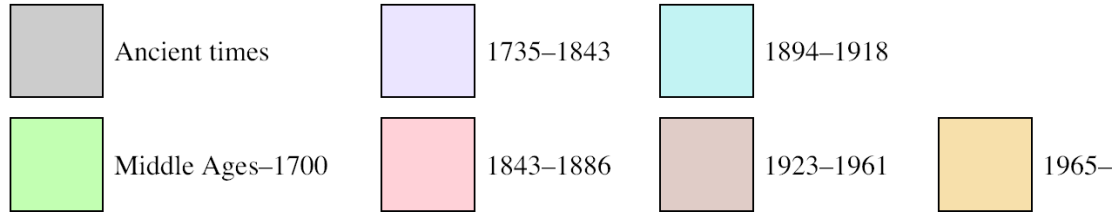


Periodic Relationships Among the Elements

When the Elements Were Discovered



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	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	

Ground State Electron Configurations of the Elements

	ns^1											ns^2					ns^2np^1					ns^2np^2		ns^2np^3		ns^2np^4		ns^2np^5		ns^2np^6																	
	1A											2A					3A		4A		5A		6A		7A		8A																				
1	1 H $1s^1$											2 He $1s^2$																																			
2	3 Li $2s^1$											4 Be $2s^2$					5 B $2s^2 2p^1$		6 C $2s^2 2p^2$		7 N $2s^2 2p^3$		8 O $2s^2 2p^4$		9 F $2s^2 2p^5$		10 Ne $2s^2 2p^6$																				
3	11 Na $3s^1$											12 Mg $3s^2$					13 Al $3s^2 3p^1$		14 Si $3s^2 3p^2$		15 P $3s^2 3p^3$		16 S $3s^2 3p^4$		17 Cl $3s^2 3p^5$		18 Ar $3s^2 3p^6$																				
4	19 K $4s^1$											20 Ca $4s^2$					21 Sc $4s^2 3d^1$		22 Ti $4s^2 3d^2$		23 V $4s^2 3d^3$		24 Cr $4s^1 3d^5$		25 Mn $4s^2 3d^5$		26 Fe $4s^2 3d^6$		27 Co $4s^2 3d^7$		28 Ni $4s^2 3d^8$		29 Cu $4s^1 3d^{10}$		30 Zn $4s^2 3d^{10}$		31 Ga $4s^2 4p^1$		32 Ge $4s^2 4p^2$		33 As $4s^2 4p^3$		34 Se $4s^2 4p^4$		35 Br $4s^2 4p^5$		36 Kr $4s^2 4p^6$
5	37 Rb $5s^1$											38 Sr $5s^2$					39 Y $5s^2 4d^1$		40 Zr $5s^2 4d^2$		41 Nb $5s^1 4d^4$		42 Mo $5s^1 4d^5$		43 Tc $5s^2 4d^5$		44 Ru $5s^1 4d^7$		45 Rh $5s^1 4d^8$		46 Pd $4d^{10}$		47 Ag $5s^1 4d^{10}$		48 Cd $5s^2 4d^{10}$		49 In $5s^2 5p^1$		50 Sn $5s^2 5p^2$		51 Sb $5s^2 5p^3$		52 Te $5s^2 5p^4$		53 I $5s^2 5p^5$		54 Xe $5s^2 5p^6$
6	55 Cs $6s^1$											56 Ba $6s^2$					57 La $6s^2 5d^1$		72 Hf $6s^2 5d^2$		73 Ta $6s^2 5d^3$		74 W $6s^2 5d^4$		75 Re $6s^2 5d^5$		76 Os $6s^2 5d^6$		77 Ir $6s^2 5d^7$		78 Pt $6s^1 5d^9$		79 Au $6s^1 5d^{10}$		80 Hg $6s^2 5d^{10}$		81 Tl $6s^2 6p^1$		82 Pb $6s^2 6p^2$		83 Bi $6s^2 6p^3$		84 Po $6s^2 6p^4$		85 At $6s^2 6p^5$		86 Rn $6s^2 6p^6$
7	87 Fr $7s^1$											88 Ra $7s^2$					89 Ac $7s^2 6d^1$		104 Rf $7s^2 6d^2$		105 Db $7s^2 6d^3$		106 Sg $7s^2 6d^4$		107 Bh $7s^2 6d^5$		108 Hs $7s^2 6d^6$		109 Mt $7s^2 6d^7$		110 Ds $7s^2 6d^8$		111 Rg $7s^2 6d^9$		112 Cn $7s^2 6d^{10}$		113 Nh $7s^2 7p^1$		114 Fl $7s^2 7p^2$		115 Mc $7s^2 7p^3$		116 Lv $7s^2 7p^4$		(117)		118 Og $7s^2 7p^6$

