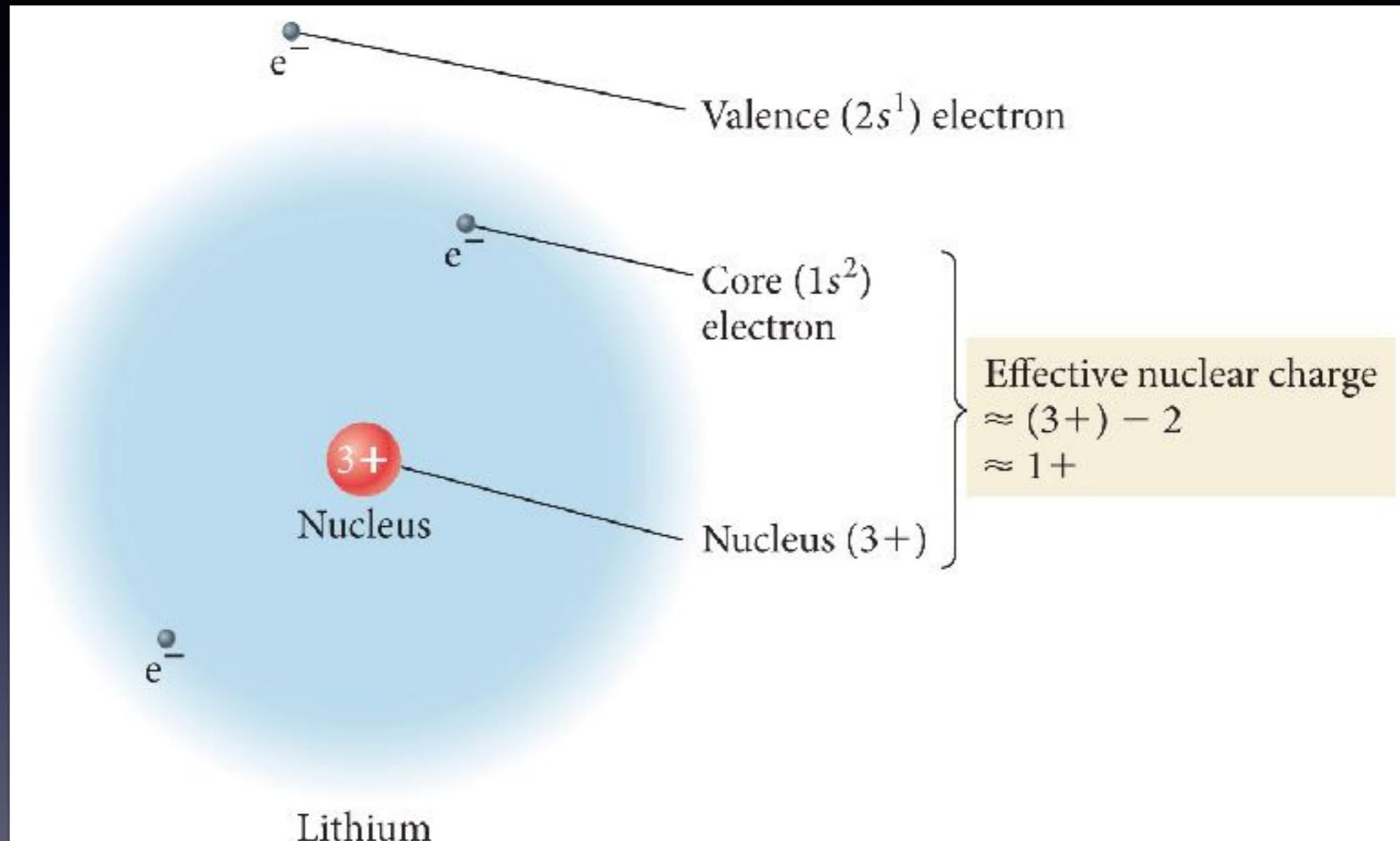


Previously in Molecularity...

Screening and “effective” nuclear charge

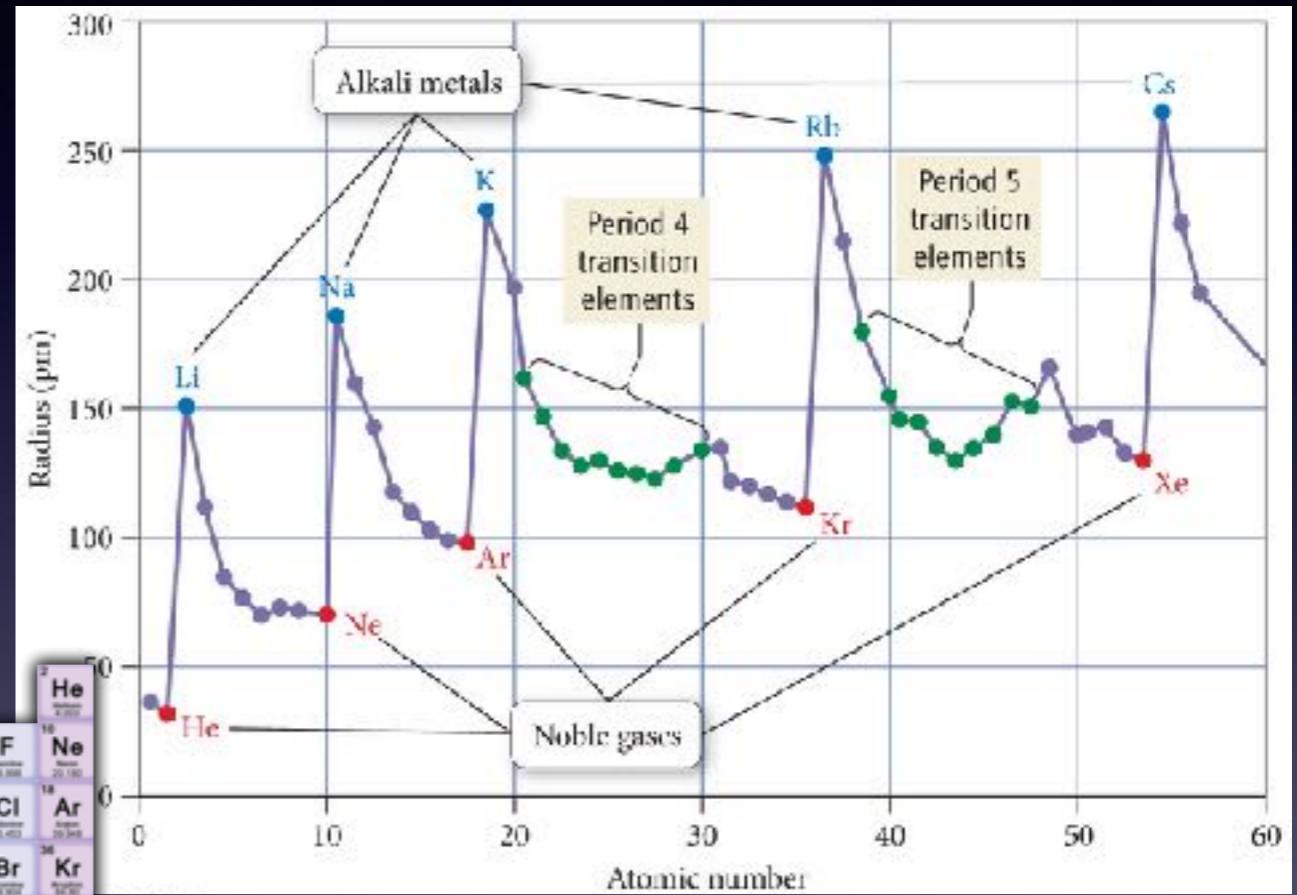
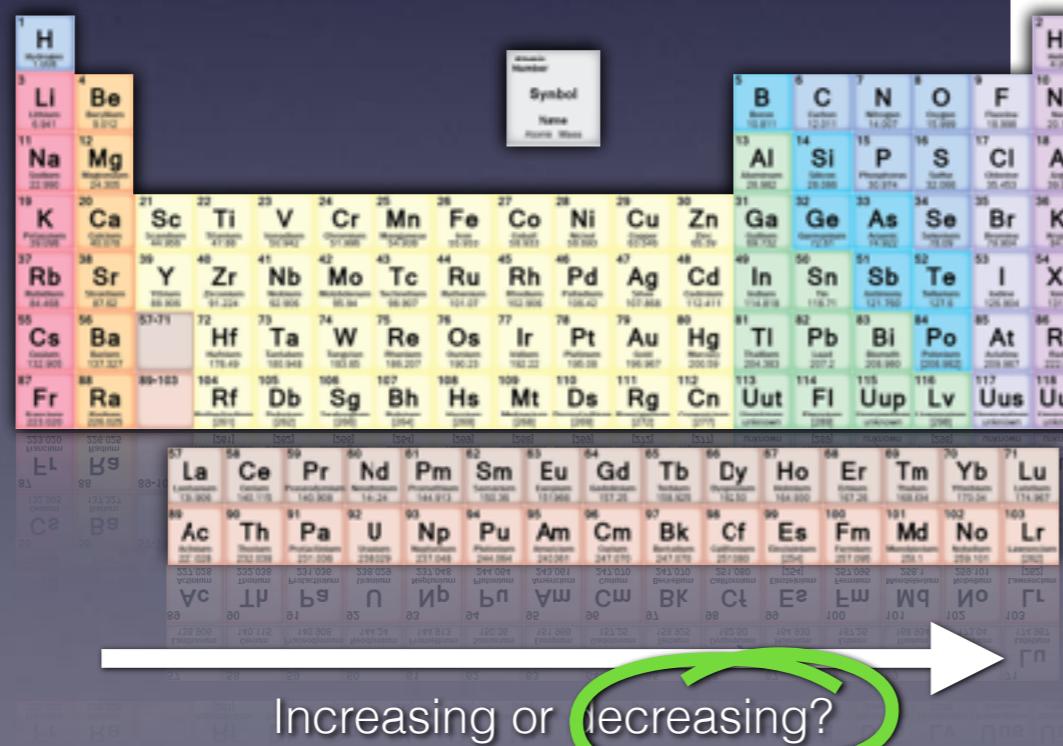


