	티탄족	토산금속족	크롬족	망간족	철족(위의 3개 원소) 백금족(아래의 6개 원소)			구리족	아연족	알루미늄족	탄소족	질소족	산소족	할로겐족	불활성 가스

란탄족	57 La 란탄 138.9	58 Ce 세륨 140.1	59 Pr 프라세오디뮴 140.9	60 Nd 네오디뮴 144.2	61 Pm 프로메튬 [145]	62 Sm 사마륨 150.4	63 Eu 유로퓸 152.0	64 Gd 가돌리늄 157.3	65 Tb 테르븀 158.9	66 Dy 디스프로슘 162.5	67 Ho 홀뮴 164.9	68 Er 에르븀 167.3	69 Tm 툴륨 168.9	70 Yb 이테르븀 173.0	71 Lu 루테튬 175.0
악티늄족	89 Ac 악티늄 [227]	90 Th 토륨 232.0	91 Pa 프로탁티늄 231.0	92 U 우라늄 238.0	93 Np 넵투늄 237.0	94 Pu 플루토늄 [244]	95 Am 아메리슘 [243]	96 Cm 퀴륨 [247]	97 Bk 버클륨 [247]	98 Cf 캘리포늄 [251]	99 Es 아인시타이늄 [254]	100 Fm 페르뮴 [257]	101 Md 멘델레븀 [258]	102 No 노벨륨 [255]	103 Lr 로렌슘 [260]

- Electron configuration on the stable state of atoms

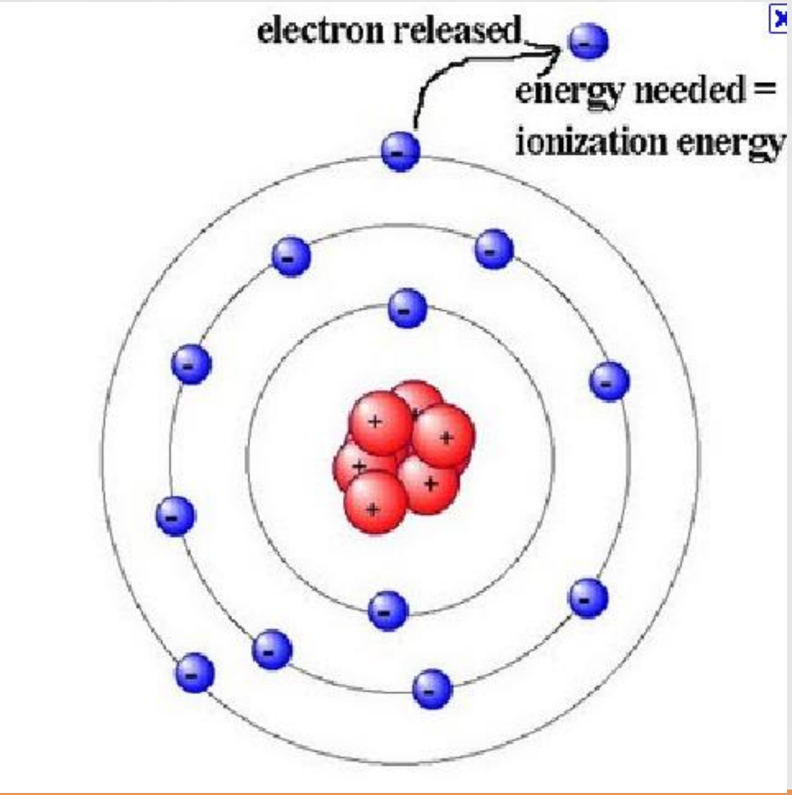
표 1-4 정상 상태에서 원자의 전자 배치.

