Unit#2
AP Chem
Topic#10
Structure (Atomic)

Student Edition

Atomic Theory
Topic#10

Light

Electromagnetic Radiation (EM Radiation)

- c = wavelength (**λ, lambda**) x frequency (**ν, nu**)
  - $c = \lambda \times \nu = 2.998\text{x}10^{8}$ m/s

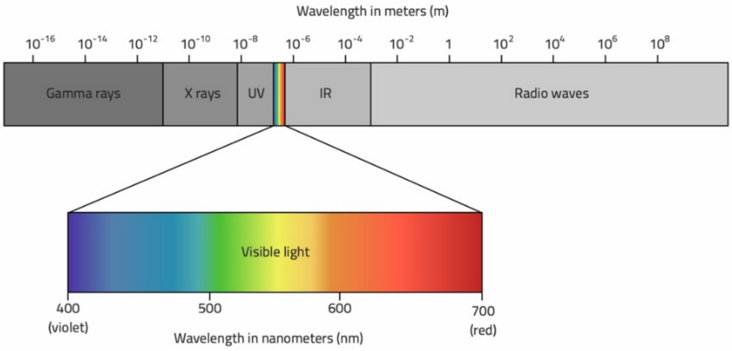
Max Planck

- Energy can only be gained/lost in whole number multiples of the quantity, $h\nu$
  - where h is Planck's constant, $6.626\text{x}10^{-34}$ J-s
  - $\Delta E = nh\nu$ (or $E_{\text{photon}} = h\nu = hc/\lambda$)
    - where n is an integer (1,2,3...)
    - quantization of energy (discrete packets called quanta)

Photoelectric Effect

- Einstein proposed light can be thought of as a stream of "massless particles" called photons.
- Electrons are emitted from the surface of a metal when light of a specific frequency hits it.
  - De Broglie's equation, $\lambda = h/mv$
- Dual nature of light - particle and wave

gamma rays	**radio waves**
short wavelength (λ)	long wavelength (λ)
high frequency (ν)	low frequency (ν)
high energy (E)	low energy (E)



Atomic Theory
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Light

Sample WS#1 - Atomic Frequency of EM Radiation

1. Calculate the frequency of red light of wavelength 6.50x10²nm. (Ans: 4.61x10¹⁴Hz (1/s)

Gun

$\lambda = 6.50 \times 10^{2}$ nm

NTK

$c = \lambda * \nu$

$c = 2.998 \times 10^{8}$ m/s

Unk

$\nu = \underline{4.61 \times 10^{14}}$ 1/s or Hz

Solve:

$$6.50 \times 10^{2}\,\cancel{nm} \times \frac{1\,m}{10^{9}\,\cancel{nm}} = 6.50 \times 10^{-7}\,m$$

$$\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^{8}\,\cancel{m}/s}{6.50 \times 10^{-7}\,\cancel{m}} = \boxed{4.61 \times 10^{14}\ 1/s}$$

2. What is the increment of energy (the quantum) that is emitted at 4.50x10²nm by CuCl? (Ans: 4.41x10⁻¹⁹J)

Gun

$\lambda = 4.50 \times 10^{2}$ nm

$(4.50 \times 10^{-7}\,m)$

$(450 \times \underbrace{10^{-9}}_{n}\,m)$

NTK

$E = \frac{hc}{\lambda}$ where $h = 6.626 \times 10^{-34}$ J·s

Unk

$E = \underline{4.14 \times 10^{-19}}$ J

Solve:

$$E = \frac{(6.626 \times 10^{-34}\,J \cdot \cancel{s})(2.998 \times 10^{8}\,\cancel{m}/\cancel{s})}{(4.50 \times 10^{-7}\,\cancel{m})} = \boxed{4.14 \times 10^{-19}\ J}$$

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3. Using de Broglie's equation, $\lambda = h/mv$, compare the wavelength for an electron (mass = $9.11\text{x}10^{-31}$kg) traveling at a speed of $1.0\text{x}10^{7}$m/s with that of a ball (mass = 0.10kg) traveling at 35m/s (Ans: $7.27\text{x}10^{-11}$m vs. $1.9\text{x}10^{-34}$m)