$4f$



$5f$

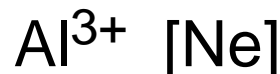
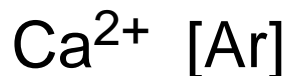
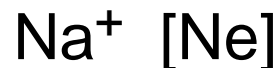


58 Ce $6s^2 4f^1 5d^1$	59 Pr $6s^2 4f^3$	60 Nd $6s^2 4f^4$	61 Pm $6s^2 4f^5$	62 Sm $6s^2 4f^6$	63 Eu $6s^2 4f^7$	64 Gd $6s^2 4f^7 5d^1$	65 Tb $6s^2 4f^9$	66 Dy $6s^2 4f^{10}$	67 Ho $6s^2 4f^{11}$	68 Er $6s^2 4f^{12}$	69 Tm $6s^2 4f^{13}$	70 Yb $6s^2 4f^{14}$	71 Lu $6s^2 4f^{14} 5d^1$
90 Th $7s^2 6d^2$	91 Pa $7s^2 5f^2 6d^1$	92 U $7s^2 5f^3 6d^1$	93 Np $7s^2 5f^4 6d^1$	94 Pu $7s^2 5f^6$	95 Am $7s^2 5f^7$	96 Cm $7s^2 5f^7 6d^1$	97 Bk $7s^2 5f^9$	98 Cf $7s^2 5f^{10}$	99 Es $7s^2 5f^{11}$	100 Fm $7s^2 5f^{12}$	101 Md $7s^2 5f^{13}$	102 No $7s^2 5f^{14}$	103 Lr $7s^2 5f^{14} 6d^1$

Classification of the Elements

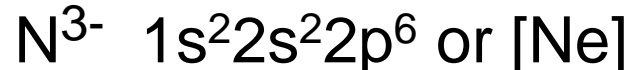
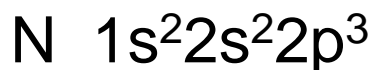
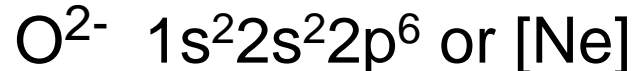
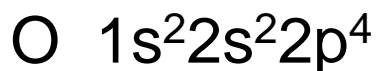
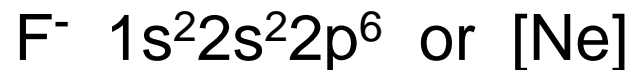
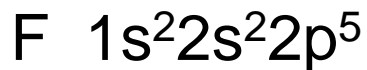
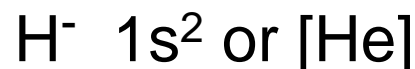
1 1A																	18 8A	
1 H	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He	
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B		10	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32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

Electron Configurations of Cations and Anions Of Representative Elements



Atoms lose electrons so that cation has a noble-gas outer electron configuration.

Atoms gain electrons so that anion has a noble-gas outer electron configuration.



