

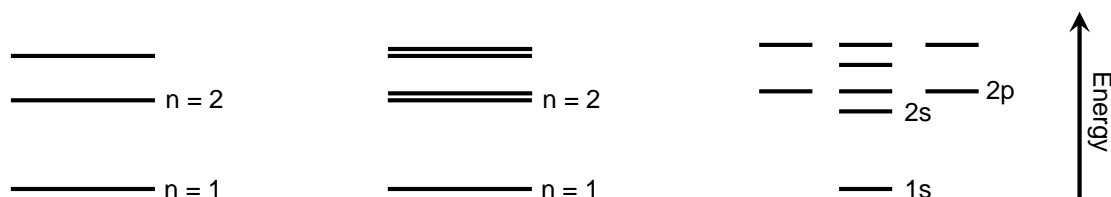
Chapter 8: Electron Configurations and Periodicity

Learning Objectives:

- 1) Write an electron configuration for an atom, ion or excited state
- 2) Write a condensed (noble gas) electron configuration for an atom, ion or excited state
- 3) Understand the relationship between electron configurations & energy level diagrams
- 4) Compare and explain the periodic trends
 - a) Atomic radius
 - b) Ionic radius
 - c) Ionization energy
 - d) Electron affinity

Summary of What We Think We Know

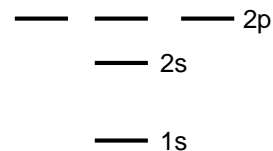
- Bohr model gives energy levels for H atom that work, but don't work for other atoms
 - Each n represents an energy level in H-atom, thus the Rydberg equation works
 - The PES data showed that after $n = 1$, many of the shells split into 'subshells'
 - Other experiments show that only 2 e^- can be in any orbital, again changing E-level diagrams



- Quantum mechanics was deduced and gave us all four quantum numbers needed to map out the energy level diagram of the atoms
 - Often, these quantum numbers are given as (n, l, m_l, m_s) for compactness
 - For example, you might say the electron in $(3, 2, 0, \frac{1}{2})$
- Unfortunately, the energy level diagrams as we've shown are unwieldy
 - To simplify the writing of these, two methods have been developed
 - Orbital diagrams: essentially showing each level as above, but from left to right
 - This is the form your text uses
 - Electronic configurations: a very compact shorthand that you must master

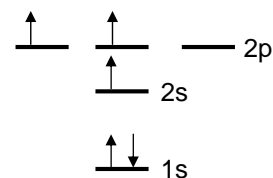
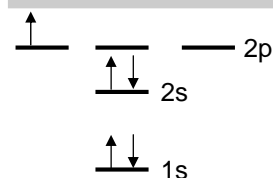
Electron Configurations

- We'll be writing three pieces of information in our electron configurations: n , l and the # of electrons in each subshell.
 - We can get the entire story from the periodic table. First, imagine the nucleus of an atom, say lithium, just sitting there
 - This Li^{3+} needs three electrons to be neutral, so let's fill up an imaginary energy level diagram:
 - Now write out, from top to bottom the electron configuration
- Let's try Nitrogen with just the periodic table. Just follow the periodic table until you've added enough electrons to make the 'bare nucleus' neutral
- OK, try iron on your own
 - Iron has 4 natural isotopes, how would they differ in terms of the electron configuration?



Ions and Excited States

- Suppose I wanted to depict an ion, say B^+ .
 - How would the energy level diagram change to become B^+ ?
 - OK, so write the electron configuration for B^+ :
- On your own, write the electron configuration for S^{2-}
- So far, we've written our electron configurations for the ground state of any atom or ion. But, thermal, electric or light energy can excite electrons such that the atom is no longer at its lowest possible energy.
 - For example, here a 2s electron in Boron has been excited. Write the electron configuration for this excited state
 - Is this the excited or ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^8$?



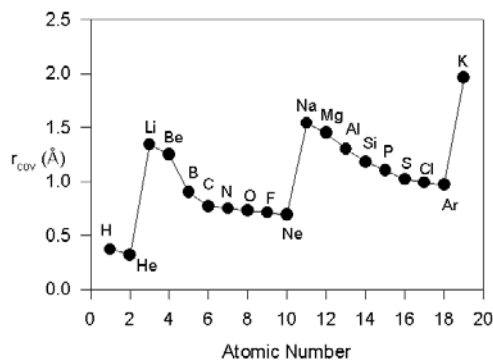
Happy Atoms and Exceptions to the Periodic Table

- From observation, it turns out that some electron configurations appear to be more **stable** than others
 - Most happy (stable) is any full outer shell (an np^6 species)
 - That is, a noble gas electron configuration
 - Next, a filled valence subshell (ns^2 or nd^{10})
 - Finally, a half filled valence subshell (ns^1 or nd^5 or np^3)
- Can apply these ideas to a few weird transition metal electron configurations: Cr and Cu for example
 - Cr
 - Cu
- Finally, we can simplify our life a bit by noting that these darn things are pretty repetitive. Let's only tell people about the outer shell (valence shell) by using the **condensed electron configuration** (noble gas configuration)
 - Simply write valence shell after writing noble gas that *precedes* the atom on the periodic table

