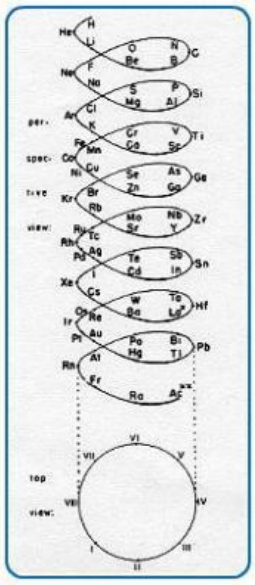
In September 1860, a group of chemists assembled at the First International Congress of Chemists in Karlsruhe, Germany.

At the Congress, Italian chemist Stanislao Cannizzaro presented a novel method for accurately measuring…

Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=86	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

De Chancourtois

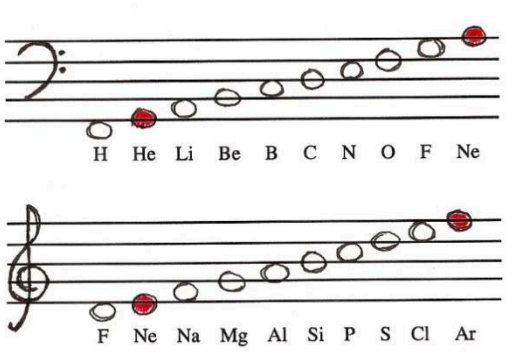


How did Alexandre-Emile Béguyer de Chancourtois arrange the elements?

What did de Chancourtois notice about the properties of the elements?

John Newlands

What law did John Newlands propose for the arrangement of elements?



What was the problem with Newlands' law?

Dmitry Mendeleev / Lothar Meyer

How did Mendeleev order the elements?

What similarities did Mendeleev notice repeating periodically at regular intervals between elements?

Why did Mendeleev leave empty spaces on his periodic table?

What was the problem with Mendeleev's periodic table?

Henry Moseley

How did Moseley revise Mendeleev's periodic table?

*Moseley's periodic table is the current, excepted ordering of the elements!

The Modern Periodic Table

Columns are referred to as _____ or _____

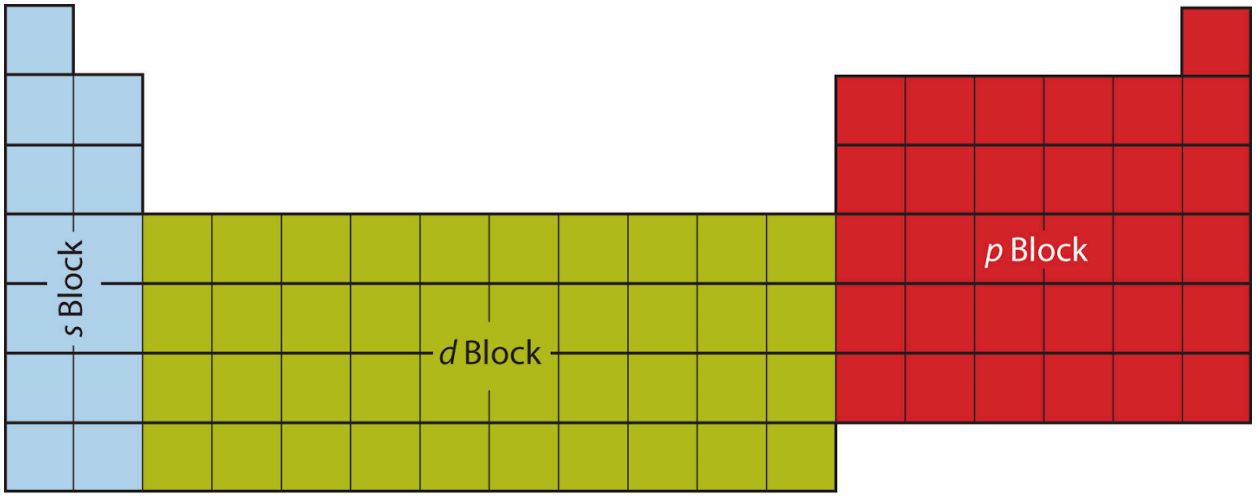
while rows are referred to as _____.

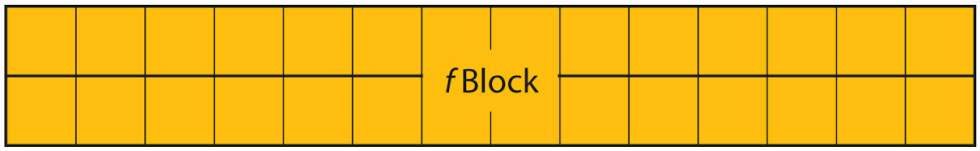
What is the difference between the **representative elements** and the **transition elements**?

What are the physical properties of metals? (Note: over 80% of the periodic table is comprised of metals!)

Luster	High conductivity
Malleability / ductility	High melting point

"Blocks" of the Periodic Table





s-block

Alkali Metals

- Group(s):
- Property(s):
- Noble gas configuration:

Alkaline Earth Metals

- Group(s):
- Property(s):
- Noble gas configuration:

Hydrogen & Helium

- Group(s):
- Property(s):
- Noble gas configurations:

p-block

Semimetals (Metalloids)

- Elements:

- Property(s):

Halogens

- Group(s):
- Property(s):
- Noble gas configuration:

Noble Gases

- Group(s):
- Property(s):
- Noble gas configuration:

d-block

Transition Metals

- Group(s):
- Property(s):

- Electron configurations:

f-block (Inner Transition Metals)

Lanthanides

- Group(s):
- Property(s):
- Electron configurations:

Actinides

- Group(s):
- Property(s):
- Electron configurations:

Review: How can we use noble-gas notation to show the configuration of electrons?

Example: **aluminum (Al)**

Step 1: Determine the noble gas that occupies the last position in the period before the given element. Write the symbol for that noble gas in brackets.

Step 2: Count the number of spaces from the left the element is in its given period.

Step 3: Using superscripts, indicate the total number of electrons in each group of sublevels. Fill all sublevels after the noble gas. Place electrons according to Hund's rules (2 in "s" sublevels, 6 in "p" sublevels, and 10 in "d" sublevels). The subscripts, when added together, should be the same as the number of spaces counted in step 2.

Practice: Write the electron configurations (with noble gas notation) for the following elements.

Silicon, Si	Fluorine, F
Selenium, Se	Manganese, Mn
Tin, Sn	Xenon, Xe

What does each electron configuration mean?