Cations and Anions Of Representative Elements

	+1 1A	+2 2A										+3 3A	+4 4A	+5 5A	+6 6A	+7 7A	18 8A	
1	H 1s ¹	He 1s ²										B 2s ² 2p ¹	C 2s ² 2p ²	N 2s ² 2p ³	O 2s ² 2p ⁴	F 2s ² 2p ⁵	Ne 2s ² 2p ⁶	
2	Li 2s ¹	Be 2s ²										Al 3s ² 3p ¹	Si 3s ² 3p ²	P 3s ² 3p ³	S 3s ² 3p ⁴	Cl 3s ² 3p ⁵	Ar 3s ² 3p ⁶	
3	Na 3s ¹	Mg 3s ²	3 3B	4 4B	5 5B	6 6B	7 7B	8B		11 1B	12 2B	13 3s ² 3p ¹	14 3s ² 3p ²	15 3s ² 3p ³	16 3s ² 3p ⁴	17 3s ² 3p ⁵	18 3s ² 3p ⁶	
4	K 4s ¹	Ca 4s ²	21 Sc 4s ² 3d ¹	22 Ti 4s ² 3d ²	23 V 4s ² 3d ³	24 Cr 4s ¹ 3d ⁵	25 Mn 4s ² 3d ⁵	26 Fe 4s ² 3d ⁶	27 Co 4s ² 3d ⁷	28 Ni 4s ² 3d ⁸	29 Cu 4s ¹ 3d ¹⁰	30 Zn 4s ² 3d ¹⁰	31 Ga 4s ² 4p ¹	32 Ge 4s ² 4p ²	33 As 4s ² 4p ³	34 Se 4s ² 4p ⁴	35 Br 4s ² 4p ⁵	36 Kr 4s ² 4p ⁶
5	Rb 5s ¹	Sr 5s ²	39 Y 5s ² 4d ¹	40 Zr 5s ² 4d ²	41 Nb 5s ¹ 4d ⁴	42 Mo 5s ¹ 4d ⁵	43 Tc 5s ² 4d ⁵	44 Ru 5s ¹ 4d ⁷	45 Rh 5s ¹ 4d ⁸	46 Pd 4d ¹⁰	47 Ag 5s ¹ 4d ¹⁰	48 Cd 5s ² 4d ¹⁰	49 In 5s ² 5p ¹	50 Sn 5s ² 5p ²	51 Sb 5s ² 5p ³	52 Te 5s ² 5p ⁴	53 I 5s ² 5p ⁵	54 Xe 5s ² 5p ⁶
6	Cs 6s ¹	Ba 6s ²	57 La 6s ² 5d ¹	72 Hf 6s ² 5d ²	73 Ta 6s ² 5d ³	74 W 6s ² 5d ⁴	75 Re 6s ² 5d ⁵	76 Os 6s ² 5d ⁶	77 Ir 6s ² 5d ⁷	78 Pt 6s ¹ 5d ⁹	79 Au 6s ¹ 5d ¹⁰	80 Hg 6s ² 5d ¹⁰	81 Tl 6s ² 6p ¹	82 Pb 6s ² 6p ²	83 Bi 6s ² 6p ³	84 Po 6s ² 6p ⁴	85 At 6s ² 6p ⁵	86 Rn 6s ² 6p ⁶
7	Fr 7s ¹	Ra 7s ²	89 Ac 7s ² 6d ¹	104 Rf 7s ² 6d ²	105 Db 7s ² 6d ³	106 Sg 7s ² 6d ⁴	107 Bh 7s ² 6d ⁵	108 Hs 7s ² 6d ⁶	109 Mt 7s ² 6d ⁷	110 Ds 7s ² 6d ⁸	111 Rg 7s ² 6d ⁹	112 7s ² 6d ¹⁰	113 7s ² 7p ¹	114 7s ² 7p ²	115 7s ² 7p ³	116 7s ² 7p ⁴	(117)	118 7s ² 7p ⁶
				58 Ce 6s ² 4f ¹ 5d ¹	59 Pr 6s ² 4f ³	60 Nd 6s ² 4f ⁴	61 Pm 6s ² 4f ⁵	62 Sm 6s ² 4f ⁶	63 Eu 6s ² 4f ⁷	64 Gd 6s ² 4f ⁷ 5d ¹	65 Tb 6s ² 4f ⁹	66 Dy 6s ² 4f ¹⁰	67 Ho 6s ² 4f ¹¹	68 Er 6s ² 4f ¹²	69 Tm 6s ² 4f ¹³	70 Yb 6s ² 4f ¹⁴	71 Lu 6s ² 4f ¹⁴ 5d ¹	
				90 Th 7s ² 6d ²	91 Pa 7s ² 5f ² 6d ¹	92 U 7s ² 5f ³ 6d ¹	93 Np 7s ² 5f ⁴ 6d ¹	94 Pu 7s ² 5f ⁶	95 Am 7s ² 5f ⁷	96 Cm 7s ² 5f ⁷ 6d ¹	97 Bk 7s ² 5f ⁹	98 Cf 7s ² 5f ¹⁰	99 Es 7s ² 5f ¹¹	100 Fm 7s ² 5f ¹²	101 Md 7s ² 5f ¹³	102 No 7s ² 5f ¹⁴	103 Lr 7s ² 5f ¹⁴ 6d ¹	