$$\text{Effective nuclear charge} \rightsquigarrow Z_{\text{eff}} = Z - S \rightsquigarrow \text{Actual nuclear charge}$$

Charge that is screened

$$E = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

On your own... which effect is stronger? Trend downwards or trend across?



For example:
Which is larger,
Ge or Sb?

A photograph of a silver fork standing upright in a field of lavender. The fork's tines are pointing downwards and its handle upwards. In the background, there is a paved road leading towards a line of trees under a clear sky.

Where are we going today?

Ch1010-A17-A03 Lecture 9

- §3.6 Periodic trends in size
- §3.7 Ionization Energy
- §3.8 Electron Affinity
- §4.4 Electronegativity

Now you try...

Order the following atoms or ions in order of increasing atomic radius, and *briefly* explain why.



Fig. 8.12

Cationic r

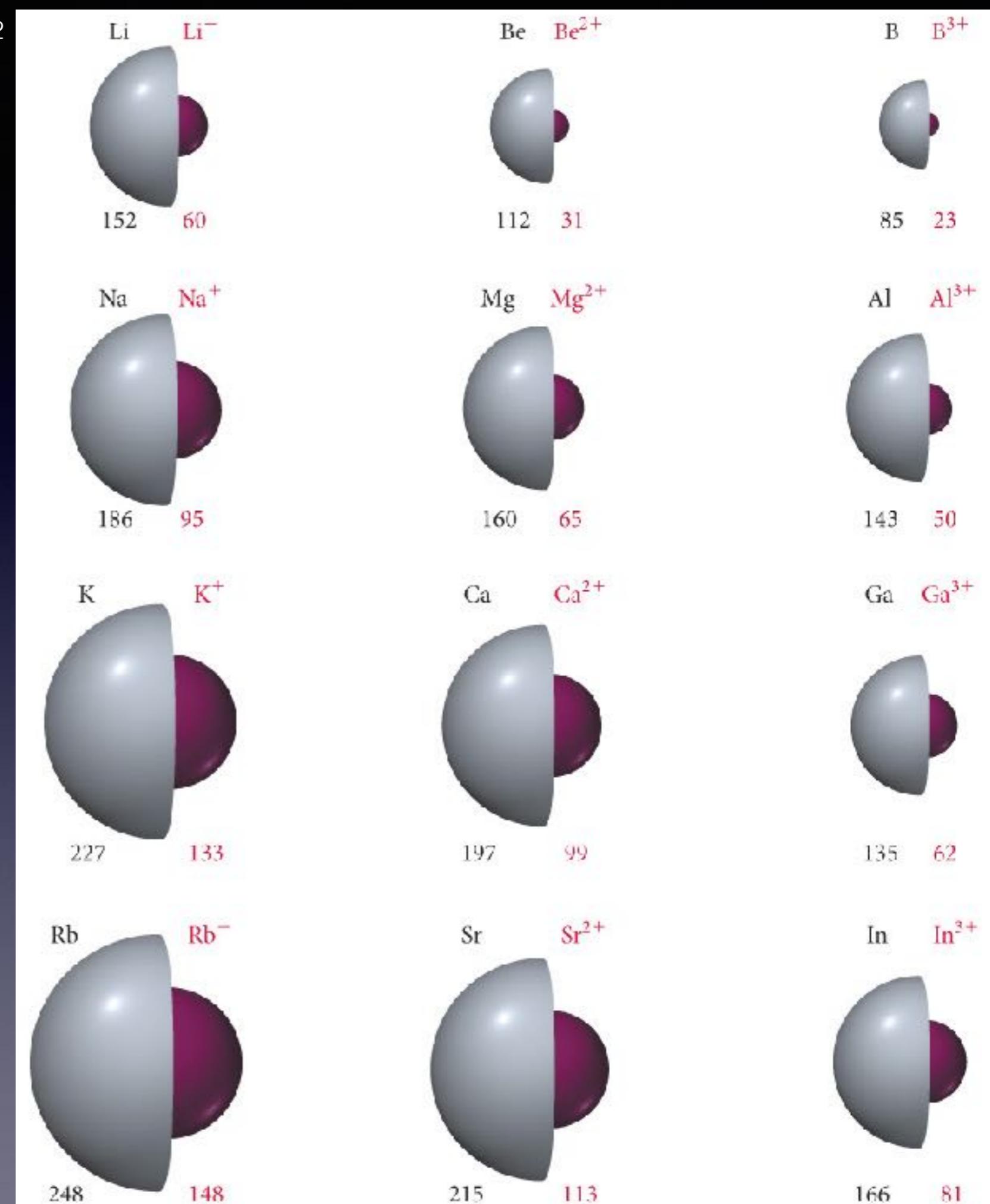
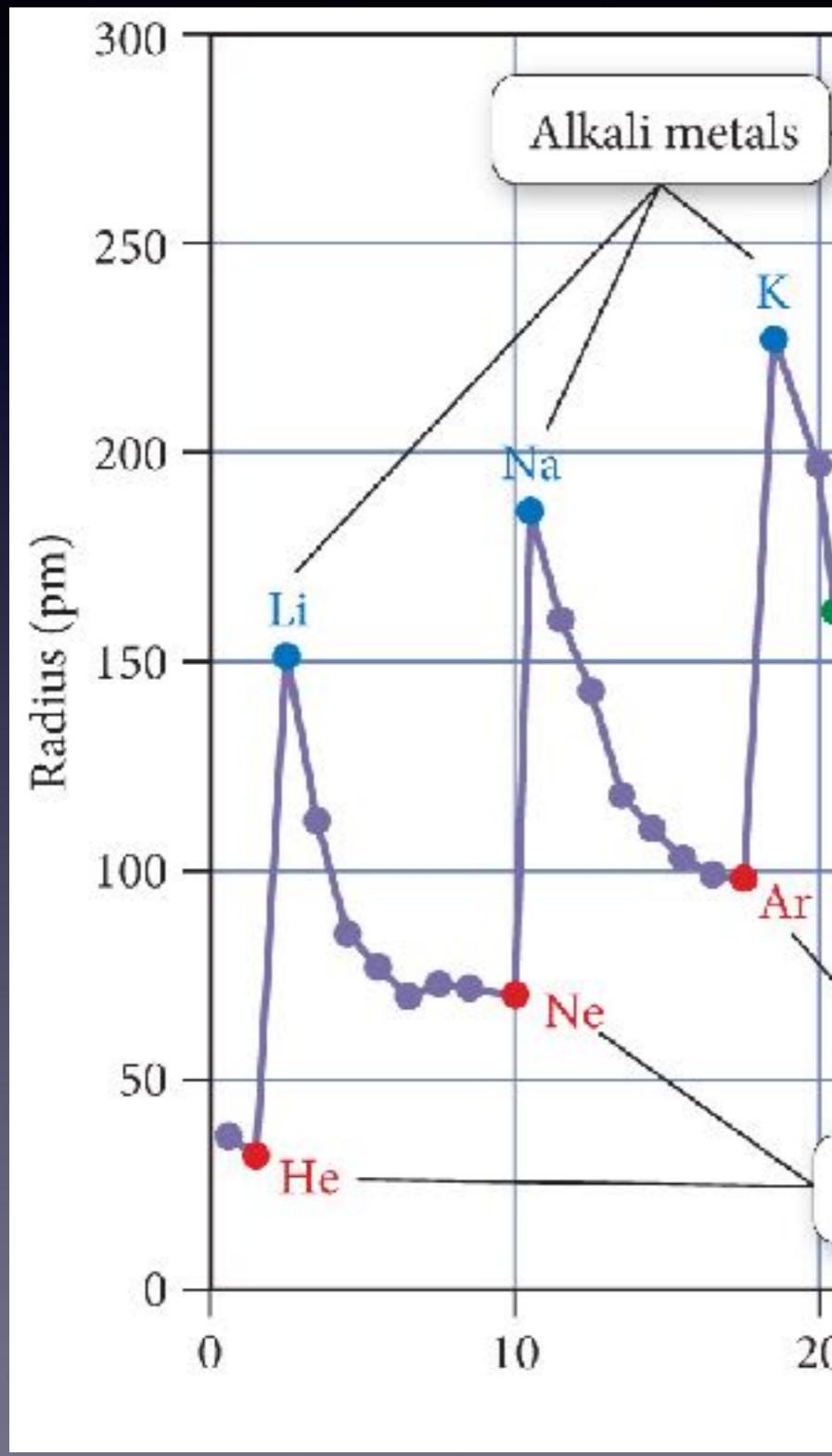
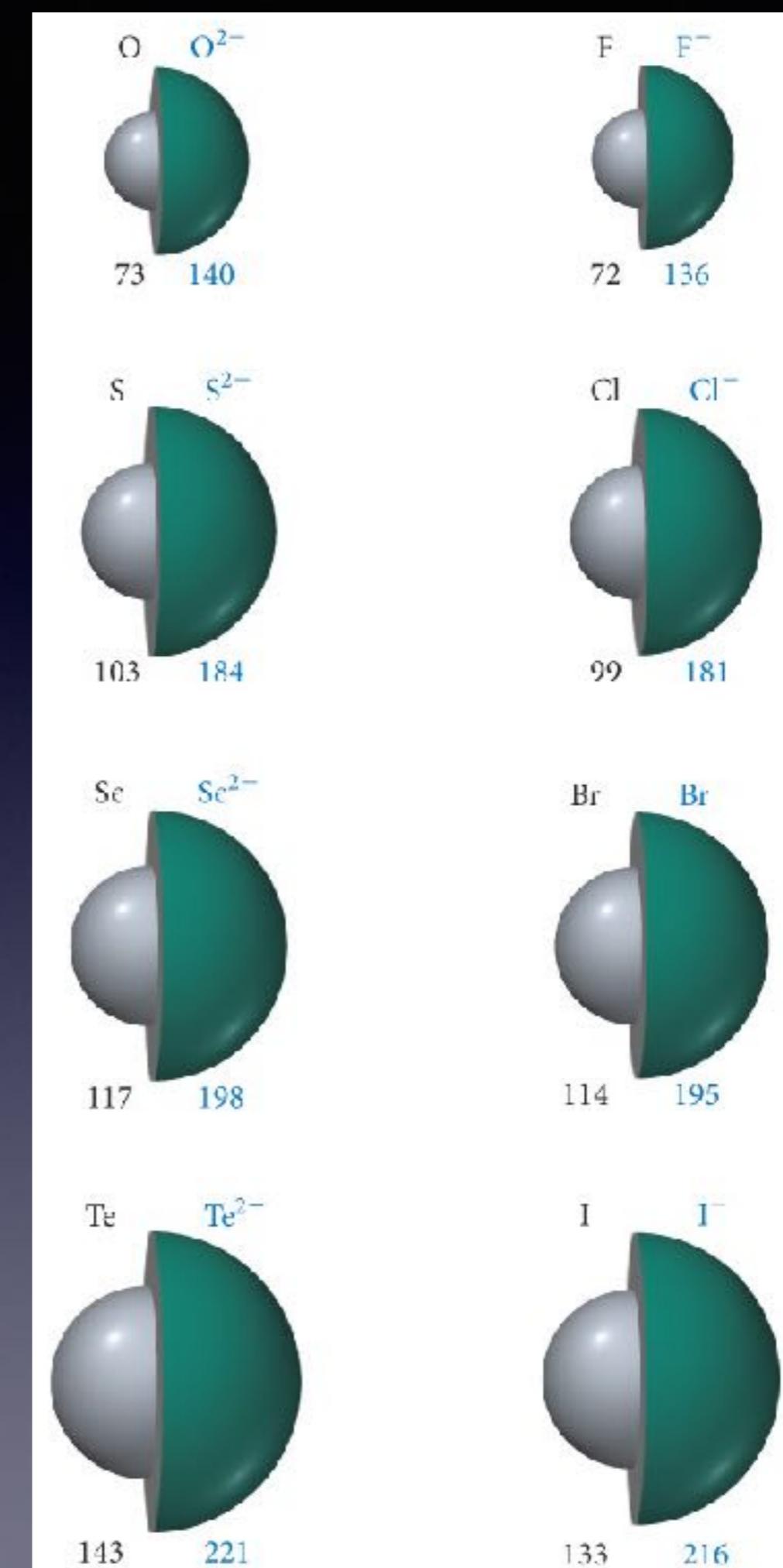
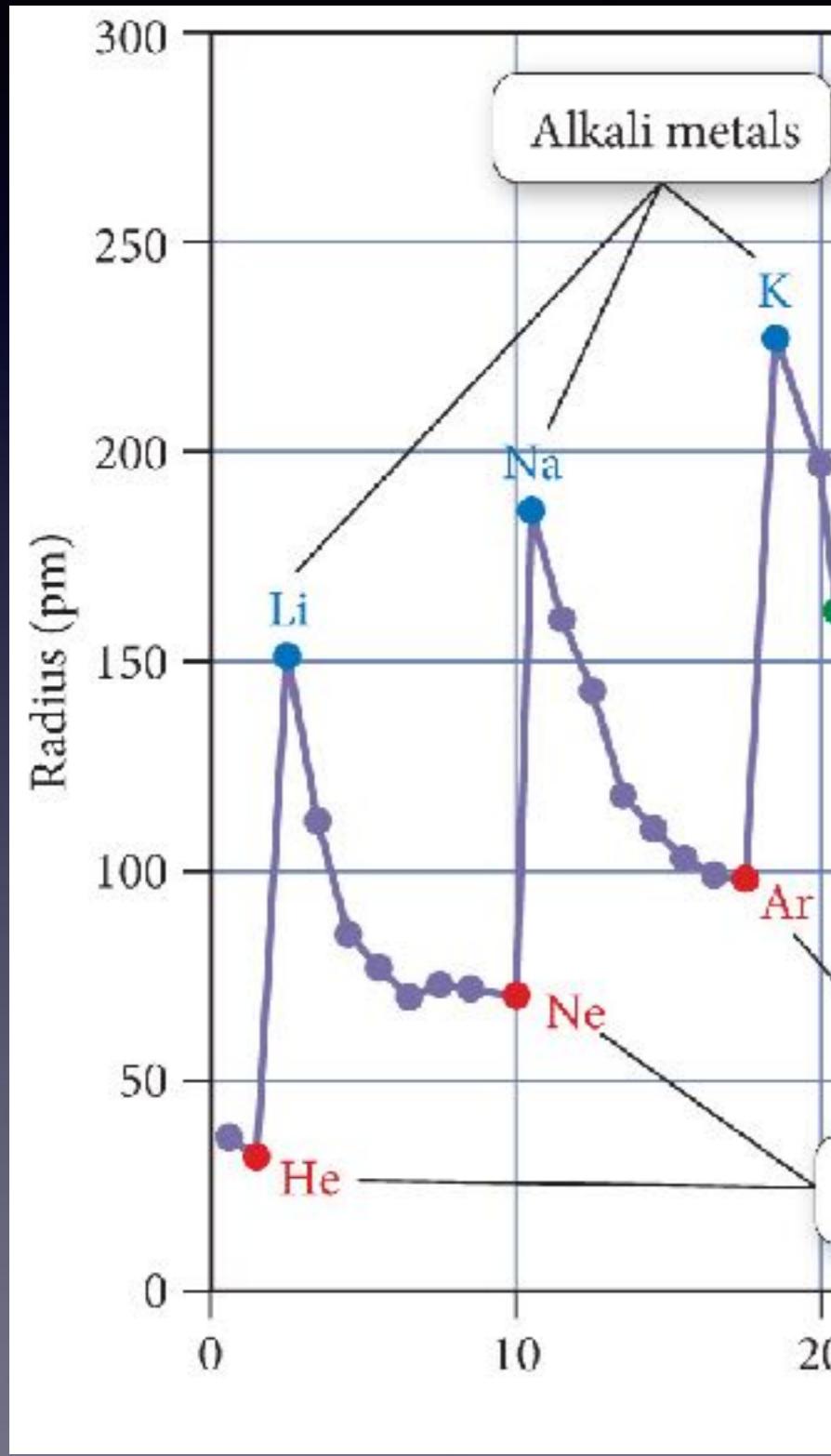
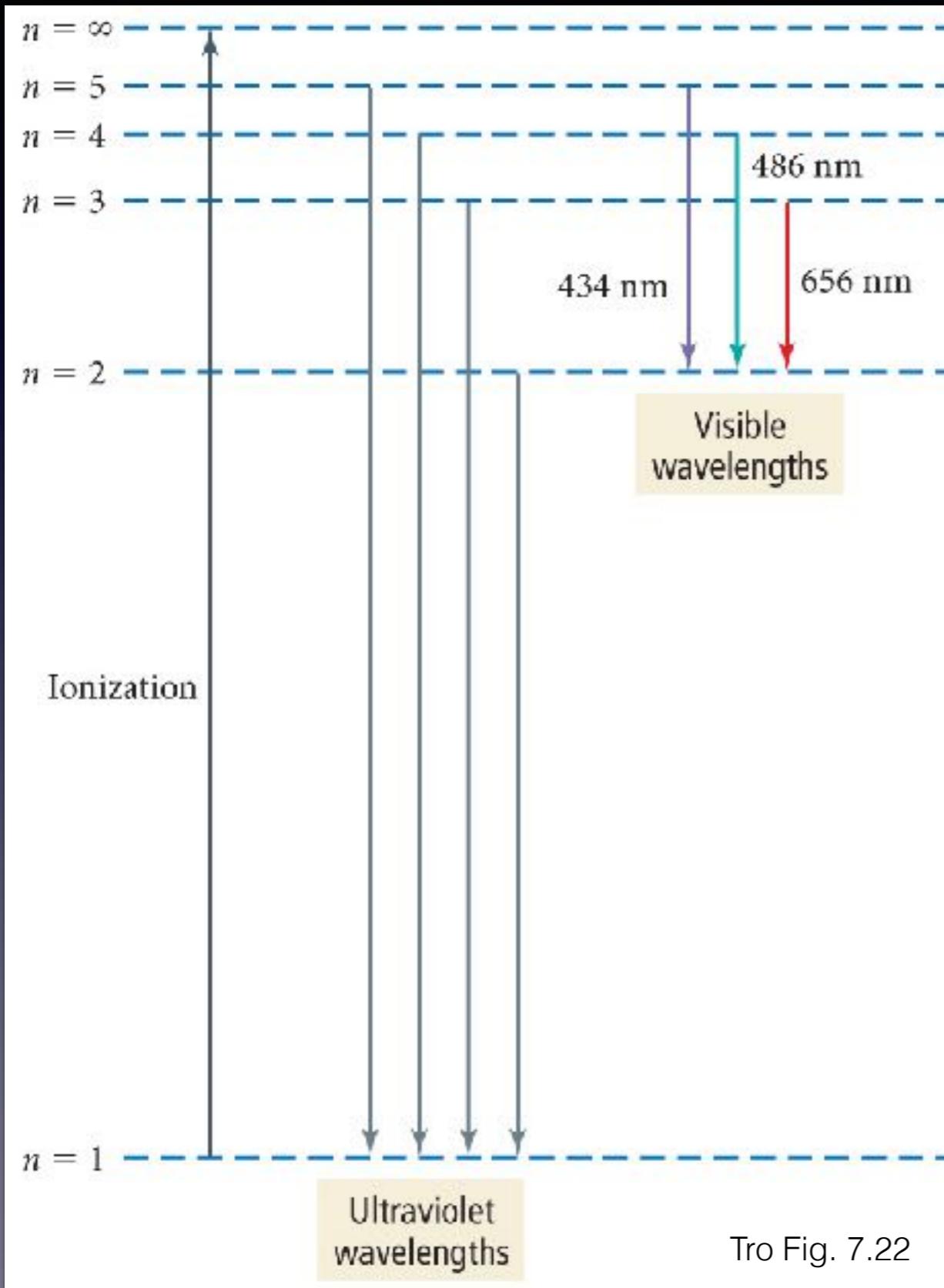