Gvn

$$\lambda = \frac{h}{mv}$$

$m_{e^-} = 9.11 \times 10^{-31}\ \text{Kg}$

$m_{bb} = 0.10\ \text{Kg}$

$V_{e^-} = 1.0 \times 10^{7}\ \text{m/s}$

$V_{bb} = 35\ \text{m/s}$

NTK

$h = 6.626 \times 10^{-34}\ \text{Kg} \cdot \text{m}^2/\text{s}$

Unk

$\lambda_{e^-} = \underline{7.27 \times 10^{-11}}\ \text{m}$

$\lambda_{bb} = \underline{1.9 \times 10^{-34}}\ \text{m}$

Solve:

$$e^-: \lambda_{e^-} = \frac{6.626 \times 10^{-34}\ \cancel{\text{Kg}} \cdot \text{m}^{\cancel{2}}/\cancel{\text{s}}}{(9.11 \times 10^{-31}\ \cancel{\text{Kg}})(1.0 \times 10^{7}\ \cancel{\text{m}}/\cancel{\text{s}})} = 7.27 \times 10^{-11}\ \text{m}$$

$$bb: \lambda_{bb} = \frac{6.626 \times 10^{-34}\ \cancel{\text{Kg}} \cdot \text{m}^{\cancel{2}}/\cancel{\text{s}}}{(0.10\ \cancel{\text{Kg}})(35\ \cancel{\text{m}}/\cancel{\text{s}})} = 1.9 \times 10^{-34}\ \text{m}$$

Atomic Theory
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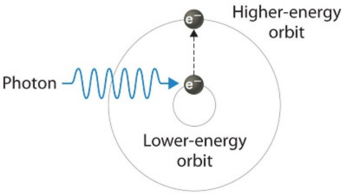
Light

Atomic Spectrum of Hydrogen

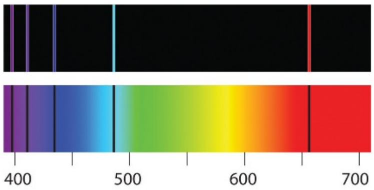
- **Continuous spectrum -** ROY G BIV
- **Line spectrum -** unique to each substance, photons of specific frequency (*E*) are formed when an electron "falls" from a higher energy state to a lower energy state, the movement "down" releases energy in the form of light (EM spectrum)

Bohr Model

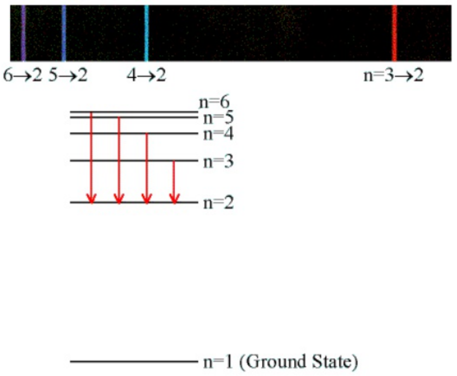
- Developed quantum model for H (a single electron of the H atom could occupy only certain energy states)
- Equation for the energy levels available for an electron in H: $E = -2.178\text{x}10^{-18}\text{J}(Z^2/n^2)$
- Ground state – lowest energy state, $n = 1$
- $\Delta E = E_F - E_I$



(a) Electronic absorption transition



(b) H_2 emission spectrum (top), H_2 absorption spectrum (bottom)



Atomic Theory
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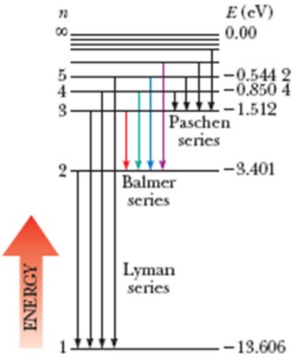

$\Delta E = E_F - E_I$ $E = -2.178\text{x}10^{-18}\text{J} \ (Z^2/n^2)$

3. Calculate the energy required to excite the hydrogen electron from level $n = 1$ to level $n = 2$. Also calculate the wavelength of light that must be absorbed by hydrogen atom in its ground state to reach this excited state.