Isoelectronic: have the same number of electrons, and hence the same ground-state electron configuration



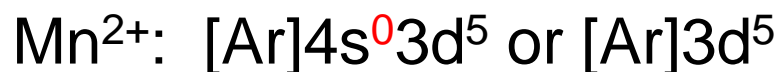
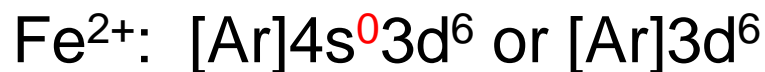
Na^+ , Al^{3+} , F^- , O^{2-} , and N^{3-} are all ***isoelectronic*** with Ne

What neutral atom is isoelectronic with H^- ?

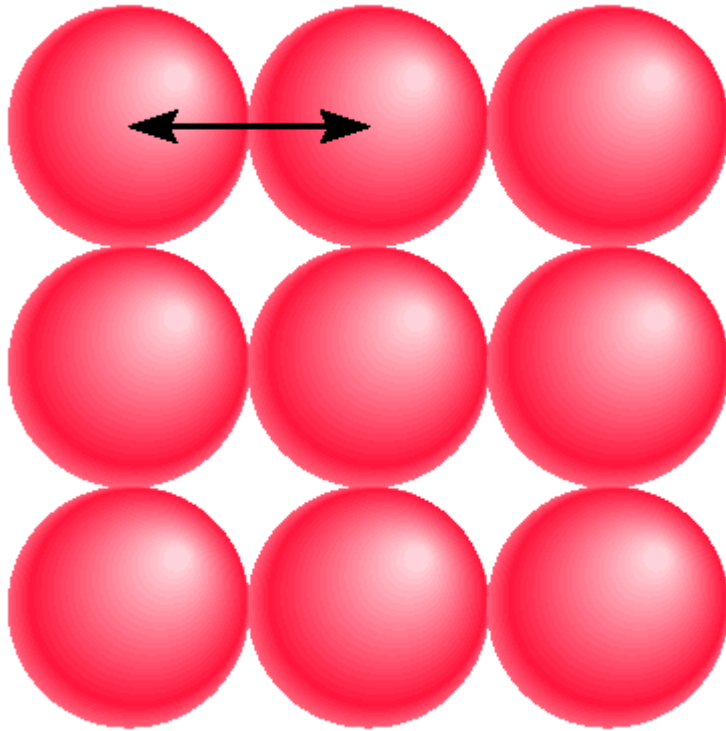


Electron Configurations of Cations of Transition Metals

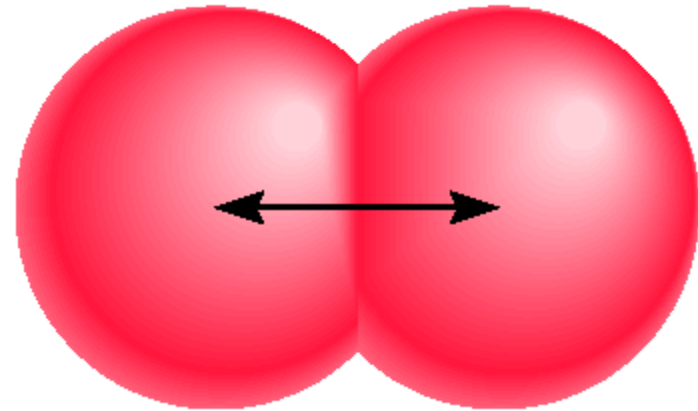
When a cation is formed from an atom of a transition metal, electrons are always removed first from the ns orbital and then from the $(n - 1)d$ orbitals.