Fig. 8.9

Anionic r



What is ionization energy?



First ionization energy



$$\text{IE}_1 = 496 \text{ kJ mol}^{-1}$$

Second ionization energy

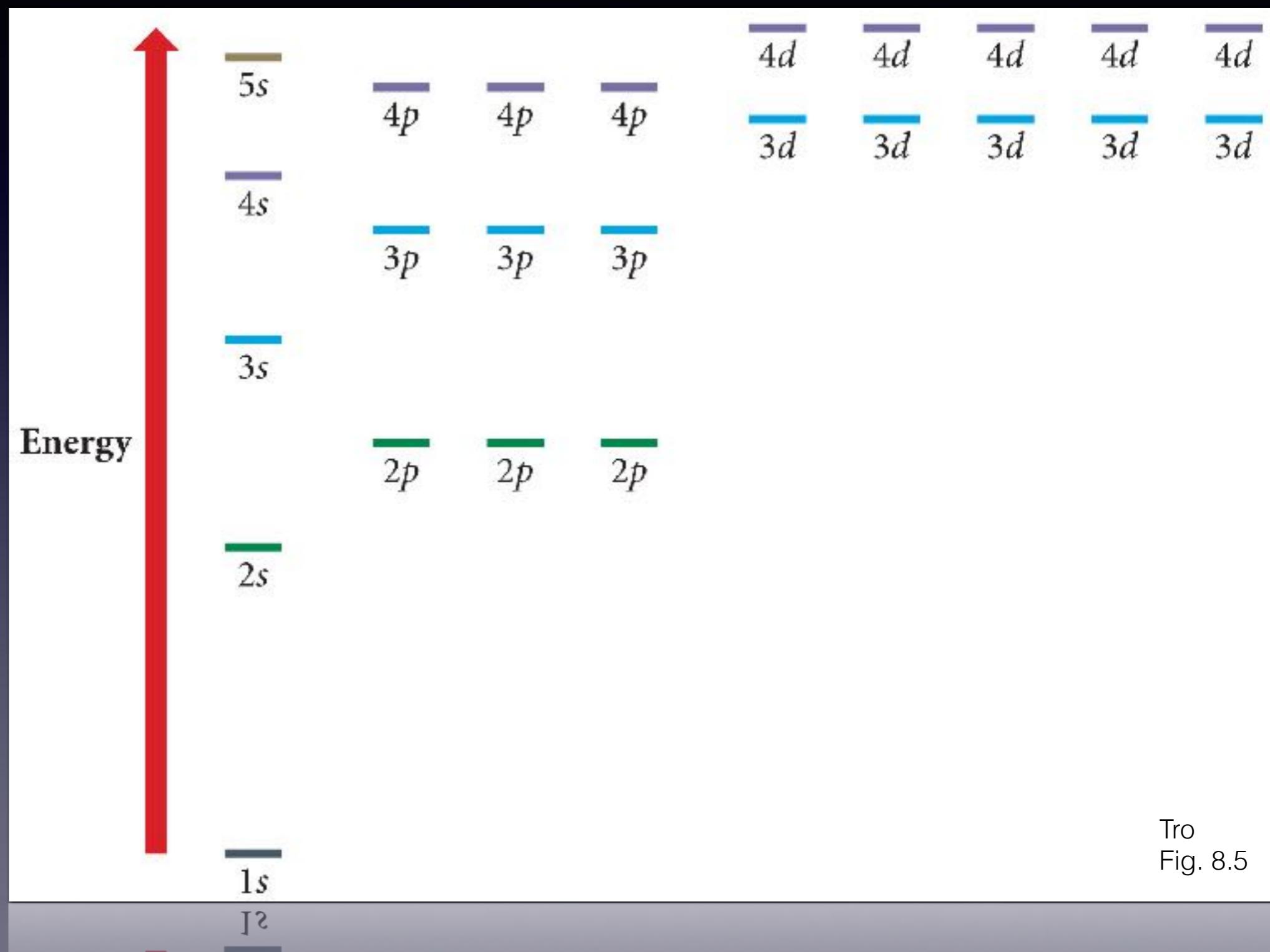


$$\text{IE}_2 = 4560 \text{ kJ mol}^{-1}$$

Tro Fig. 7.22

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
		Atomic Number	553,050,151

Trends in IE_1



Tro
Fig. 8.5

Periodic trend in IE_1

Increasing or decreasing?