		He	Ne		Ar		Kr		
		1*s*	2*s*	2*p*	3*s*	3*p*	3*d*	4*s*	4*p*
H	1	1							
He	2	2							
Li	3	2	1						
Be	4	2	2						
B	5	2	2	1					
C	6	2	2	2					
N	7	2	2	3					
O	8	2	2	4					
F	9	2	2	5					
Ne	10	2	2	6					
Na	11					1			
Mg	12					2			
Al	13				2	1			
Si	14	Ne 속			2	2			
P	15				2	3			
S	16				2	4			
Cl	17				2	5			
Ar	18	2	2	6	2	6			
K	19						1		
Ca	20						2		
Sc	21						1	2	
Ti	22						2	2	
V	23						3	2	
Cr	24						5	1	
Mn	25						5	2	
Fe	26						6	2	
Co	27	Ar 속					7	2	
Ni	28						8	2	
Cu	29						10	1	
Zn	30						10	2	
Ga	31						10	2	1
Ge	32						10	2	2
As	33						10	2	3
Se	34						10	2	4
Br	35						10	2	5
Kr	36	2	2	6	2	6	10	2	6

- From the periodic table, we can study the ionization energy, electron affinity, electronegativity, radius of the elements to understand the bonding of atoms.

Ionization Energy

The ionization energy is the amount of energy needed to remove an outer electron. This is harder to do if the electrons are closer to the nucleus, so the trend is the reverse of the radius trend: the ionization energy increases as you go across a period and increases as you go up a row.



Ionization energy (이온화 에너지) of elements

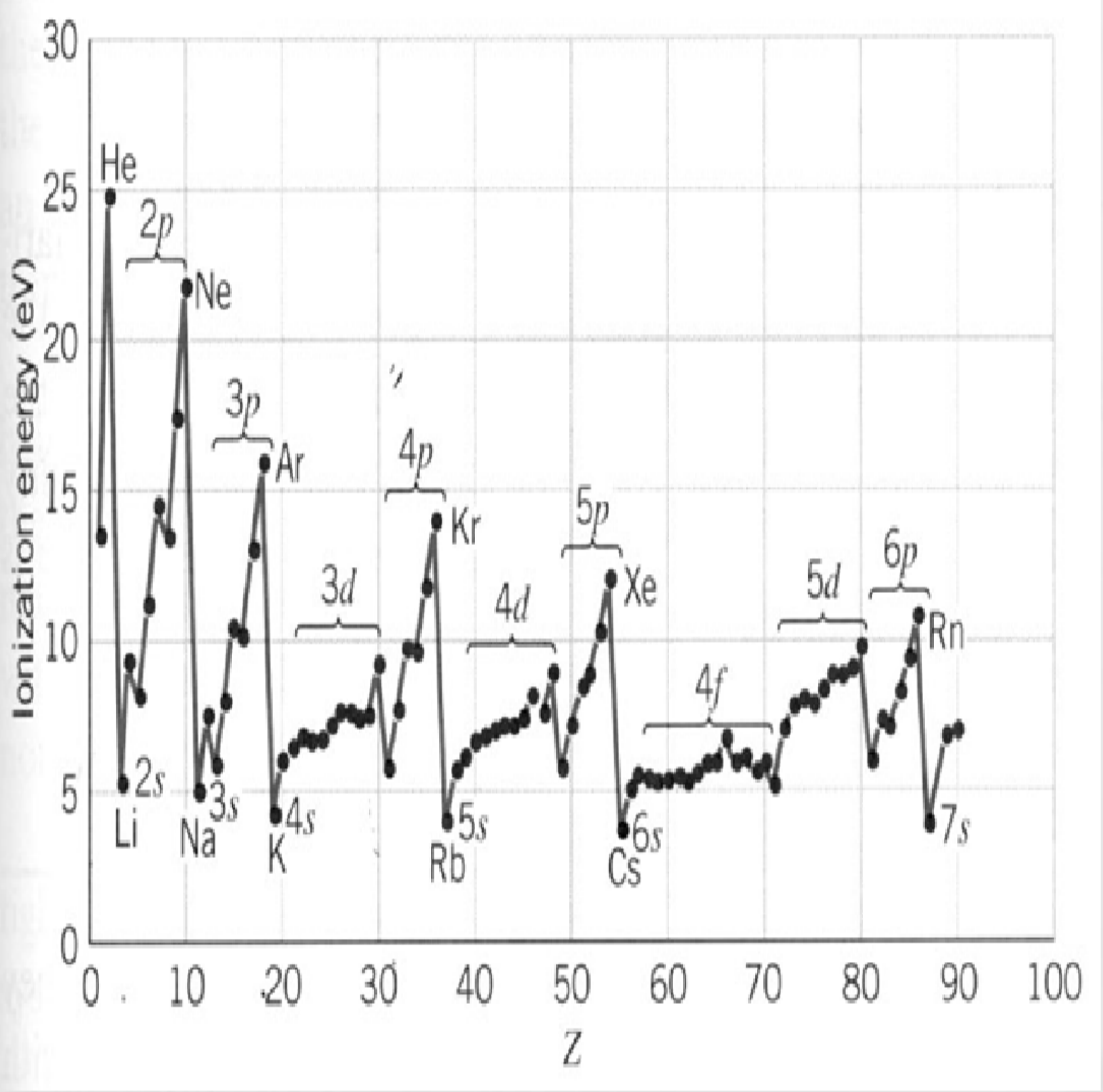
- Alkali metal element have very low ionization energy because they have one electron outside the closed shell.