Atomic Radii

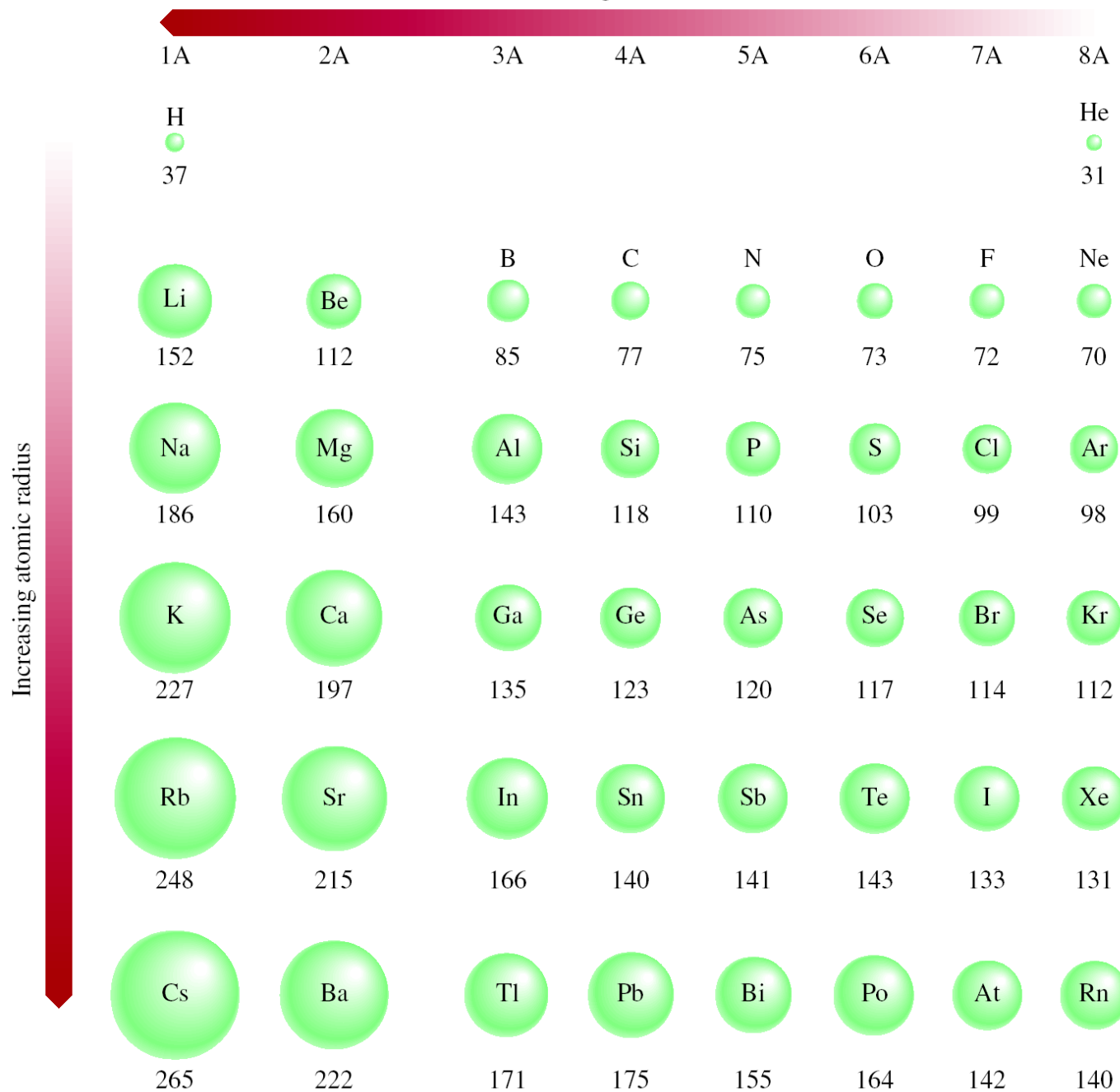


metallic radius

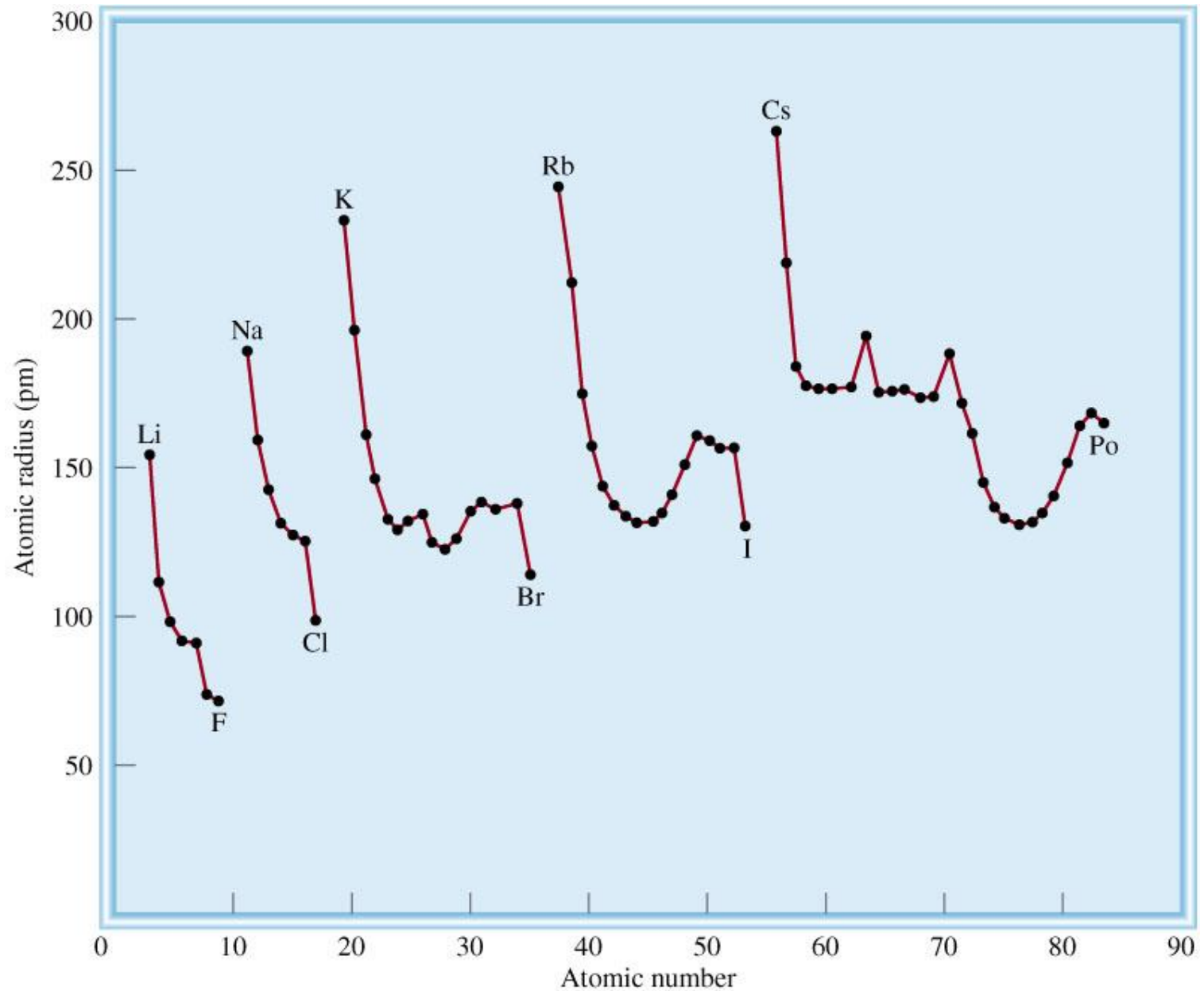


covalent radius

Increasing atomic radius



Trends in Atomic Radii



Ionization energy is the minimum energy (kJ/mol) required to remove an electron from a gaseous atom in its ground state.