Atomic Number	Symbol	Name	Atomic Mass
1	H	Hydrogen	1.008
3	Li	Lithium	6.941
4	Be	Beryllium	9.012
11	Na	Sodium	22.990
12	Mg	Magnesium	24.305
19	K	Potassium	39.098
20	Ca	Calcium	40.078
21	Sc	Scandium	44.956
22	Ti	Titanium	47.88
23	V	Vanadium	50.942
24	Cr	Chromium	51.996
25	Mn	Manganese	54.938
26	Fe	Iron	55.933
27	Co	Cobalt	58.933
28	Ni	Nickel	58.693
29	Cu	Copper	63.546
30	Zn	Zinc	65.39
31	Ga	Gallium	69.732
32	Ge	Germanium	72.61
33	As	Arsenic	74.922
34	Se	Selenium	78.09
35	Br	Bromine	79.904
36	Kr	Krypton	84.80
37	Rb	Rubidium	84.468
38	Sr	Strontium	87.62
39	Y	Yttrium	88.906
40	Zr	Zirconium	91.224
41	Nb	Niobium	92.906
42	Mo	Molybdenum	95.94
43	Tc	Technetium	98.907
44	Ru	Ruthenium	101.07
45	Rh	Rhodium	102.906
46	Pd	Palladium	106.42
47	Ag	Silver	107.868
48	Cd	Cadmium	112.411
49	In	Indium	114.818
50	Sn	Tin	118.71
51	Sb	Antimony	121.760
52	Te	Tellurium	127.6
53	I	Iodine	126.904
54	Xe	Xenon	131.29
55	Cs	Cesium	132.905
56	Ba	Barium	137.327
57-71			
72	Hf	Hafnium	178.49
73	Ta	Tantalum	180.948
74	W	Tungsten	183.85
75	Re	Rhenium	186.207
76	Os	Osmium	190.23
77	Ir	Iridium	192.22
78	Pt	Platinum	195.08
79	Au	Gold	196.967
80	Hg	Mercury	200.59
81	Tl	Thallium	204.383
82	Pb	Lead	207.2
83	Bi	Bismuth	208.980
84	Po	Polonium	[208.982]
85	At	Astatine	209.987
86	Rn	Radon	222.018
87	Fr	Francium	223.020
88	Ra	Radium	226.025
89-103			
104	Rf	Rutherfordium	[261]
105	Db	Dubnium	[262]
106	Sg	Seaborgium	[266]
107	Bh	Bohrium	[264]
108	Hs	Hassium	[269]
109	Mt	Meitnerium	[268]
110	Ds	Darmstadtium	[269]
111	Rg	Roentgenium	[272]
112	Cn	Copernicium	[277]
113	Uut	Ununtrium	unknown
114	Fl	Flerovium	[289]
115	Uup	Ununpentium	unknown
116	Lv	Livermorium	[298]
117	Uus	Ununseptium	unknown
118	Uuo	Ununoctium	unknown
57	La	Lanthanum	138.906
58	Ce	Cerium	140.115
59	Pr	Praseodymium	140.908
60	Nd	Neodymium	144.24
61	Pm	Promethium	144.913
62	Sm	Samarium	150.36
63	Eu	Europium	151.966
64	Gd	Gadolinium	157.25
65	Tb	Terbium	158.925
66	Dy	Dysprosium	162.50
67	Ho	Holmium	164.930
68	Er	Erbium	167.26
69	Tm	Thulium	168.934
70	Yb	Ytterbium	173.04
71	Lu	Lutetium	174.967
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Increasing or decreasing?

Periodic trend in IE_1

Increasing or decreasing?

Atomic Number	Symbol	Name	Atomic Mass
1	H	Hydrogen	1.008
3	Li	Lithium	6.941
4	Be	Beryllium	9.012
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22	Ti	Titanium	47.88
23	V	Vanadium	50.942
24	Cr	Chromium	51.996
25	Mn	Manganese	54.938
26	Fe	Iron	55.933
27	Co	Cobalt	58.933
28	Ni	Nickel	58.693
29	Cu	Copper	63.546
30	Zn	Zinc	65.39
31	Ga	Gallium	69.732
32	Ge	Germanium	72.61
33	As	Arsenic	74.922
34	Se	Selenium	78.09
35	Br	Bromine	79.904
2	He	Helium	4.003
10	Ne	Neon	20.180
37	Rb	Rubidium	84.468
38	Sr	Strontium	87.62
39	Y	Yttrium	88.906
40	Zr	Zirconium	91.224
41	Nb	Niobium	92.906
42	Mo	Molybdenum	95.94
43	Tc	Technetium	98.907
44	Ru	Ruthenium	101.07
45	Rh	Rhodium	102.906
46	Pd	Palladium	106.42
47	Ag	Silver	107.868
48	Cd	Cadmium	112.411
49	In	Indium	114.818
50	Sn	Tin	118.71
51	Sb	Antimony	121.760
52	Te	Tellurium	127.6
53	I	Iodine	126.904
54	Xe	Xenon	131.29
55	Cs	Cesium	132.905
56	Ba	Barium	137.327
57-71			
72	Hf	Hafnium	178.49
73	Ta	Tantalum	180.948
74	W	Tungsten	183.85
75	Re	Rhenium	186.207
76	Os	Osmium	190.23
77	Ir	Iridium	192.22
78	Pt	Platinum	195.08
79	Au	Gold	196.967
80	Hg	Mercury	200.59
81	Tl	Thallium	204.383
82	Pb	Lead	207.2
83	Bi	Bismuth	208.980
84	Po	Polonium	[208.982]
85	At	Astatine	209.987
86	Rn	Radon	222.018
87	Fr	Francium	223.020
88	Ra	Radium	226.025
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104	Rf	Rutherfordium	[261]
105	Db	Dubnium	[262]
106	Sg	Seaborgium	[266]
107	Bh	Bohrium	[264]
108	Hs	Hassium	[269]
109	Mt	Meitnerium	[268]
110	Ds	Darmstadtium	[269]
111	Rg	Roentgenium	[272]
112	Cn	Copernicium	[277]
113	Uut	Ununtrium	unknown
114	Fl	Flerovium	[289]
115	Uup	Ununpentium	unknown
116	Lv	Livermorium	[298]
117	Uus	Ununseptium	unknown
118	Uuo	Ununoctium	unknown
57	La	Lanthanum	138.906
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60	Nd	Neodymium	144.24
61	Pm	Promethium	144.913
62	Sm	Samarium	150.36
63	Eu	Europium	151.966
64	Gd	Gadolinium	157.25
65	Tb	Terbium	158.925
66	Dy	Dysprosium	162.50
67	Ho	Holmium	164.930
68	Er	Erbium	167.26
69	Tm	Thulium	168.934
70	Yb	Ytterbium	173.04
71	Lu	Lutetium	174.967
10			
89	Ac	Actinium	227.028
90	Th	Thorium	232.038
91	Pa	Protactinium	231.036
92	U	Uranium	238.029
93	Np	Neptunium	237.048
94	Pu	Plutonium	244.064
95	Am	Americium	243.061
96	Cm	Curium	247.070
97	Bk	Berkelium	247.070
98	Cf	Californium	251.080
99	Es	Einsteinium	[254]
100	Fm	Fermium	257.095
101	Md	Mendelevium	258.1
102	No	Nobelium	259.101
103	Lr	Lawrencium	[262]

Increasing or decreasing?

Trends in first ionization energy

3 Li Lithium 6.941	4 Be Beryllium 9.012	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
55 manganese 24.302	56 manganese 24.302	57 manganese 24.302	58 silicon 28.086	59 phosphorus 30.974	60 sulfur 32.066	61 chlorine 35.453	62 argon 39.948

What would the trend look like across a row?

$$Z_{\text{eff}} = Z - S$$

↑ ↘

Effective nuclear charge Actual nuclear charge Charge that is screened

$$E = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

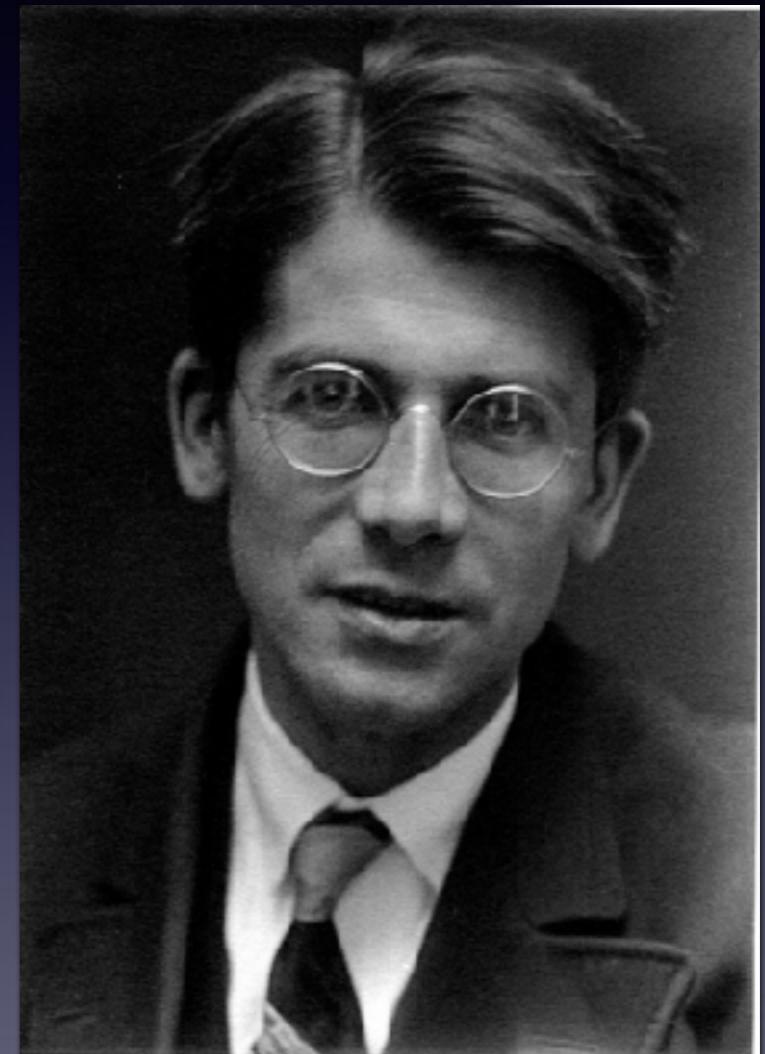
Minute paper...