Number:

Letter:

Superscript:

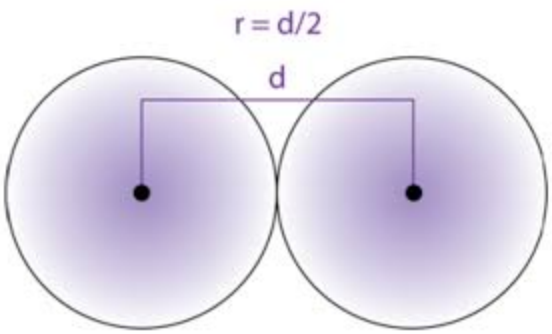
Practice: Identify the energy level, the shape of the orbitals, and the number of electrons in the highlighted sublevel.

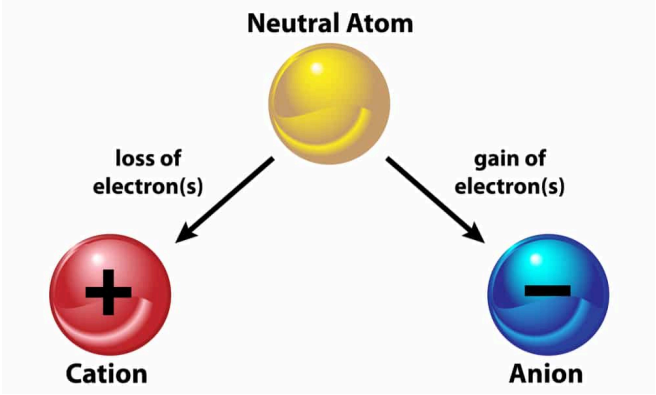
Lithium, Li [He] **2s^{1}**	Fluorine, F [He] 2s^{2} **2p^{5}**
Magnesium, Mg [Ne] **3s^{2}**	Phosphorus, P [Ne] 3s^{2} **3p^{3}**
Gallium, Ga [Ar] **4s^{2}** 3d^{10} 4p^{1}	Molybdenum, Mo [Kr] 5s^{1} **4d^{5}**

Practice: For the following elements, identify the family to which the element belongs, at least one likely property, and the block in which the element can be found.

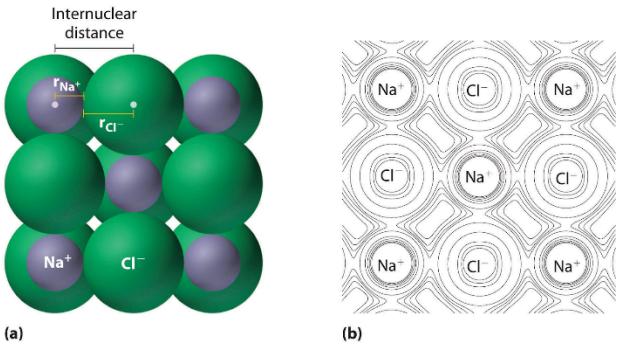
Lithium, Li	Gold, Au
Krypton, Kr	Bromine, Br
Arsenic, As	Neptunium, Np
Praseodymium, Pr	Fluorine, F
Francium, Fr	Mercury, Hg

Essential Vocabulary

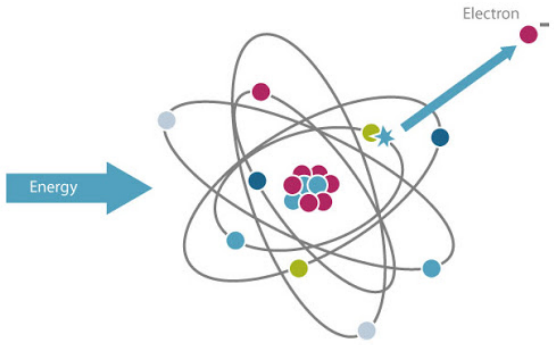
Atomic radius: 
Ion/Octet Rule:



Ionic radius:



Ionization energy:



Equation

$$E(g) \rightarrow E^{+}(g) + e^{-} \quad I_1 = \text{1st ionization energy}$$

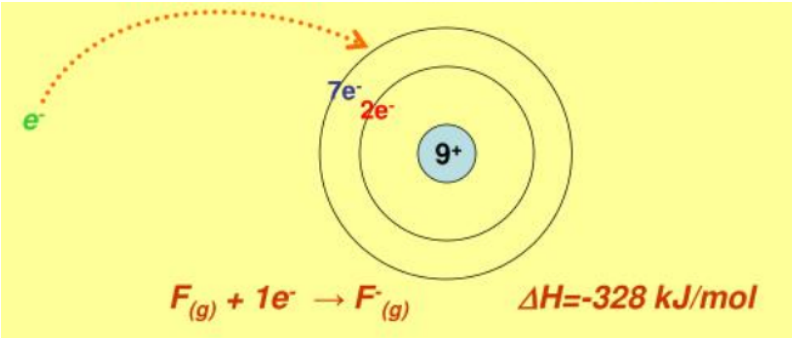
Equation

$$E^{+}(g) \rightarrow E^{2+}(g) + e^{-} \quad I_2 = \text{2nd ionization energy}$$

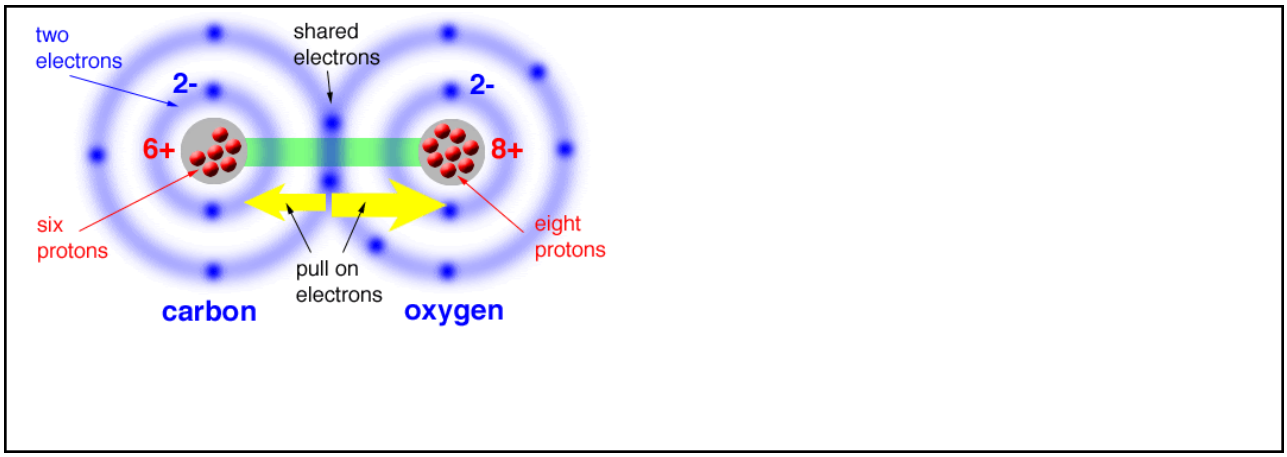
Equation

$$E^{(n-1)+}(g) \rightarrow E^{n+}(g) + e^{-} \quad I_n = n\text{th ionization energy}$$