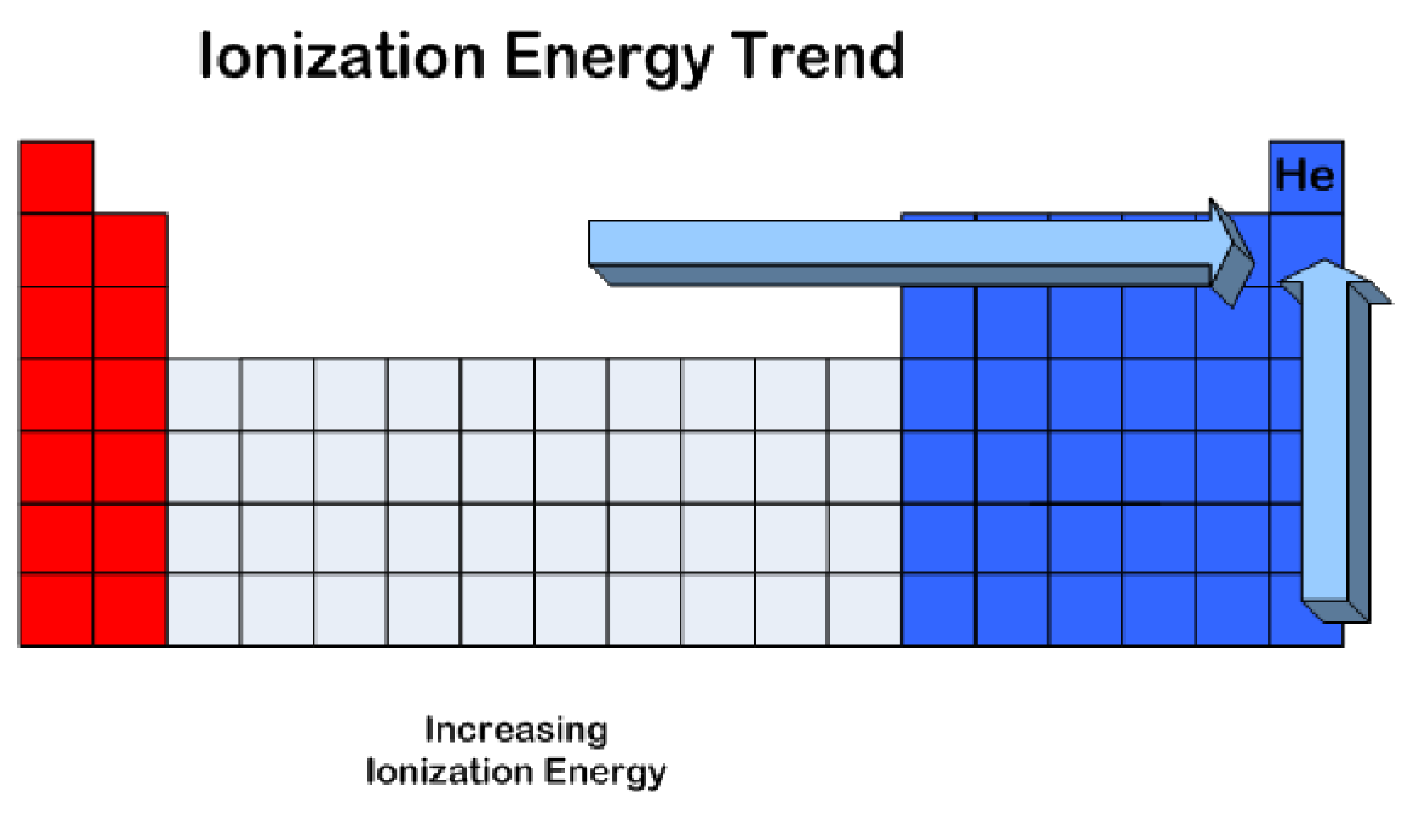
Li(Z=3, first electron on 2s-subshell).