- Fluorine has one more electron and one more proton than oxygen...

Which has a larger ionization energy, oxygen or fluorine? Why?

- Oxygen has one more electron and one more proton than nitrogen...

Which has a larger ionization energy, nitrogen or oxygen? Why?

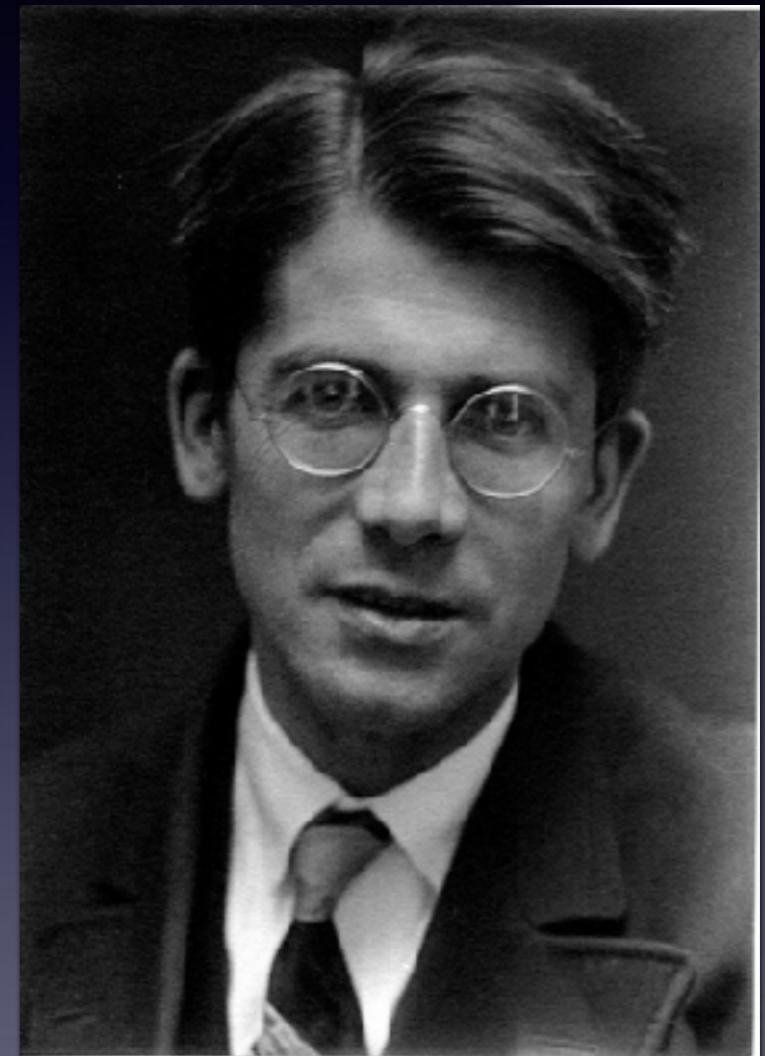


Fredrich Hund

upload.wikimedia.org
Hund%2CFriedrich_1920er_Göttingen.jpg

Guides for electron filling

- Electrons “spread out” in p, d, f orbitals before pairing up.
- Completely filled orbitals are extremely stable.
- Half-filled orbitals are particularly stable.



Fredrich Hund

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Hund%2CFriedrich_1920er_Göttingen.jpg

Trends in first ionization energy

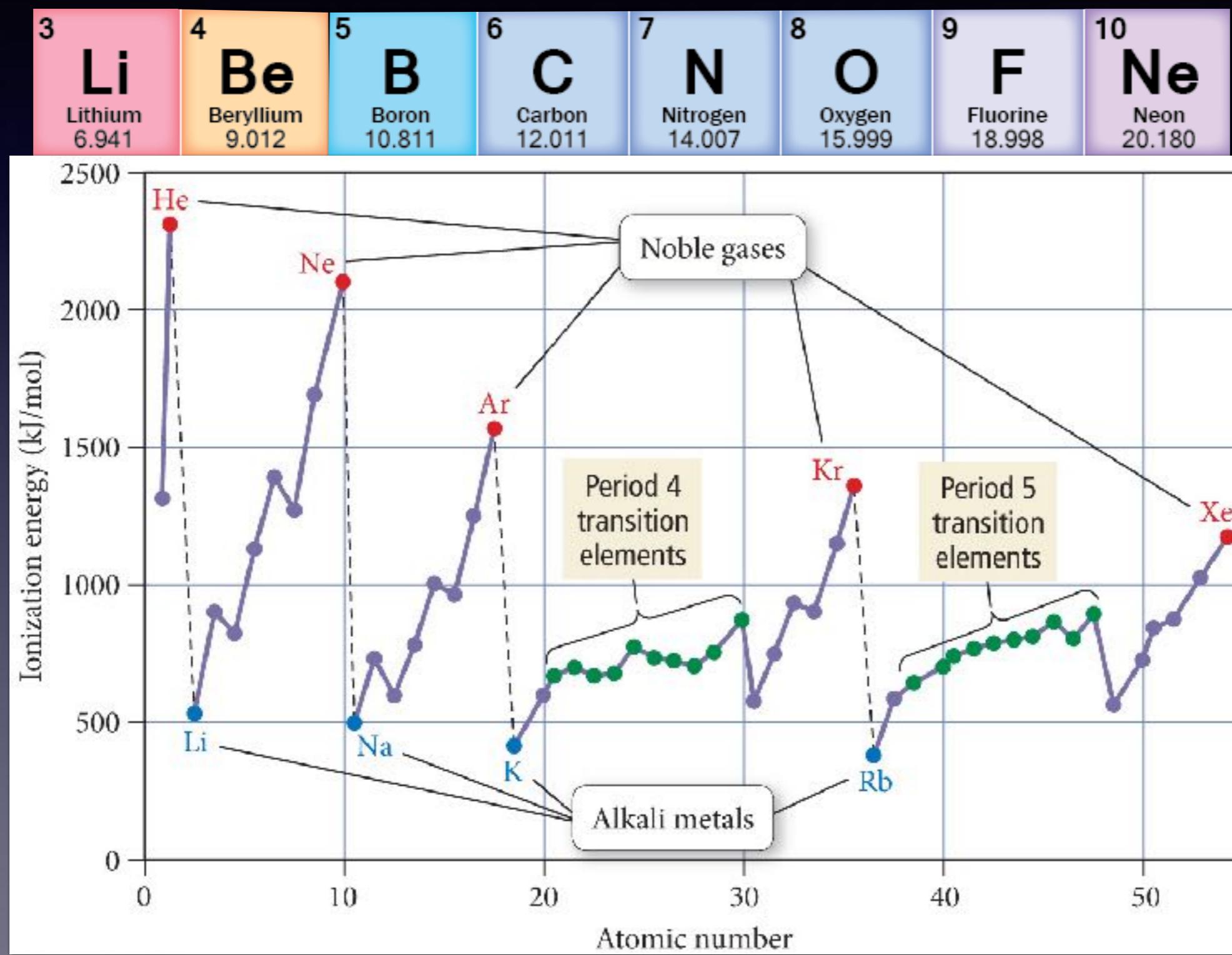


Fig 8.14

Trends in first ionization energy

Write down electron configuration of neutral atom.

Write down electron configuration of the first cation.

Is one of these configurations particularly stable?
How does this inform your analysis?

Now you try...

Arrange these elements in order of increasing IE_1 :
Si, F, In, N

Periodic trend in IE_1

Increasing or decreasing?