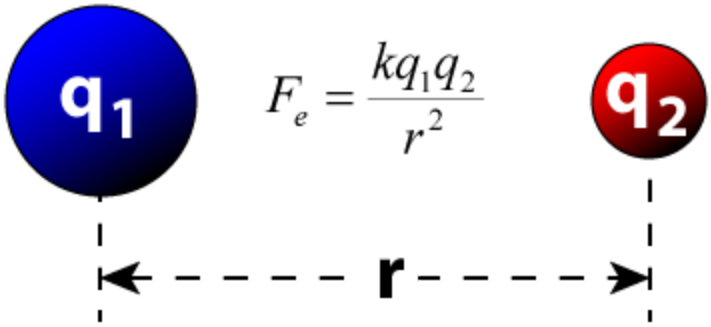
Electron Affinity:



Electronegativity:

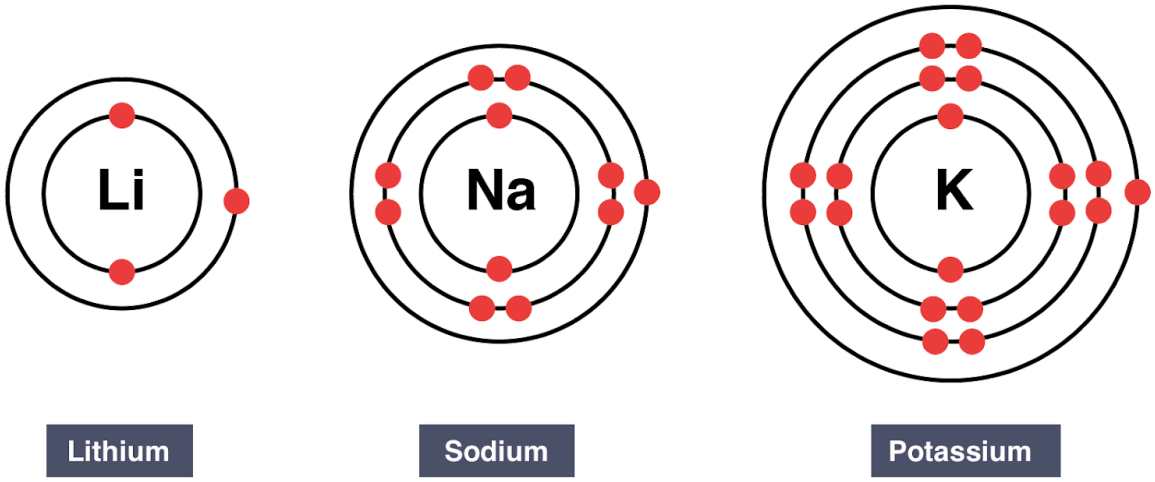


Coulomb's Law

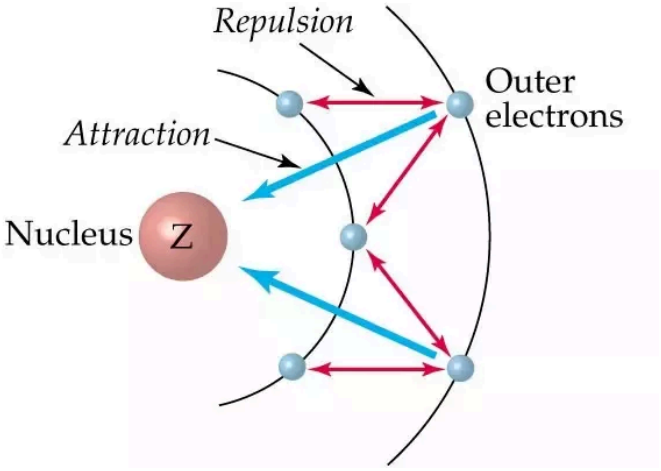


Essential Facts

1) As you move from top to bottom in a given group, you add another _____ of electrons. These extra "shells" of electrons are further from the nucleus. In addition, inner "shells" of electrons "push" outer shells away from the nucleus in a process called **shielding**.



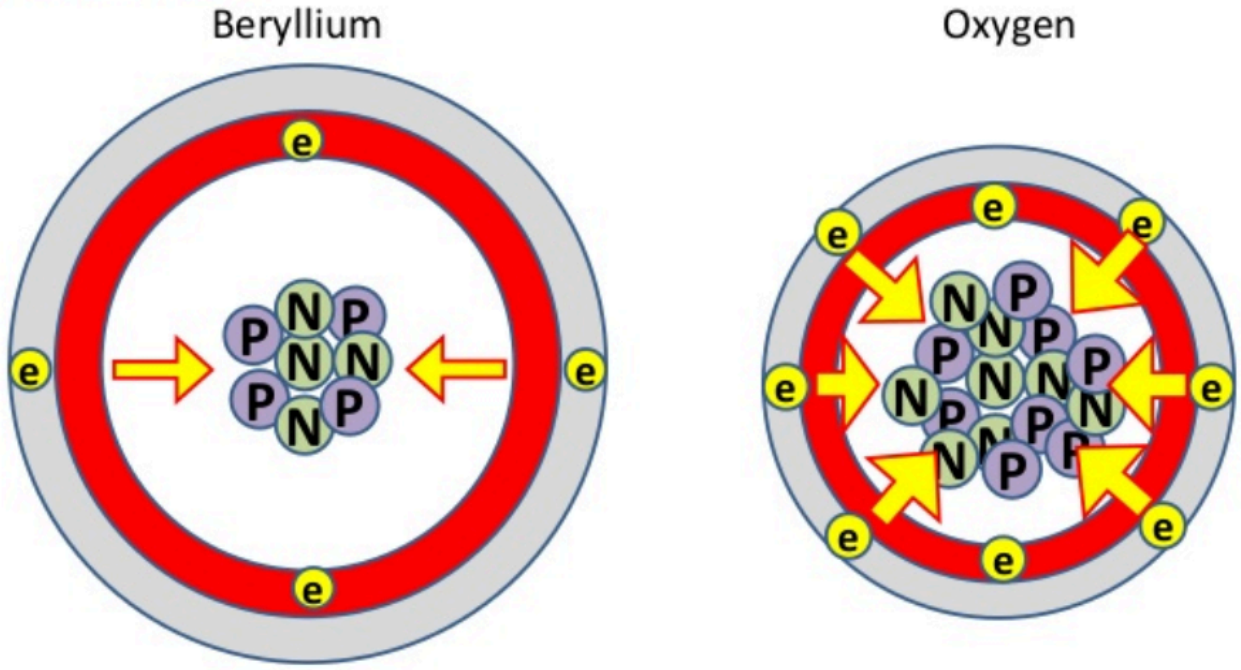
Shielding:



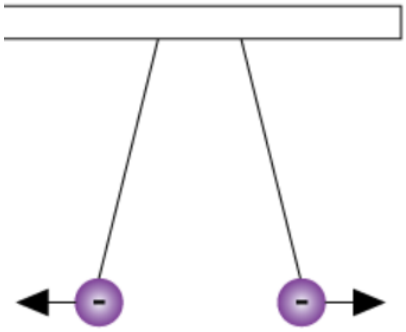
2) As you move from left to right across a period, more and more protons are being added without adding a new energy level of electrons. This causes the outer electrons to "feel" more of an

_____(Z_{eff}) pulling them towards the nucleus. Any

additional electrons added to the energy level do not benefit from additional shielding (not being added to inner core).