Na(Z=11, first electron on 3s-subshell).

K(Z=19, first electron on 4s-subshell).

Rb(Z=37, first electron on 5s-subshell)





- If you compare the ionizations energies of the noble gases, helium is higher than neon, which is higher than argon, and etc. Helium's outer electron is in shell number one close to the nucleus, so it takes a lot of energy to remove that electron. Neon's outer electron is in shell number two. This is farther from the nucleus and not quite as difficult to remove. Argon's outer electron is in shell number three, farther from the nucleus and easier to remove.

Ionization energy of elements

The electron affinity (전자친화도) of elements

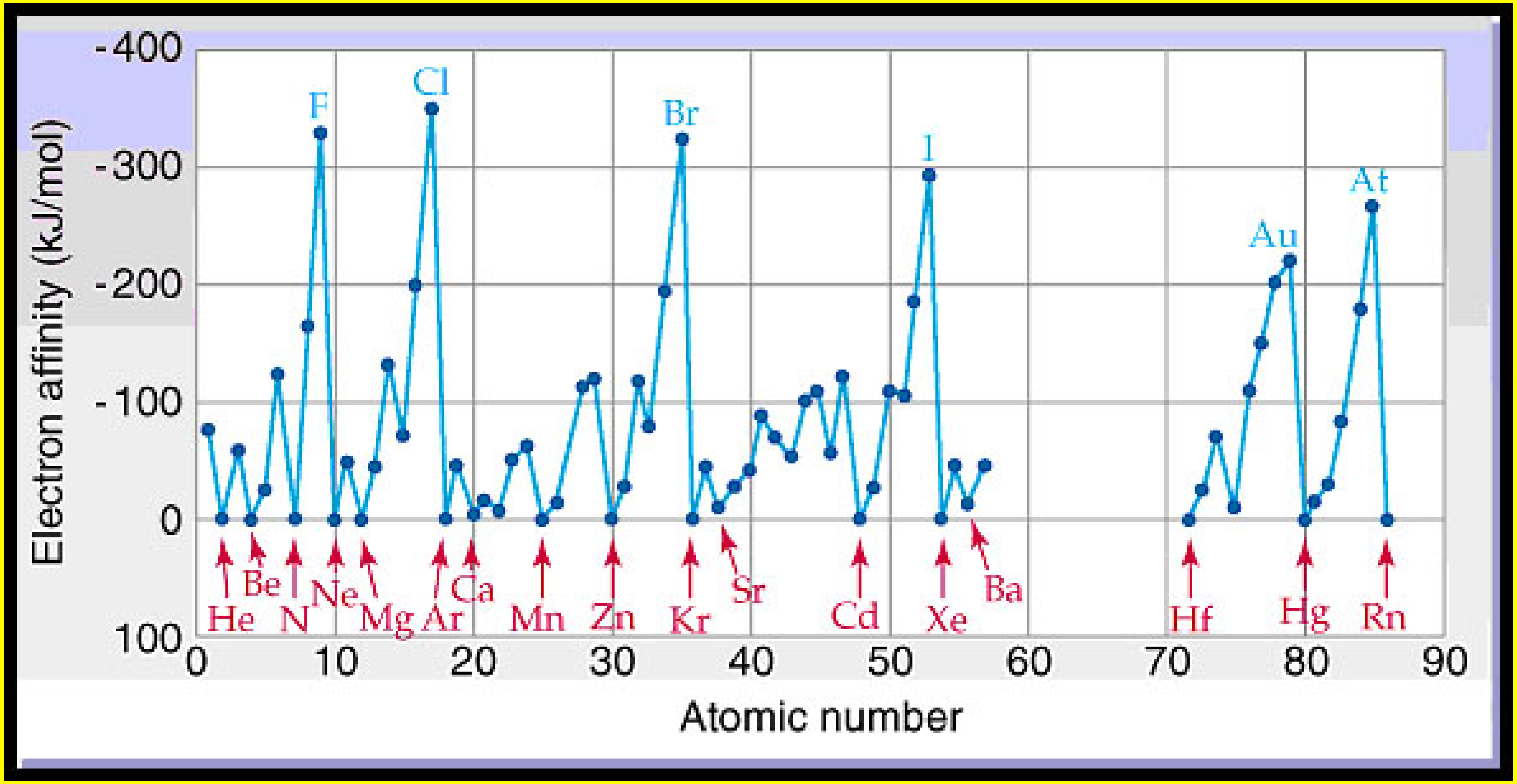
Electron affinity is, essentially the opposite of the ionization energy: Instead of removing an electron from the element we add an electron to the element to create an anion.