Atomic Number	Symbol	Name	Atomic Mass	2	He	Helium 4.003
1	H	Hydrogen	1.008	5	B	Boron 10.811
3	Li	Lithium	6.941	6	C	Carbon 12.011
4	Be	Beryllium	9.012	7	N	Nitrogen 14.007
11	Na	Sodium	22.990	8	O	Oxygen 15.999
12	Mg	Magnesium	24.305	9	F	Fluorine 18.998
19	K	Potassium	39.098	10	Ne	Neon 20.180
20	Ca	Calcium	40.078	13	Al	Aluminum 26.982
21	Sc	Scandium	44.956	14	Si	Silicon 28.086
22	Ti	Titanium	47.88	15	P	Phosphorus 30.974
23	V	Vanadium	50.942	16	S	Sulfur 32.066
24	Cr	Chromium	51.996	17	Cl	Chlorine 35.453
25	Mn	Manganese	54.938	18	Ar	Argon 39.948
26	Fe	Iron	55.933	31	Ga	Gallium 69.732
27	Co	Cobalt	58.933	32	Ge	Germanium 72.61
28	Ni	Nickel	58.693	33	As	Arsenic 74.922
29	Cu	Copper	63.546	34	Se	Selenium 78.09
30	Zn	Zinc	65.39	35	Br	Bromine 79.904
31	Ga	Gallium	69.732	36	Kr	Krypton 84.80
32	Ge	Germanium	72.61	37	Rb	Rubidium 84.468
33	As	Arsenic	74.922	38	Sr	Strontium 87.62
34	Se	Selenium	78.09	39	Y	Yttrium 88.906
35	Br	Bromine	79.904	40	Zr	Zirconium 91.224
36	Kr	Krypton	84.80	41	Nb	Niobium 92.906
37	Rb	Rubidium	84.468	42	Mo	Molybdenum 95.94
38	Sr	Strontium	87.62	43	Tc	Technetium 98.907
39	Y	Yttrium	88.906	44	Ru	Ruthenium 101.07
40	Zr	Zirconium	91.224	45	Rh	Rhodium 102.906
41	Nb	Niobium	92.906	46	Pd	Palladium 106.42
42	Mo	Molybdenum	95.94	47	Ag	Silver 107.868
43	Tc	Technetium	98.907	48	Cd	Cadmium 112.411
44	Ru	Ruthenium	101.07	49	In	Indium 114.818
45	Rh	Rhodium	102.906	50	Sn	Tin 118.71
46	Pd	Palladium	106.42	51	Sb	Antimony 121.760
47	Ag	Silver	107.868	52	Te	Tellurium 127.6
48	Cd	Cadmium	112.411	53	I	Iodine 126.904
49	In	Indium	114.818	54	Xe	Xenon 131.29
50	Sn	Tin	118.71	55	Cs	Cesium 132.905
51	Sb	Antimony	121.760	56	Ba	Barium 137.327
52	Te	Tellurium	127.6	57-71		
53	I	Iodine	126.904	72	Hf	Hafnium 178.49
54	Xe	Xenon 131.29	73	Ta	Tantalum 180.948	
55	Cs	Cesium	132.905	74	W	Tungsten 183.85
56	Ba	Barium	137.327	75	Re	Rhenium 186.207
57-71			76	Os	Osmium 190.23	
72	Hf	Hafnium	178.49	77	Ir	Iridium 192.22
73	Ta	Tantalum	180.948	78	Pt	Platinum 195.08
74	W	Tungsten	183.85	79	Au	Gold 196.967
75	Re	Rhenium	186.207	80	Hg	Mercury 200.59
76	Os	Osmium	190.23	81	Tl	Thallium 204.383
77	Ir	Iridium	192.22	82	Pb	Lead 207.2
78	Pt	Platinum	195.08	83	Bi	Bismuth 208.980
79	Au	Gold	196.967	84	Po	Polonium [208.982]
80	Hg	Mercury	200.59	85	At	Astatine 209.987
81	Tl	Thallium	204.383	86	Rn	Radon 222.018
82	Pb	Lead	207.2	87	Fr	Francium 223.020
83	Bi	Bismuth	208.980	88	Ra	Radium 226.025
84	Po	Polonium	[208.982]	89-103		
85	At	Astatine	209.987	104	Rf	Rutherfordium [261]
86	Rn	Radon	222.018	105	Db	Dubnium [262]
87	Fr	Francium	223.020	106	Sg	Seaborgium [266]
88	Ra	Radium	226.025	107	Bh	Bohrium [264]
89	Ac	Actinium	227.028	108	Hs	Hassium [269]
90	Th	Thorium	232.038	109	Mt	Meitnerium [268]
91	Pa	Protactinium	231.036	110	Ds	Darmstadtium [269]
92	U	Uranium	238.029	111	Rg	Roentgenium [272]
93	Np	Neptunium	237.048	112	Cn	Copernicium [277]
94	Pu	Plutonium	244.064	113	Uut	Ununtrium unknown
95	Am	Americium	243.061	114	Fl	Flerovium [289]
96	Cm	Curium	247.070	115	Uup	Ununpentium unknown
97	Bk	Berkelium	247.070	116	Lv	Livermorium [298]
98	Cf	Californium	251.080	117	Uus	Ununseptium unknown
99	Es	Einsteinium [254]		118	Uuo	Ununoctium unknown
100	Fm	Fermium	257.095			
101	Md	Mendelevium	258.1			
102	No	Nobelium	259.101			
103	Lr	Lawrencium [262]				

Increasing or decreasing?

What I'm not going to talk about (But you're responsible for...)

Second ionization energies

Successive (3rd, 4th, etc.) ionization energies

Electron affinity (EA)



$$\text{EA} = -349 \text{ kJ mol}^{-1}$$

What does it mean for this value to be negative?

Trends in electron affinity (kJ mol^{-1})

1A								8A
H								He
H	-73	2A	3A	4A	5A	6A	7A	He >0
Li	-60	Be	B	C	N	O	F	Ne >0
Na	-53	Mg	Al	Si	P	S	Cl	Ar >0
K	-48	Ca	Ga	Ge	As	Se	Br	Kr >0
Rb	-47	Sr	In	Sn	Sb	Te	I	Xe >0

Tro
Fig 8.16

Periodic trend in EA

Increasing or decreasing?

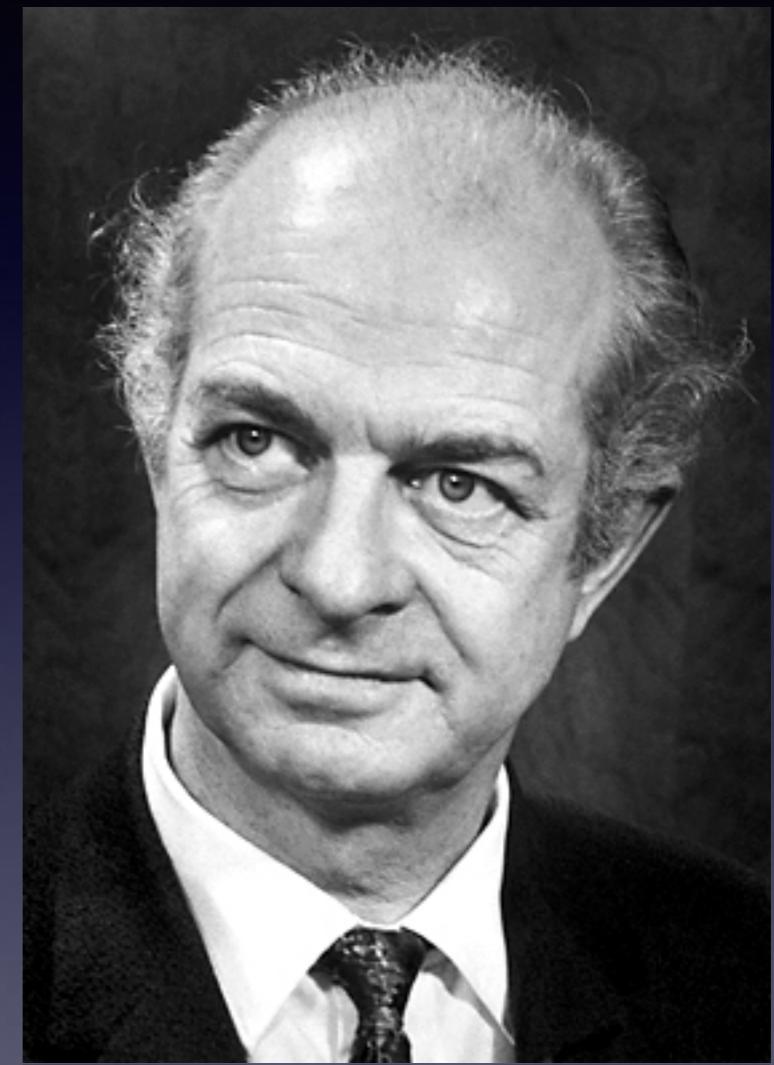
meh

Atomic Number	Symbol	Name	Atomic Mass
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27	Co	Cobalt	58.933
28	Ni	Nickel	58.693
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2	He	Helium	4.003
10	Ne	Neon	20.180
13	Al	Aluminum	26.982
14	Si	Silicon	28.086
15	P	Phosphorus	30.974
16	S	Sulfur	32.066
17	Cl	Chlorine	35.453
18	Ar	Argon	39.948
36	Kr	Krypton	84.80
37	Rb	Rubidium	84.468
38	Sr	Strontium	87.62
39	Y	Yttrium	88.906
40	Zr	Zirconium	91.224
41	Nb	Niobium	92.906
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47	Ag	Silver	107.868
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49	In	Indium	114.818
50	Sn	Tin	118.71
51	Sb	Antimony	121.760
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53	I	Iodine	126.904
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113	Uut	Ununtrium	unknown
114	Fl	Flerovium	[289]
115	Uup	Ununpentium	unknown
116	Lv	Livermorium	[298]
117	Uus	Ununseptium	unknown
118	Uuo	Ununoctium	unknown
57	La	Lanthanum	138.906
58	Ce	Cerium	140.115
59	Pr	Praseodymium	140.908
60	Nd	Neodymium	144.24
61	Pm	Promethium	144.913
62	Sm	Samarium	150.36
63	Eu	Europium	151.966
64	Gd	Gadolinium	157.25
65	Tb	Terbium	158.925
66	Dy	Dysprosium	162.50
67	Ho	Holmium	164.930
68	Er	Erbium	167.26
69	Tm	Thulium	168.934
70	Yb	Ytterbium	173.04
71	Lu	Lutetium	174.967
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Increasing or decreasing?
meh