Periodic Trends: Atomic Radii

- Even though only s-orbitals are spheres, atoms still seem to be spherical
 - Their size can be described by the radius of this sphere, then.
 - Different experiments allow the data to the right to be collected and plotted
- Describe the general trend you see:
 - Does the atomic radius tend to increase left to right, or right to left?
 - Does the atomic radius tend to increase top to bottom, or bottom to top?
- As a group, come up with a physical explanation as to the trends above.

Covalent Radius versus Atomic Number



Periodic Trends: Ionic Radii

- Atomic radius is a balance between attractive and repulsive forces inside the atom
 - If we add or remove an electron (making an ion), this balance is disturbed and the radius should change.
- In your group, predict how the radius will change if an electron is removed from the atom (a positive charge)

- In your group, predict how the radius will change if an electron is added from the atom (a negative charge)

- Not unusual to compare isoelectronic species, such as S^{2-} , Cl^- , Ar, and K^+ . Rank in terms of radius!

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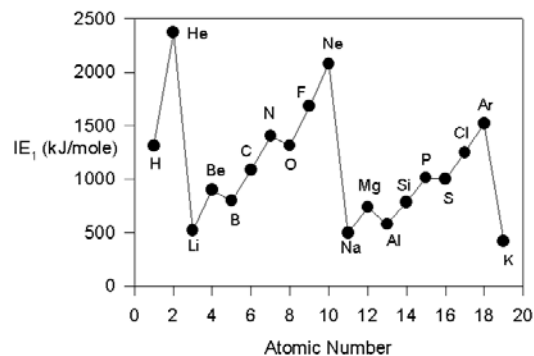
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Periodic Trends: Ionization Energy

- The energy needed to remove the first electron from an atom can be compared. Call this the **ionization energy**. It represents the reaction:
 $X(g) \rightarrow X^+(g) + e^-$
- Does the ionization energy increase or decrease as we move down the periodic table (use the data to the right to aid you).
 - Can you explain why this is true?

First Ionization Energy versus Atomic Number



- In general, as we move across any period (left to right), the IE tends to increase. However, the plots show a consistent 'jump' in IE in two places. Explain these jumps.

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Periodic Trends: Electron Affinity

- The energy given off after the addition of the first electron to a neutral atom can be compared. Call this the **electron affinity**. It represents the reaction:
 $X(g) + e^- \rightarrow X^-(g)$

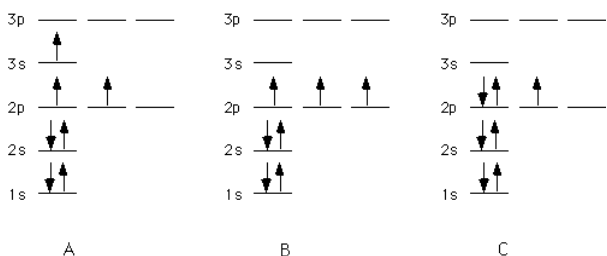
Periodic Table of the Elements
Electron Affinity (kJ/mol)

1 H -73																	2 He 21
3 Li -60	4 Be 19											5 B -27	6 C -122	7 N 0	8 O -141	9 F -328	10 Ne 29
11 Na -53	12 Mg 19											13 Al -44	14 Si -134	15 P -72	16 S -200	17 Cl -349	18 Ar 35
19 K -48	20 Ca 10	21 Sc -18	22 Ti -8	23 V -51	24 Cr -64	25 Mn 0	26 Fe -16	27 Co -64	28 Ni -112	29 Cu -118	30 Zn 47	31 Ga -29	32 Ge -116	33 As -78	34 Se -195	35 Br -325	36 Kr 39

- Note, if energy is needed to remove an electron (the IE), then the opposite process (adding an electron) should give off energy!
 - Thus, the negative values. The more negative, the more energy was given off after the addition of an electron. If the value is positive, then...
- In general, what type of atom wants to make a negative ion?
 - This would have a high electron affinity (large, negative value)
- In general, what type of atom doesn't want to make a negative ion?
 - This would have a low EA
- And the weird parts are...

Concept Check

- Which energy level diagram represents a ground state atom?



- Write the electron configuration for the species represented in choice A to the left, assuming the atom is neutral.

- Rank choices A, B, and C from lowest IE to highest IE.

- Which one of the following has the largest atomic radius?

- Fe
- F
- Br
- Sr

- Which one of the following has the largest ionic radius?

- N^{3-}
- Al^{3+}
- F^-
- Na^+

- Rank choices A, B, and C from lowest (least negative) EA to highest EA (most negative).