M + e- ----> M- E.A.

Generally, the energy that results from this process (the electron affinity) is negative or close to zero. The more negative this energy the more this process is favored. In the figure below we see the trends in the electron affinity for many of the elements.

$$X_{(g)} + e^- \rightarrow X^-_{(g)} + E_1 \qquad (1\text{-}47)$$

The electron affinity (전자친화도) of elements



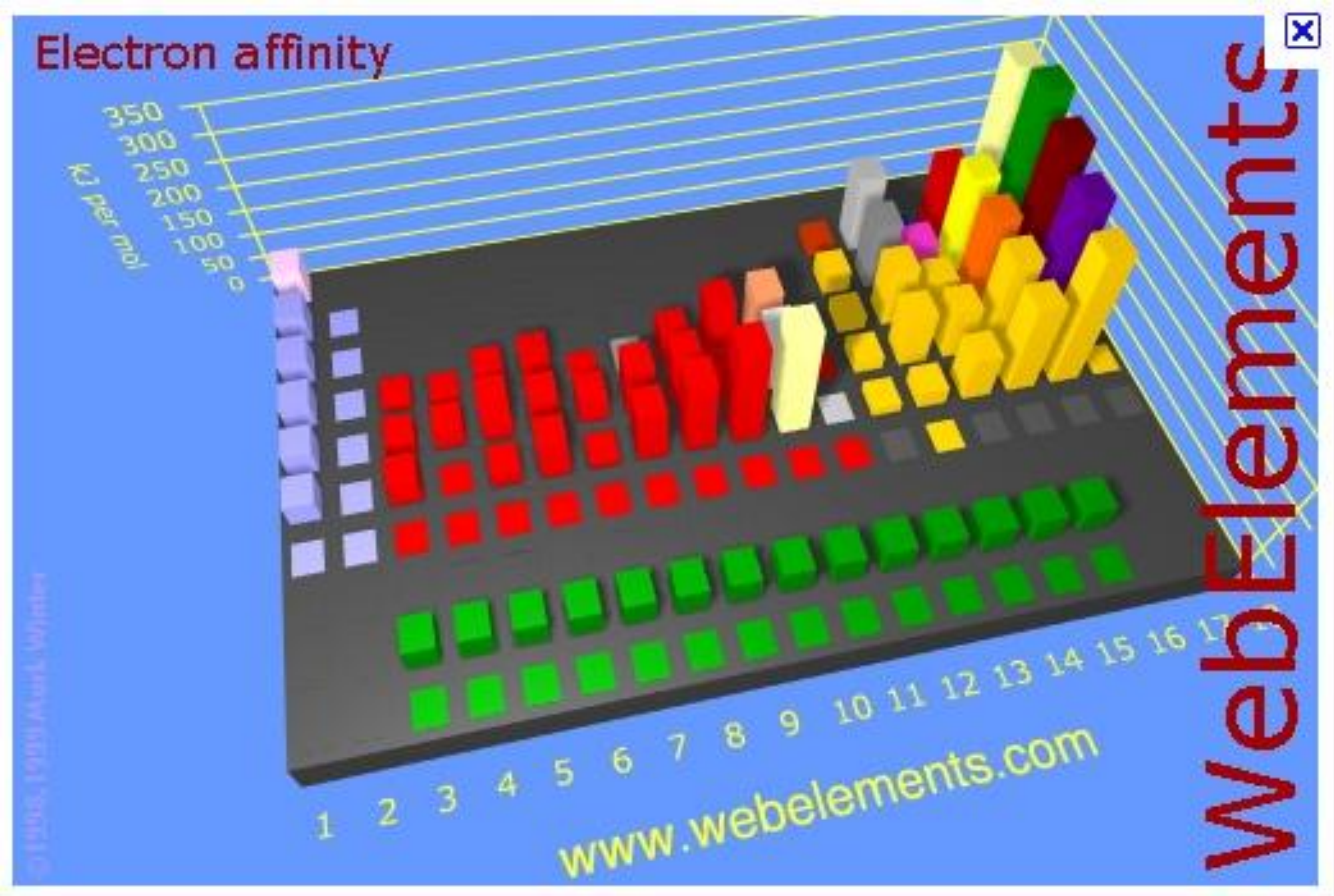
Note that the noble gases, alkali metals and alkali earth metals have E.A. close to zero – indicating that these groups of elements do not particularly like to become anions. However, the nonmetals and especially the halogens are highly negative and thus readily become anions. A periodic trend is evident, as was the case for the ionization energy. This periodic trend can be understood as a reflection of the underlying periodicity in the electronic configuration of the elements.