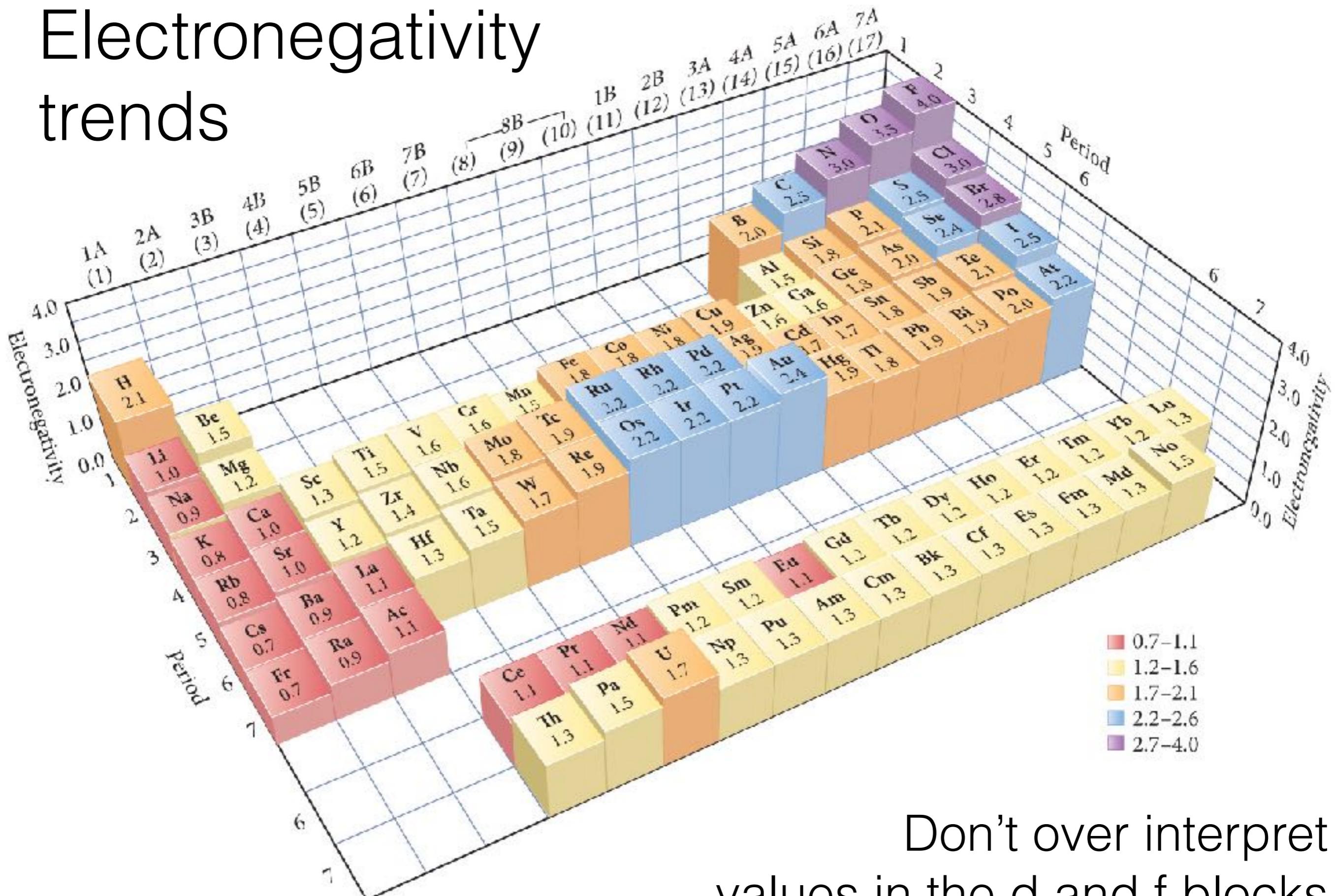
Electronegativity

- Describes an atom's preference to gain electrons.
- Scale 1 (low pref.) – 4 (high pref.)
- Qualitatively assigned values based on bond energies, but quantitative definitions exist.
- Also predicts which atom in a bond would “win” the electrons.



Linus Pauling
[www.nobelprize.org
pauling_postcard.jpg](http://www.nobelprize.org/pauling_postcard.jpg)

Electronegativity trends



Don't over interpret values in the d and f blocks

Periodic trend in electronegativity

Increasing or decreasing?

The following table shows the first two columns of the periodic table, illustrating the increasing trend in atomic number from left to right.

Atomic Number	Symbol	Name	Atomic Mass
1	H	Hydrogen	1.008
3	Li	Lithium	6.941
4	Be	Beryllium	9.012
11	Na	Sodium	22.990
12	Mg	Magnesium	24.305
19	K	Potassium	39.098
20	Ca	Calcium	40.078
21	Sc	Scandium	44.956
22	Ti	Titanium	47.88
23	V	Vanadium	50.942
24	Cr	Chromium	51.996
25	Mn	Manganese	54.938
26	Fe	Iron	55.933
27	Co	Cobalt	58.933
28	Ni	Nickel	58.693
29	Cu	Copper	63.546
30	Zn	Zinc	65.39
31	Ga	Gallium	69.732
32	Ge	Germanium	72.61
33	As	Arsenic	74.922
34	Se	Selenium	78.09
35	Br	Bromine	79.904
2	He	Helium	4.003
37	Rb	Rubidium	84.468
38	Sr	Strontium	87.62
39	Y	Yttrium	88.906
40	Zr	Zirconium	91.224
41	Nb	Niobium	92.906
42	Mo	Molybdenum	95.94
43	Tc	Technetium	98.907
44	Ru	Ruthenium	101.07
45	Rh	Rhodium	102.906
46	Pd	Palladium	106.42
47	Ag	Silver	107.868
48	Cd	Cadmium	112.411
49	In	Indium	114.818
50	Sn	Tin	118.71
51	Sb	Antimony	121.760
52	Te	Tellurium	127.6
53	I	Iodine	126.904
54	Xe	Xenon	131.29
55	Cs	Cesium	132.905
56	Ba	Barium	137.327
57-71			
72	Hf	Hafnium	178.49
73	Ta	Tantalum	180.948
74	W	Tungsten	183.85
75	Re	Rhenium	186.207
76	Os	Osmium	190.23
77	Ir	Iridium	192.22
78	Pt	Platinum	195.08
79	Au	Gold	196.967
80	Hg	Mercury	200.59
81	Tl	Thallium	204.383
82	Pb	Lead	207.2
83	Bi	Bismuth	208.980
84	Po	Polonium	[208.982]
85	At	Astatine	209.987
86	Rn	Radon	222.018
87	Fr	Francium	223.020
88	Ra	Radium	226.025
89-103			
104	Rf	Rutherfordium	[261]
105	Db	Dubnium	[262]
106	Sg	Seaborgium	[266]
107	Bh	Bohrium	[264]
108	Hs	Hassium	[269]
109	Mt	Meitnerium	[268]
110	Ds	Darmstadtium	[269]
111	Rg	Roentgenium	[272]
112	Cn	Copernicium	[277]
113	Uut	Ununtrium	unknown
114	Fl	Flerovium	[289]
115	Uup	Ununpentium	unknown
116	Lv	Livermorium	[298]
117	Uus	Ununseptium	unknown
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60	Nd	Neodymium	144.24
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67	Ho	Holmium	164.930
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69	Tm	Thulium	168.934
70	Yb	Ytterbium	173.04
71	Lu	Lutetium	174.967

Increasing or decreasing?



A photograph of a silver fork standing upright in a field of lavender plants. The fork's tines are pointing downwards, and its handle is pointing upwards. The background is a dense field of lavender, with some green leaves visible on the left side.

Where did we go today?

Ch1010-A17-A03 Lecture 10

- §3.6 Periodic trends in size
- §3.7 Ionization Energy
- §3.8 Electron Affinity
- §4.4 Electronegativity

Next time...

- §4.1 The nature of the chemical bond