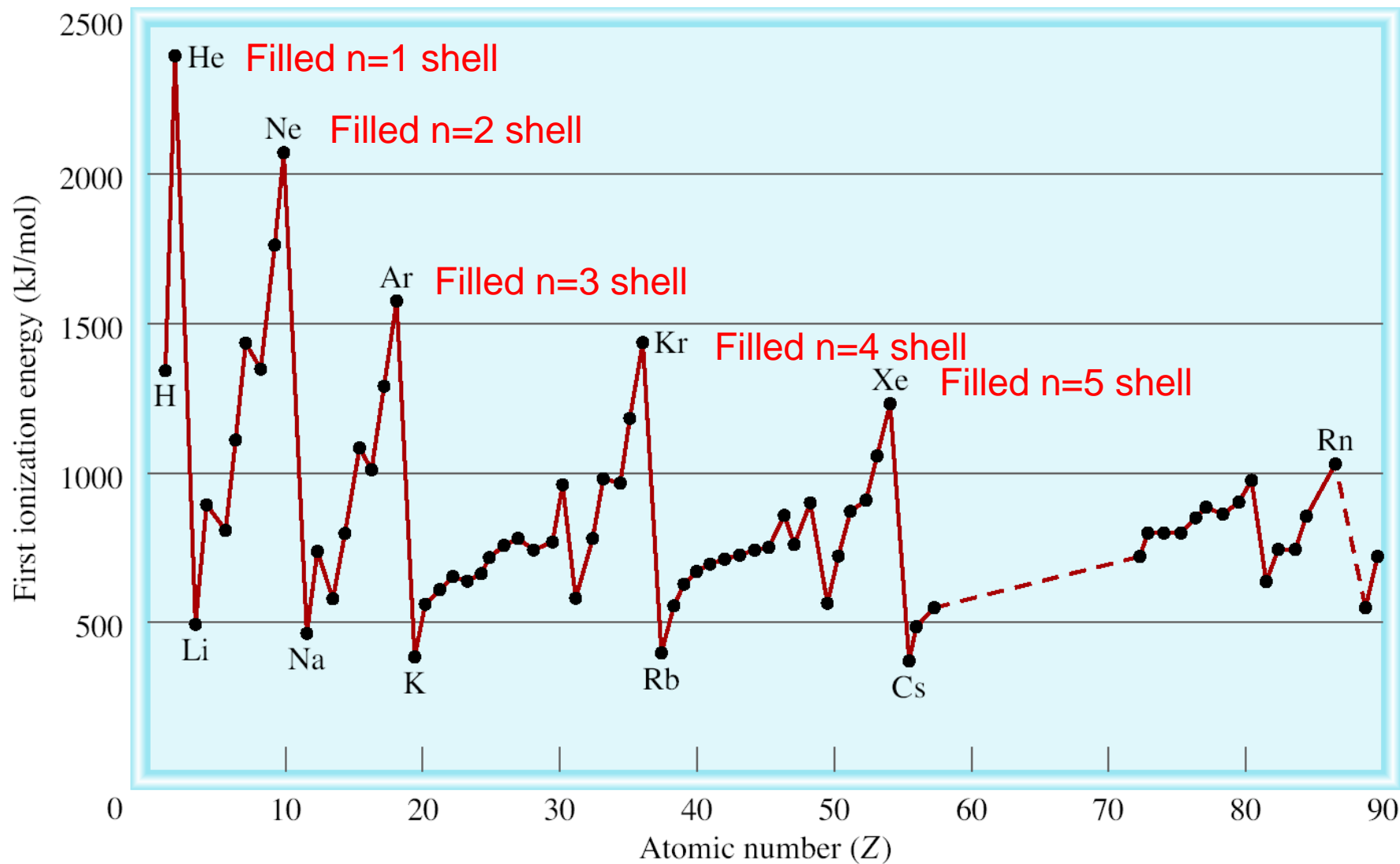


$$I_1 < I_2 < I_3$$

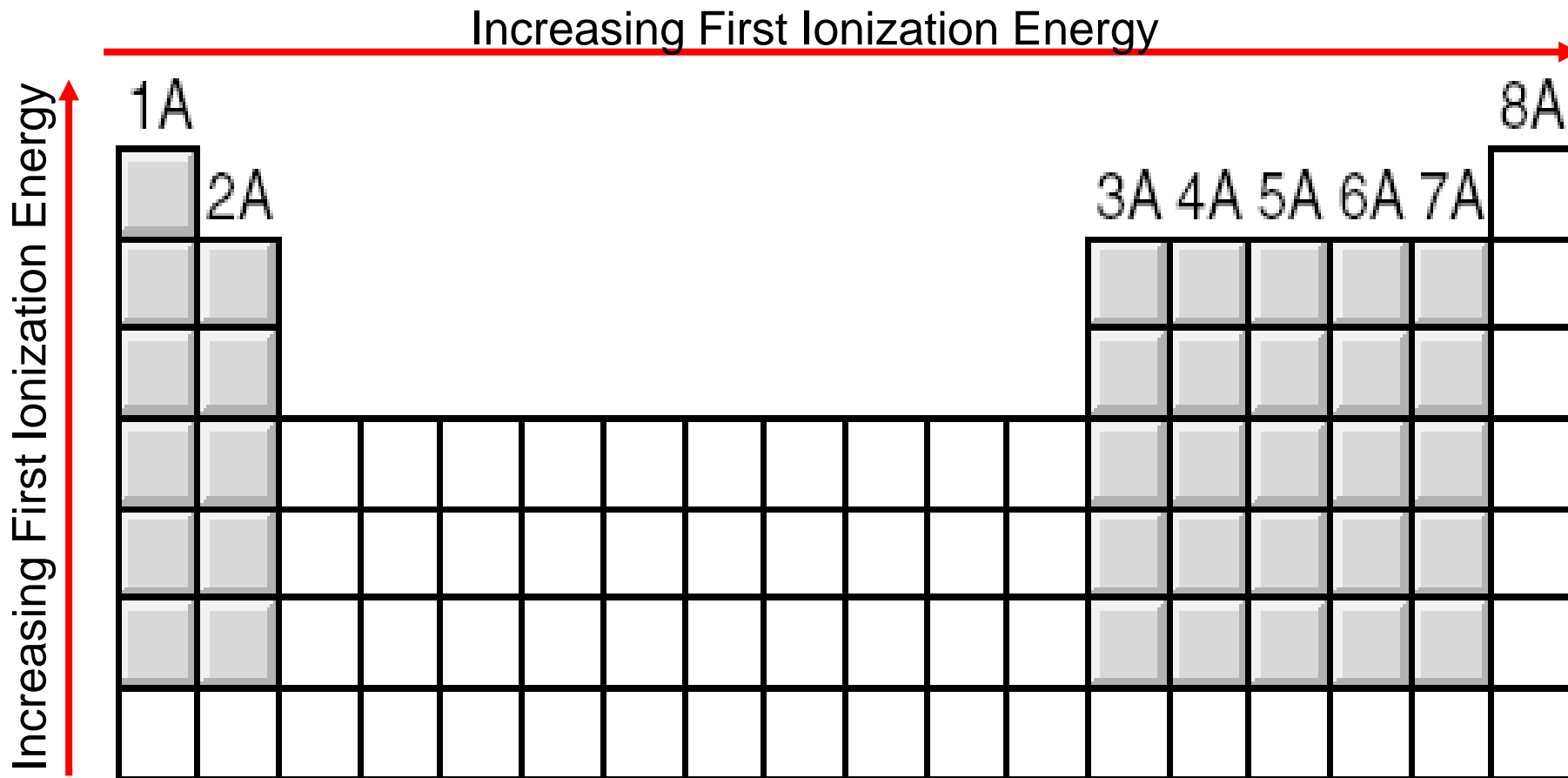
TABLE 8.2 The Ionization Energies (kJ/mol) of the First 20 Elements

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

Variation of the First Ionization Energy with Atomic Number



General Trends in First Ionization Energies



Electron affinity is the negative of the energy change that occurs when an electron is accepted by an atom in the gaseous state to form an anion.