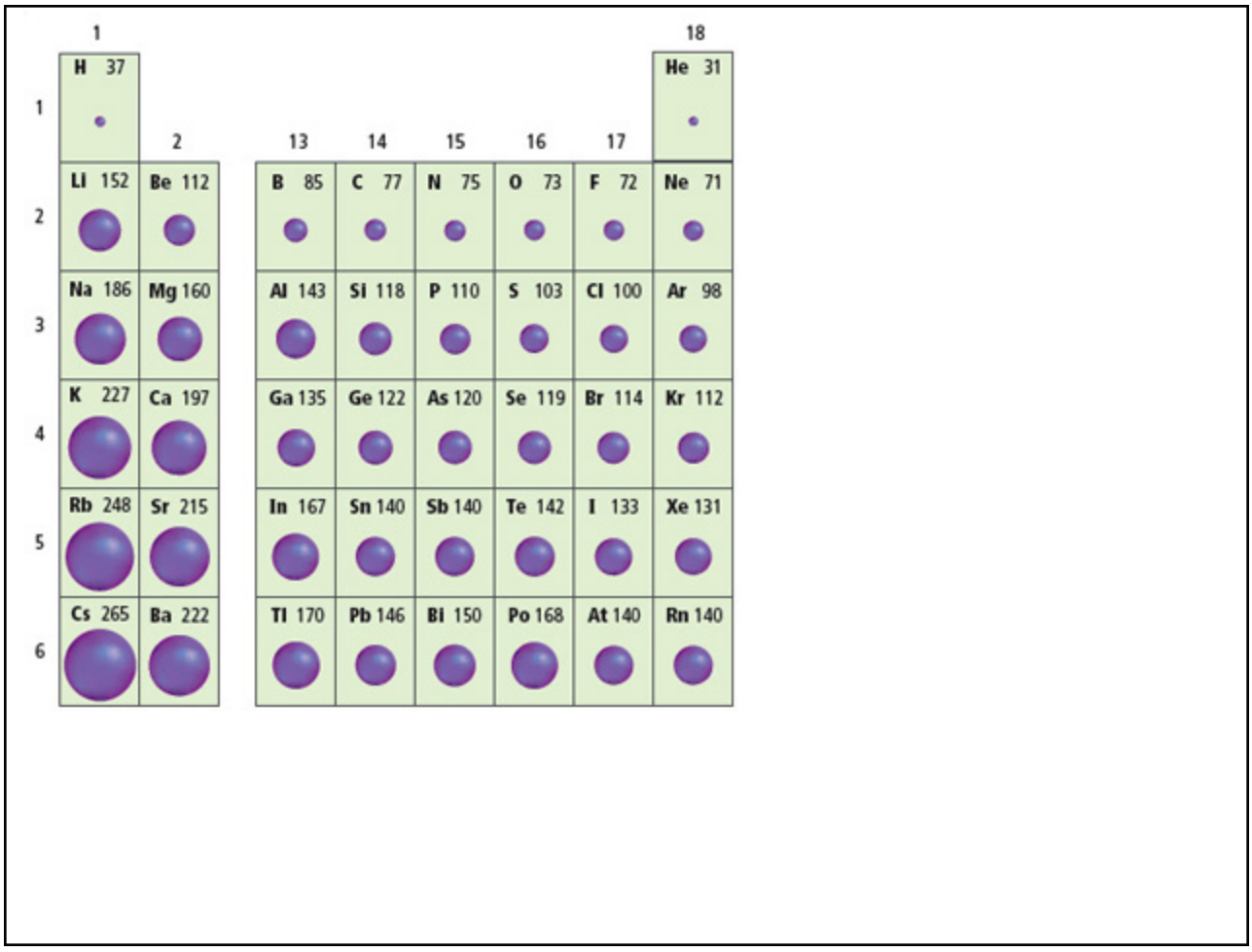


3) When more and more electrons are added to the same energy level and sublevel, they tend to repel each other. Particles with the same charge do not like to be near one another.