(Ans: $1.633\text{x}10^{-18}$J, $1.216\text{x}10^{-7}$m)

Gvn

$E_i = n = 1$

$E_f = n = 2$

NTK

$E = \frac{hc}{\lambda}$ $\Delta E = E_f - E_i$

$\lambda = \frac{hc}{E}$ $E = -2.178 \times 10^{-18} \text{ J} \left(\frac{Z^3}{n^2}\right)$

UNK

$E = \underline{1.634 \times 10^{-18} \text{ J}}$

$\lambda = \underline{1.21 \times 10^{-7} \text{ m}}$

Solve:

$E_i = -2.178 \times 10^{-18} \text{ J} \left(\frac{1^2}{1^2}\right) = -2.178 \times 10^{-18} \text{ J}$

$E_f = -2.178 \times 10^{-18} \text{ J} \left(\frac{1^2}{2^2}\right) = -5.445 \times 10^{-19} \text{ J}$

$\Delta E = -5.445 \times 10^{-19} - (-2.178 \times 10^{-18}) = 1.634 \times 10^{-18} \text{ J}$

$\lambda = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(2.998 \times 10^{8})}{(1.634 \times 10^{-18})}$

$\lambda = 1.21 \times 10^{-7} \text{ m}$

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$\mathbf{\Delta E = E_F - E_I}$ $\mathbf{E = -2.178 \times 10^{-18} J\ (Z^2/n^2)}$

5. (OYO) Calculate the energy required to remove the electron from a hydrogen atom in its ground state. (Ans: $2.178x10^{-18}$J)

Atomic Theory
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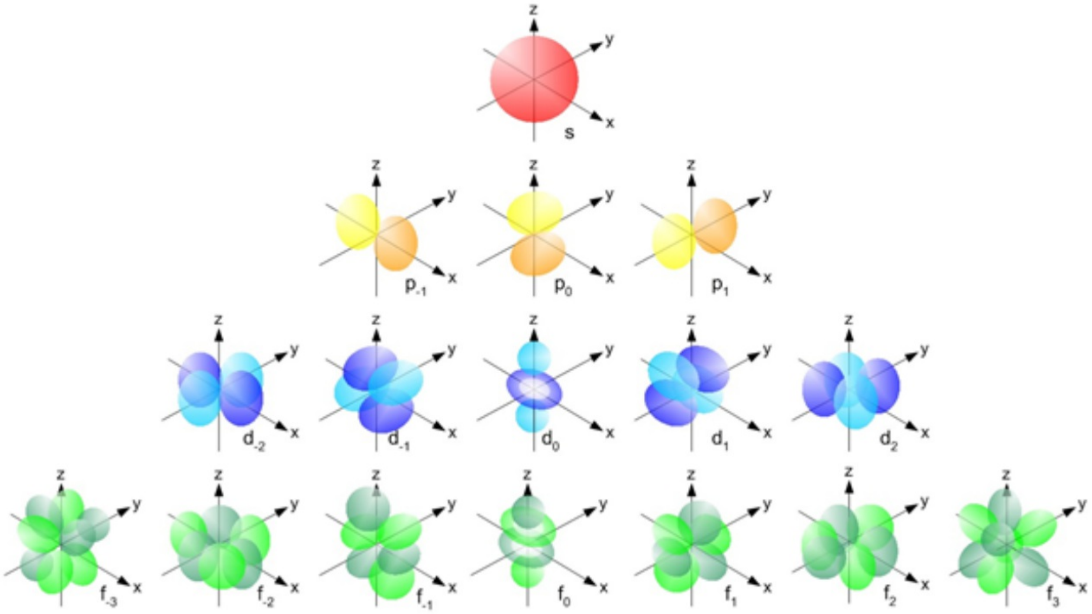
Quantum-Mechanical Model of the Atom