The electron affinity (전자친화도) of elements

표 1-6 전자 친화도.

원소	eV	kJ mol^{-1}
H	0.75	70
Li	0.5	50
F	3.4	330
Cl	3.6	350
Br	3.4	320
I	3.1	300
O	1.5	140
S	2.1	200

The electron affinity (전자친화도) of elements

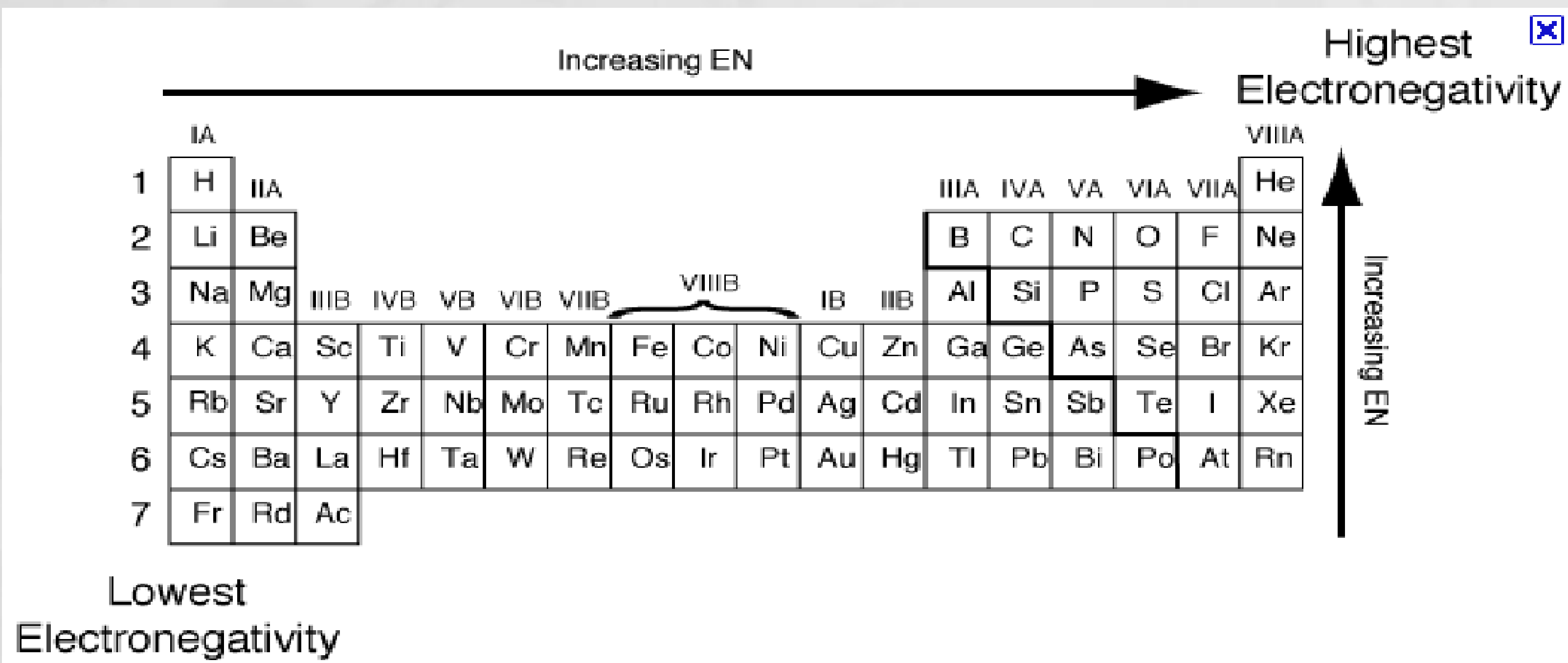


Electronegativity of the elements

- Electronegativity is the strength with which an atom pulls on the electrons it shares in a covalent bond. If the electronegatively values for two bonded atoms are the same, the electrons are shared evenly. A bond of this type is called non-polar. If there is a significant difference in the electronegativity values for two bonded atoms, the electrons are more likely to be found close to one atom than the other. A bond of this type is called polar covalent. Although the atom does not gain an extra electron at another atom's expense, the idea is similar to that of electron affinity.
- ***Electronegativity*** is defined as the ability of an atom in a crystal structure or molecule to attract electrons into its outer shell. Elements with low values of electronegativity are electron donors, and those with high values are electron acceptors. The Noble gases have electronegativity values of zero, because they neither accept or donate electrons. As we will see in our later discussion, electronegativity difference between atoms plays an important role in determining they type of chemical bond that forms between elements.

- The **periodic trend for electronegativity** is the same as for **electron affinity**: it increases from left to right across a period and increases from bottom to top up a group. The positively charged nucleus pulls on the outer electrons, so the smaller the atom the higher the electronegativity. Also like electron affinity, the noble gas group does not obey the trend due to the stability they gain from having full outer shells.

Trend of electronegativity.