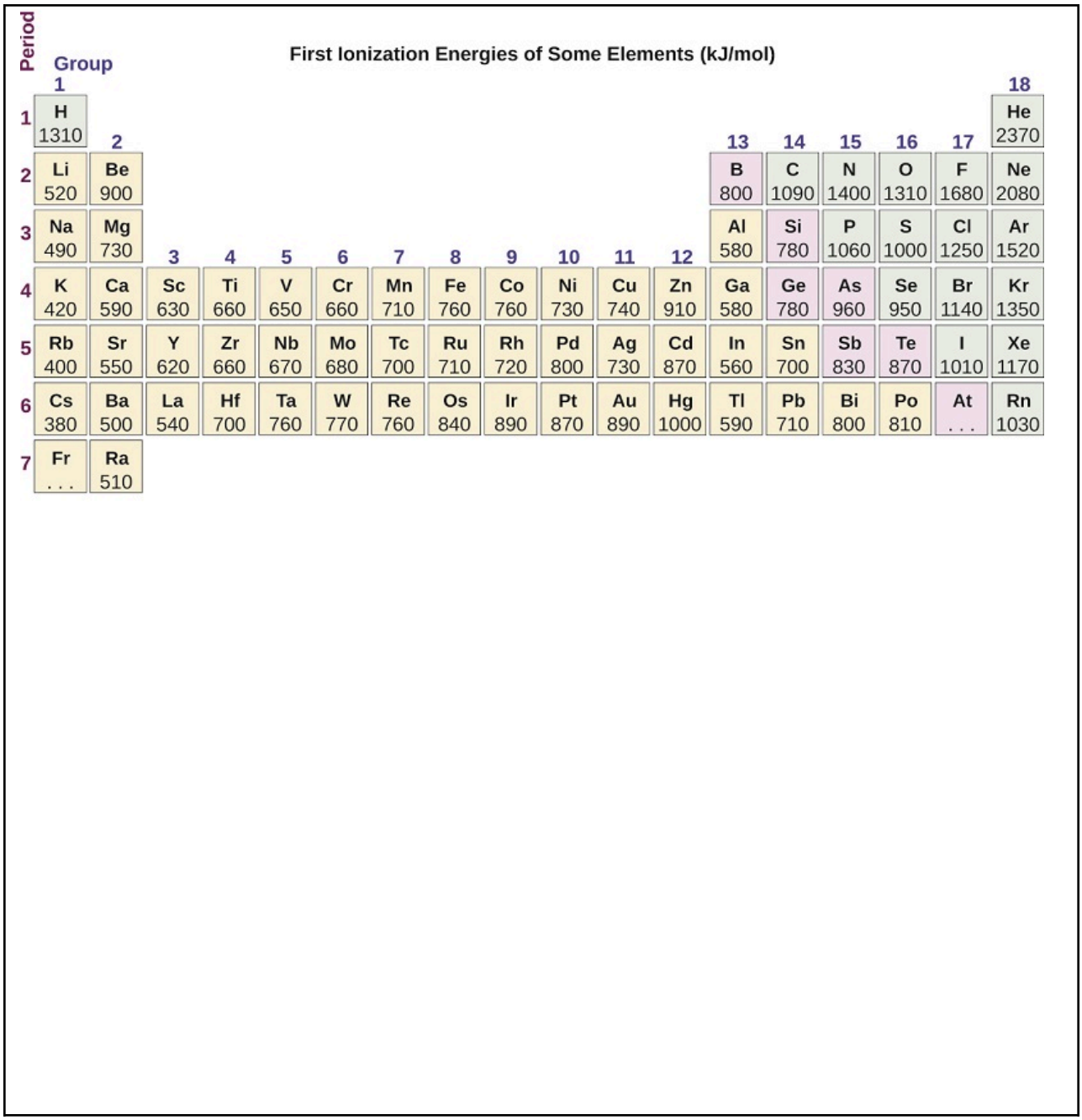


Periodic Trends

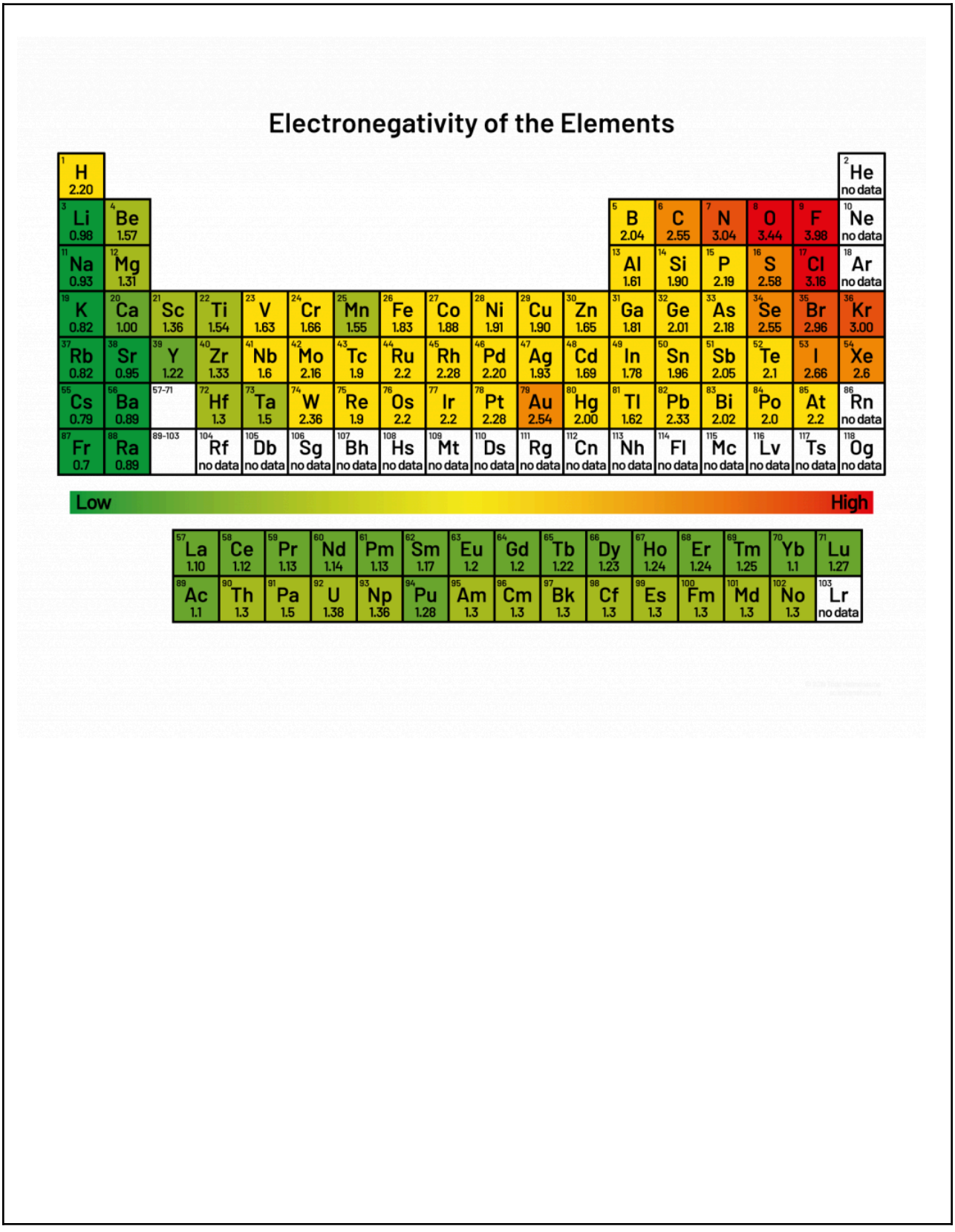
1) Atomic radius



2) Ionization energy


First Ionization Energies of Some Elements (kJ/mol)
Period
Group
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1 H 1310 He 2370
2 Li 520 Be 900 B 800 C 1090 N 1400 O 1310 F 1680 Ne 2080
3 Na 490 Mg 730 Al 580 Si 780 P 1060 S 1000 Cl 1250 Ar 1520
4 K 420 Ca 590 Sc 630 Ti 660 V 650 Cr 660 Mn 710 Fe 760 Co 760 Ni 730 Cu 740 Zn 910 Ga 580 Ge 780 As 960 Se 950 Br 1140 Kr 1350
5 Rb 400 Sr 550 Y 620 Zr 660 Nb 670 Mo 680 Tc 700 Ru 710 Rh 720 Pd 800 Ag 730 Cd 870 In 560 Sn 700 Sb 830 Te 870 I 1010 Xe 1170
6 Cs 380 Ba 500 La 540 Hf 700 Ta 760 W 770 Re 760 Os 840 Ir 890 Pt 870 Au 890 Hg 1000 Tl 590 Pb 710 Bi 800 Po 810 At . . . Rn 1030
7 Fr . . . Ra 510