Quantum Wave Mechanical Model of Atom

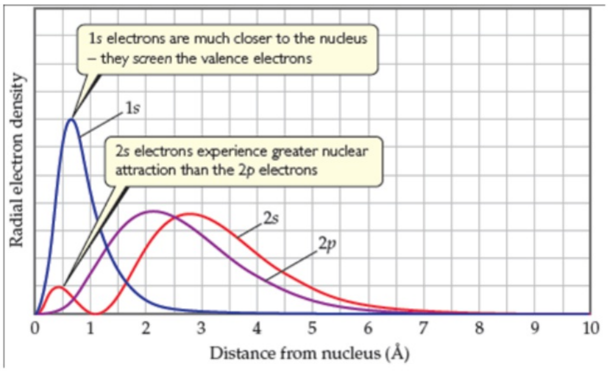
- Heisenberg Uncertainty Principle - cannot know position and momentum of a particle at the same time.
- Orbital - energy level where an electron can exist
- Quantum numbers
  - Principal quantum number, $n = 1$ to 7
  - Angular momentum quantum number (l) - shape (type) of orbital $l = 0$ (s), $l = 1$ (p), $l = 2$ (d), $l = 3$ (f)
  - Magnetic quantum number (m_l) - orientation of orbital in space
    - s-orbital - $m_l = 0$ 1 orbital with a maximum of 2 electrons
    - p-orbital - $m_l = -1, 0, 1$ 3 orbitals with a maximum of 6 electrons
    - d-orbital - $m_l = -2, -1, 0, 1, 2$ 5 orbitals with a maximum of 10 electrons
    - f-orbital - $m_l = -3, -2, -1, 0, 1, 2, 3$ 7 orbitals with a maximum of 14 electrons
  - Spin quantum number (m_s) - an electron spins clockwise (+1/2) or counterclockwise (-1/2)
  - Each electron has a unique set of four quantum numbers (n,l, m_l, m_s)

Quantum-Mechanical Model of the Atom



Different Shapes of Orbitals

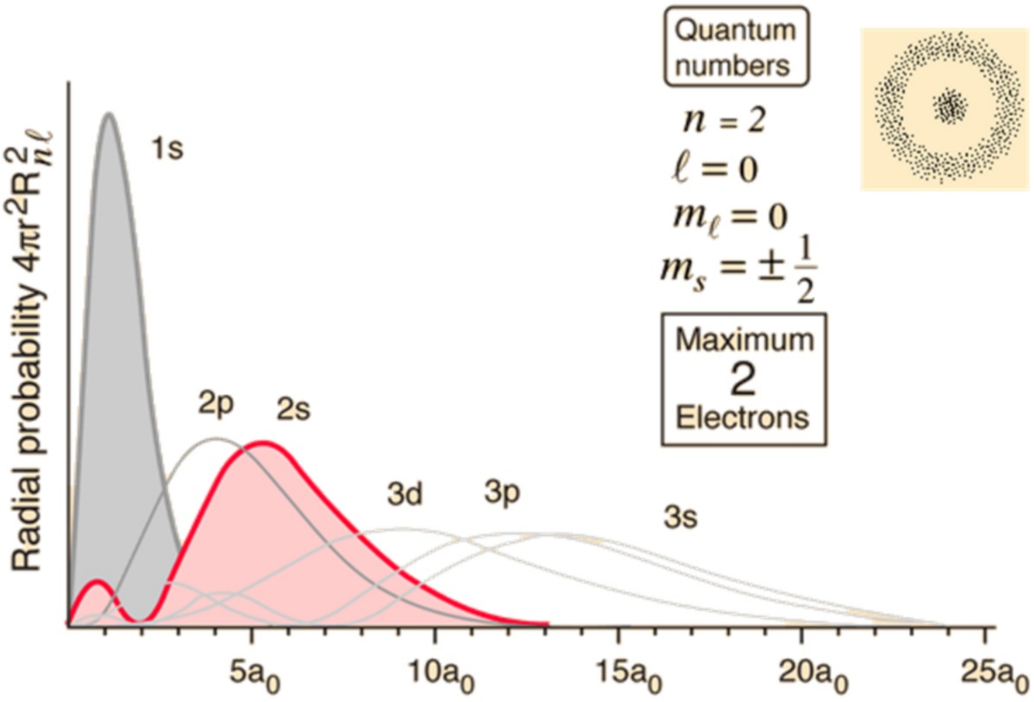
Quantum-Mechanical Model of the Atom



Polyelectric Atoms - atoms with more than one electron

- $E_s < E_p < E_d < E_f$
- electrons "prefer" the orbitals in th eorder *s*, *p*, *d*, and then *f*
- Notice that 2*p* has its maximum probability closer to the nucleus than the 2*s*
- But, notice the small hump of the 2*s* electron very close to the nucleus? This small amount of time when a 2*s* electron is near the nucleus.
- The 2*s* electron "penetrates" to the nucleus more than the 2*p*
- Therefore, the 2*s* electron has a lower energy than the 2*p* electron.