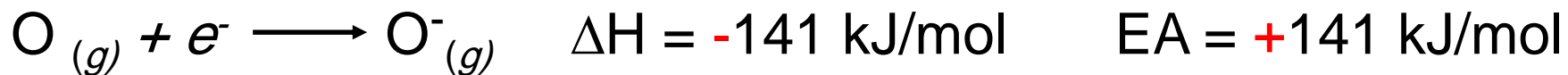
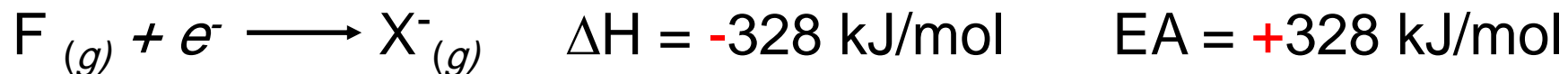
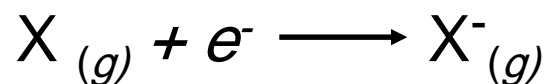


TABLE 8.3**Electron Affinities (kJ/mol) of Some Representative Elements and the Noble Gases***

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

*The electron affinities of the noble gases, Be, and Mg have not been determined experimentally, but are believed to be close to zero or negative.

Variation of Electron Affinity With Atomic Number (H – Ba)