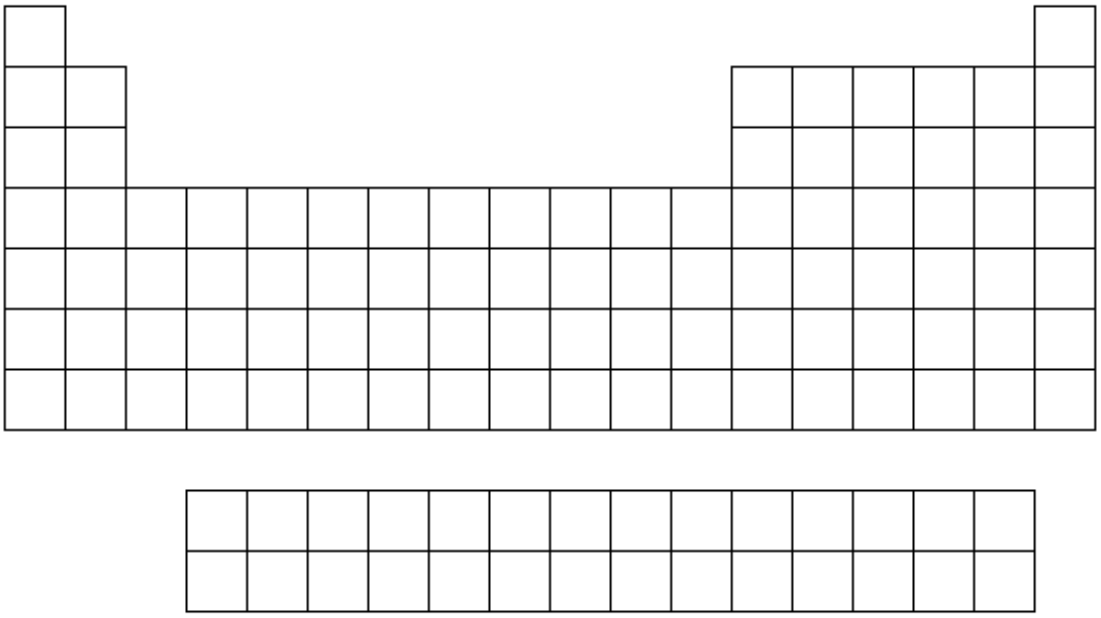
3) Electronegativity



4) Ionic size

Cations

Anions



Practice: Place the following elements in order of **increasing electronegativity**. Then, **justify** the order in which you placed them.

Be, F, O, C, N

Practice: Place the following elements in order of **decreasing first ionization energy**. Then, **justify** the order in which you placed them.

Cs, Li, Rb, K, Na

Practice: Place the following elements in order of **increasing atomic radius**. Then, **justify** the order in which you placed them.

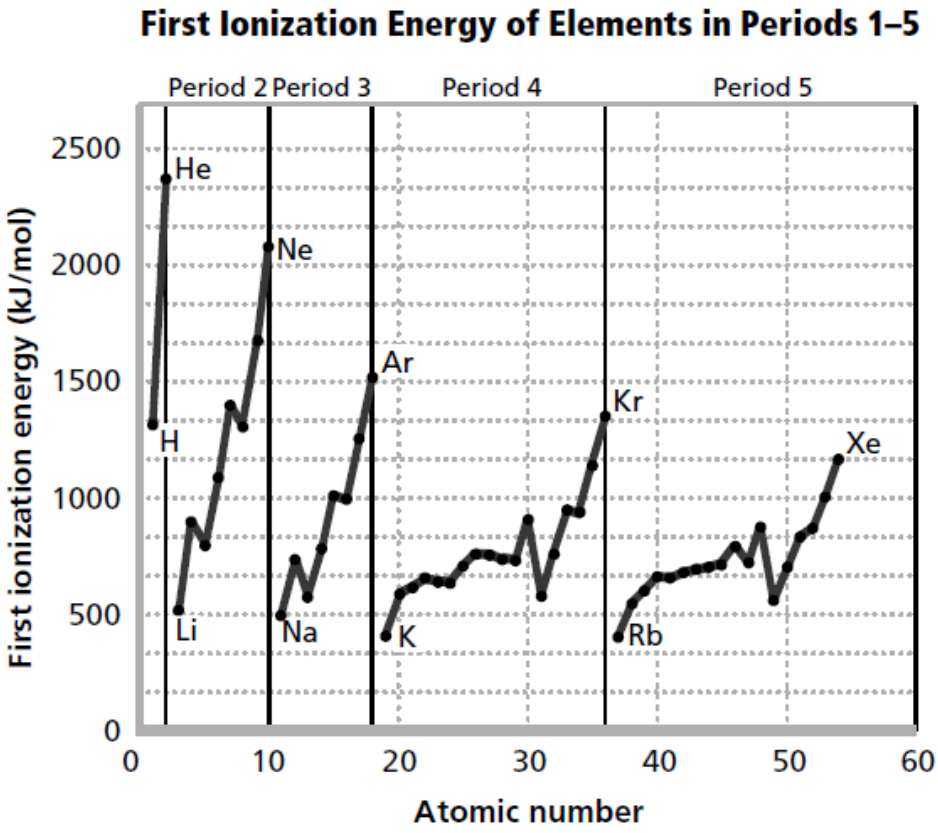
O, Po, N, Te, Sb

Practice:

1) The ionic radius of Ca^{2+} is 114 pm while the atomic radius of elemental Ca is 231 pm. Account for this discrepancy using atomic structure and Coulomb's law.

2) Which chemical species would you predict to have a larger radius--a bromine atom or a bromine anion? Explain your answer.

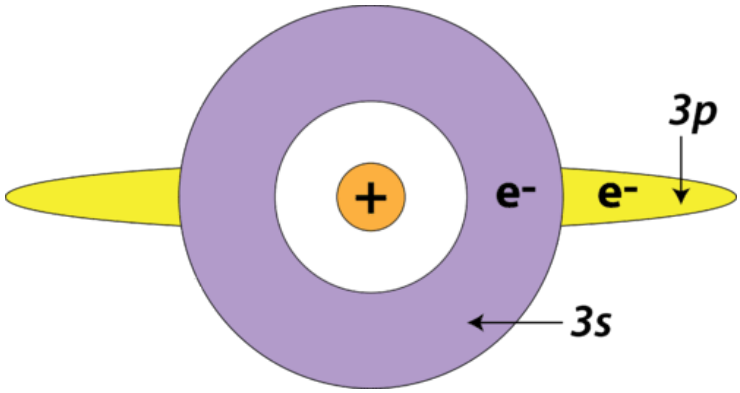
Advanced Topics in Periodic Trends



*What accounts for the deviations in first ionization energy in this graph?