Quantitative scale of electronegativity

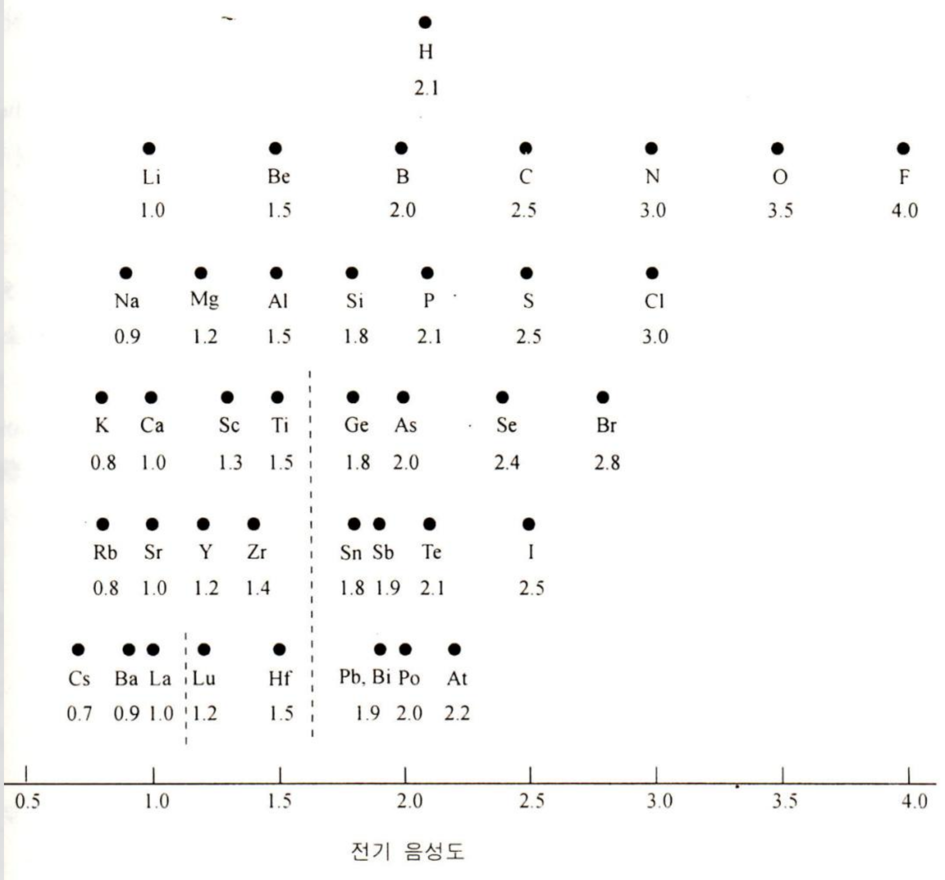
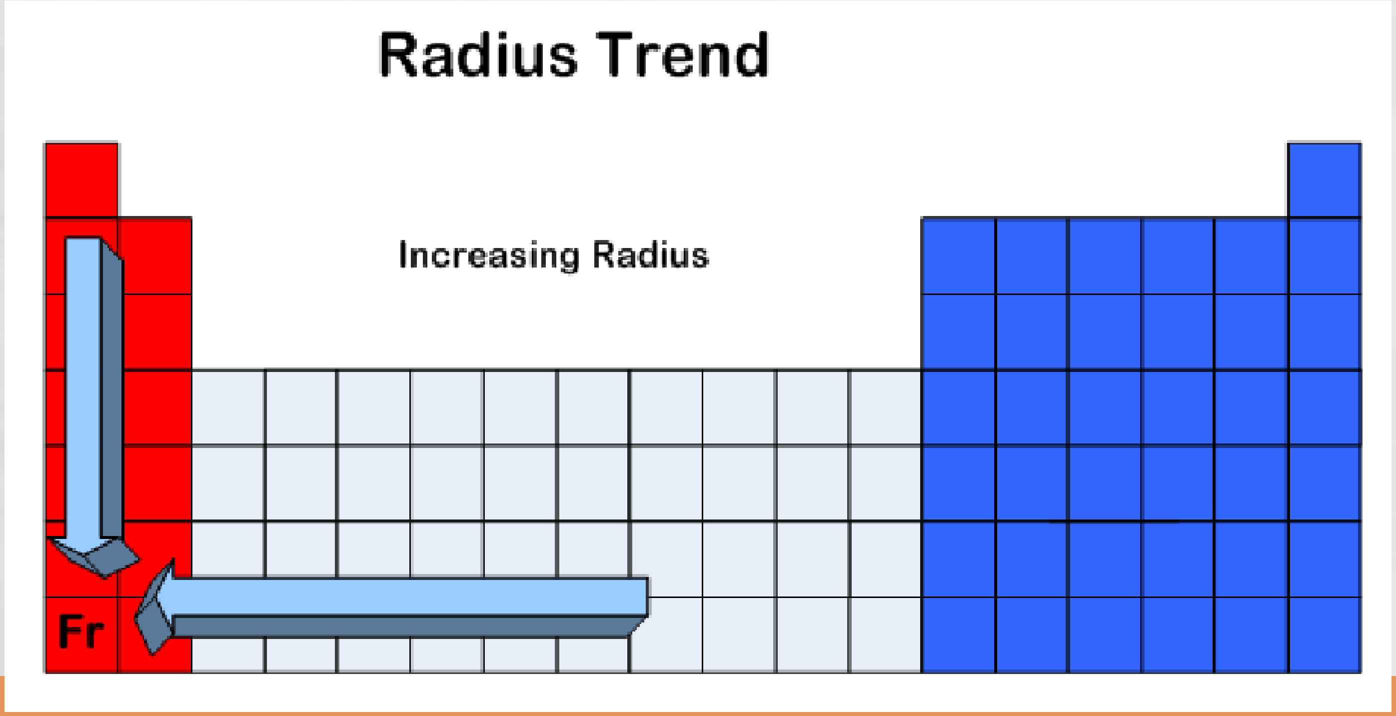


그림 1-16 전기 음성도를 정량적인 척도로 나타낸 그림.

The radius of atom

- One factor that influences the atomic radius is the number of shells that are occupied in an atom's ground state. The greater the value of the principle quantum number is, the farther the electrons are from the nucleus. As you move down a row on the periodic table, the elements have higher numbered shells occupied by electrons. Higher numbered shells have electrons farther from the nucleus, so atoms are bigger as you go down a period.



The radius of atom

- Another factor that influences an atom's size is the effective nuclear charge. Electrons are negative and the nucleus is positive, so they attract one another. Inner core electrons screen some of the positive charge from the outer electrons. As electron count increases, so does proton count. The nucleus gets progressively more positive as you go across a period. As you move across a period, each successive electron enters the same shell.