Essential Facts

1) "p" orbitals in the same energy level as "s" orbitals are shielded slightly from the "s" orbitals. This is due to the "p" orbitals extending a little farther than the "s" orbitals from the nucleus.



Practice: The element aluminum (Al) has a slightly lesser first ionization energy (in magnitude) compared to magnesium (Mg). Explain this observation using principles of atomic structure.

2) In almost every period on the periodic table, the first ionization energy decreases from elements in group 15 to elements in group 16. Can we use orbital diagrams to explain this in period 2?

Practice: Use principles of atomic structure to justify why the first ionization energy of tellurium (Te) is lower than that of antimony (Sb).

3) It becomes increasingly harder and harder to remove electrons from atoms.

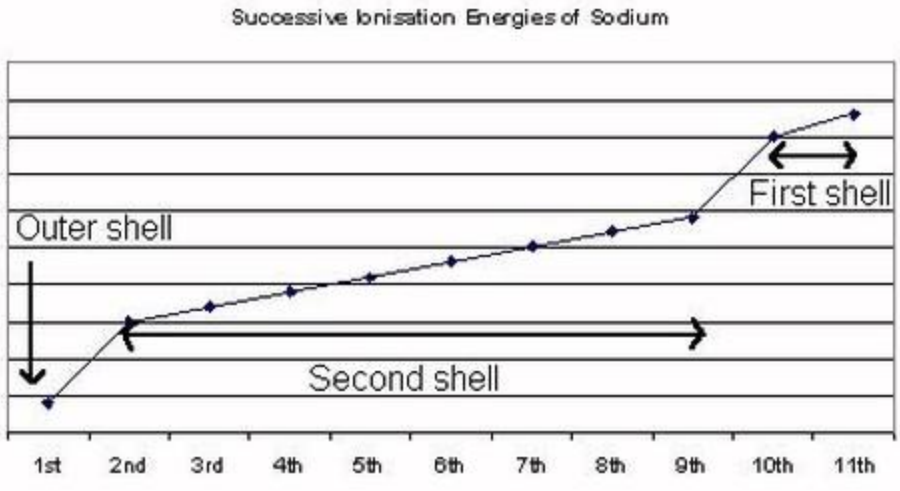
Successive Ionization Energies for the Period 2 Elements

Element	Valence electrons	Ionization energy (kJ/mol)* 1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Li	1	520	7300							
Be	2	900	1760	14,850						
B	3	800	2430	3660	25,020					
C	4	1090	2350	4620	6220	37,830				
N	5	1400	2860	4580	7480	9440	53,270			
O	6	1310	3390	5300	7470	10,980	13,330	71,330		
F	7	1680	3370	6050	8410	11,020	15,160	17,870	92,040	
Ne	8	2080	3950	6120	9370	12,180	15,240	20,000	23,070	115,380

* mol is an abbreviation for mole, a quantity of matter.

Why does this happen?

Practice: Explain why the magnitude of the second ionization energy of sodium is so much larger than the first.



Practice: Which of the following elements--Mg or Al--would you expect to have a higher 3rd ionization energy? Explain your answer.

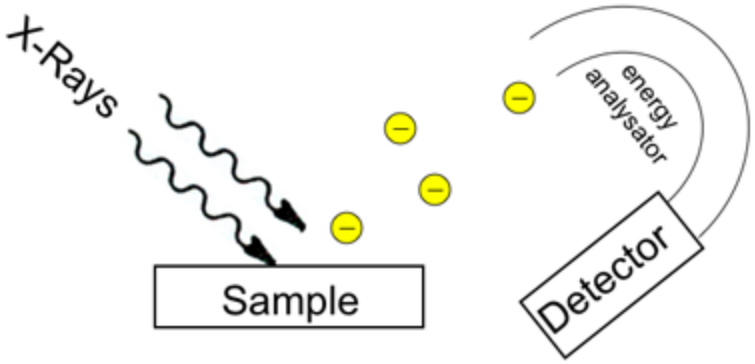
Isoelectronic species:

Example: How are F^-, Ne, and Na^+ isoelectronic? Which species would have the largest radius?

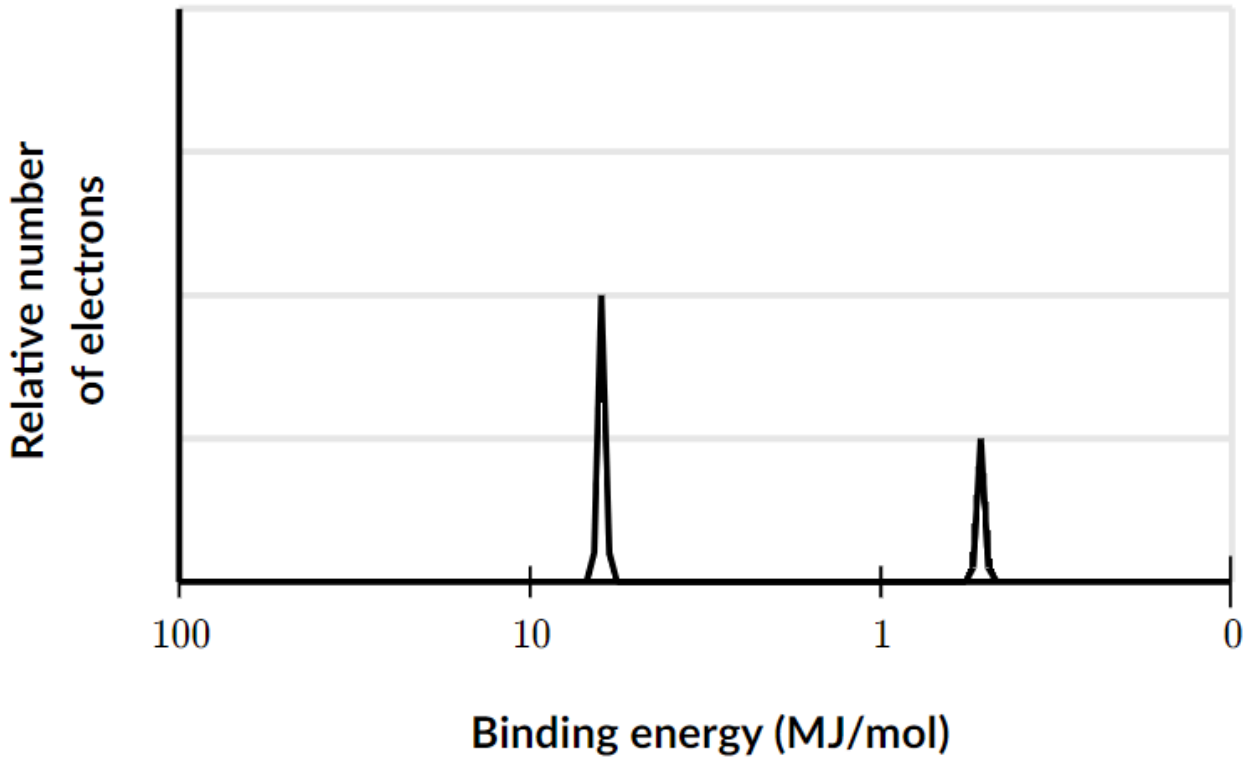
Practice: Which of the following chemical species has the largest atomic radius? Why?

Te^{-2}, I^{-1}, Xe, Cs^{+1}, Ba^{+2}

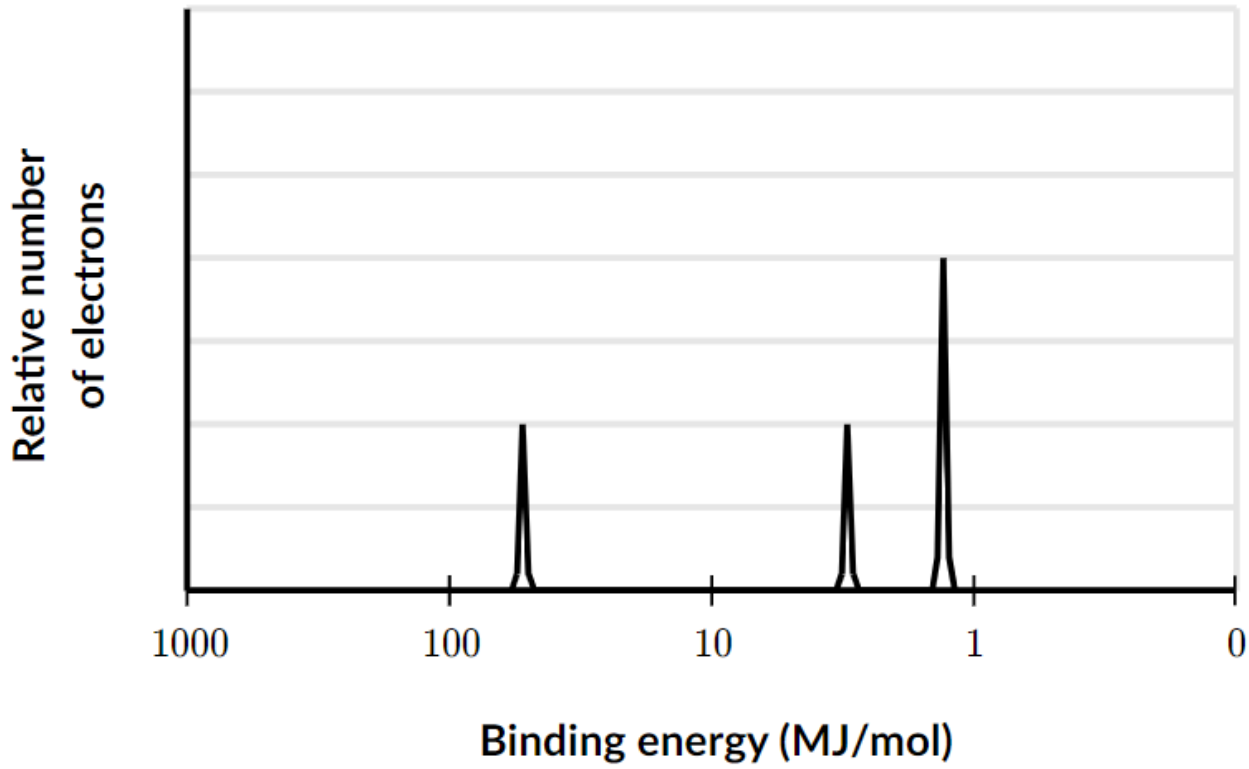
Photoelectron spectroscopy (PES):



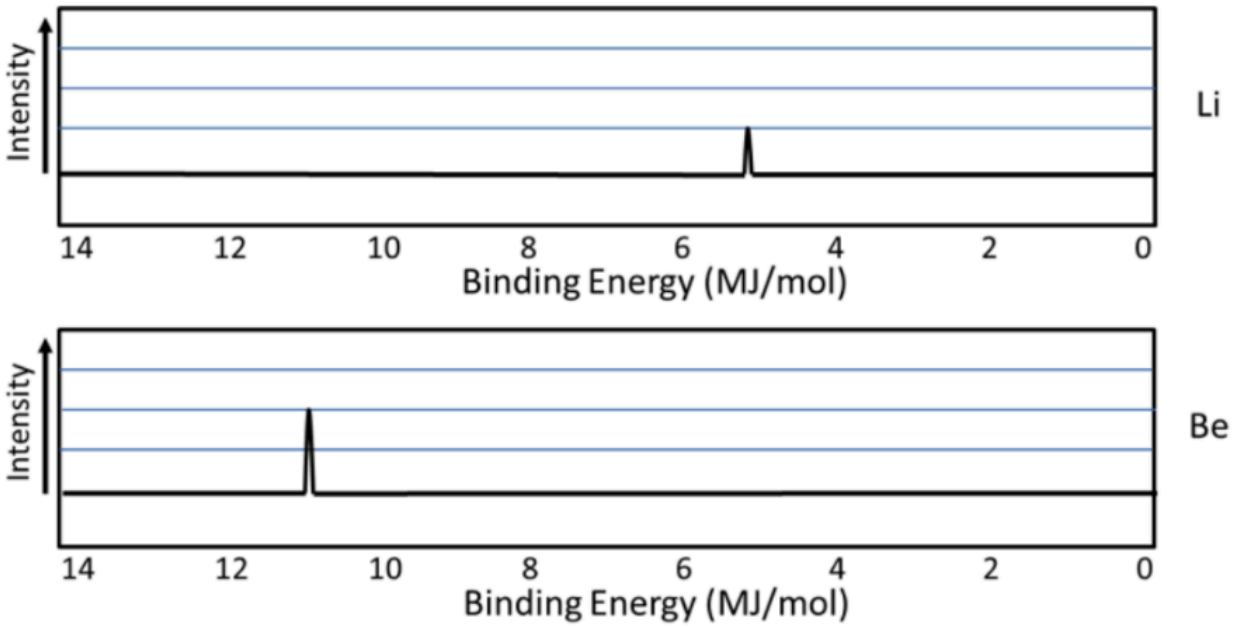
Example:



Practice: What element does this PES spectrum appear to represent?



Practice: Both of these spectra correspond to the 2s peaks for lithium and beryllium, respectively. Explain the difference in the peaks using atomic theory.


Intensity
Li
14
12
10
8
6
4
2
0
Binding Energy (MJ/mol)
Intensity
Be
14
12
10
8
6
4
2
0
Binding Energy (MJ/mol)