Quantum-Mechanical Model of the Atom



History of the Periodic Table

6. For principal quantum number $n = 5$, determine the number of allowable subshells (n), orbitals (n^2), and electrons ($2n^2$).

(Ans: 5 (s, p, d, f, and g), 25, and 50)

GVN

$n = 5$

NTK

\# subshells $= n = 5$

\# orbitals $= n^2 = 5^2 = 25$

\# electrons $= 2n^2 = 2(5^2) = 50$

UNK

subshells → 5 (s, p, d, f, & g)

orbitals → 25

electrons → 50

Atomic Theory
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Electron Configurations

- **Aufbau Principle** - electrons move to lowest energy (Exceptions Cr, Mo, and W and Cu, Ag, and Au)
- **Pauli exclusion principle** - no two electrons can have the same four quantum numbers (two electrons per orbital with one having a +1/2 spin (↑) and the other -1/2 spin (↓))
- **Hund's rule** - lowest energy is when an atom has the lowest number of unpaired electrons (so, 1 electron in each orbital before a second can be added.)
- Elements in the same group have the same number of valence electrons ($ns^{1\text{-}2}np^{0\text{-}6}$)
- **Isoelectric** - ions that have the same electron configuration as the closest noble gas
  - N^{3-}, O^{2-}, F^{1-}, Ne, Na^{1+}, Mg^{2+}, and Al^{3+} all have the same electron configuration: $1s^2 2s^2 2p^6$ or $[He]2s^2 2p^6$
- **Valence electrons** - outer *s* and *p* electrons of the atom
  - ■ For example, N's valence electrons are $2s^2 2p^3$
- **Core electrons** - the inner electrons
  - ■ For example, N's core electrons are $1s^2$
- Noble Gas Electron Configuration - replace inner core electrons with the symbol of the Noble gas symbol with brackets: $1s^2 2s^2 2p^3$ or $[He]2s^2 2p^3$
  - ■ these are the inner core electrons of the element
- **Paramagnetic** - when the species can be affected by a magnetic field.
- **Diamagnetic** - when a species cannot be affected by a magnetic field.

Nitrogen (Z = 7)

___ ___ ___ ___ ___
1*s* 2*s* 2*p*

Nitride, N^{3-} ($7e^- + 3e^- = 10\text{-}^-$)

___ ___ ___ ___ ___
1*s* 2*s* 2*p*

Atomic Theory
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Electron Configurations

7. Give the electron configuration, Noble gas (abbreviated) electron configuration, valence electrons, electron dot, and ion formed for sulfur, cadmium, hafnium, and radium.

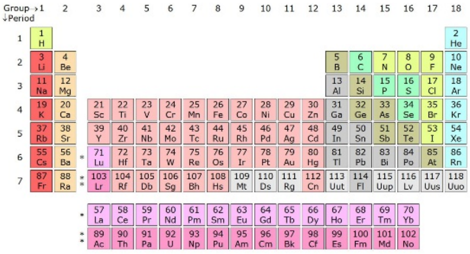
	Z	Electron Configuration	Nobel Gas (abbr) e^- configuration	Valence e^-	Electron Dot	Ion
S	16	$1s^2 2s^2 2p^6 3s^2 3p^4$	$[Ne] 3s^2 3p^4$	$3s^2 3p^4$	$\overset{\cdot\cdot}{\underset{\cdot}{\cdot S \cdot}}$	S^{2-}
Zn	30	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$	$[Ar] 4s^2 3d^{10}$	$4s^2$	$\overset{\cdot}{Zn}\cdot$	Zn^{2+}

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑	↑
1s	2s		2p		3s		3p	

paramagnitic

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓
1s	2s		2p		3s		3p		4s			3d		

diamagnetic



Group→ ↓Period	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	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
5	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
6	55 Cs	56 Ba	*	71 Lu	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
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
			*	57 La	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		
			**	89 Ac	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		

Atomic Theory
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Electron Configurations

7. Give the electron configuration, Noble gas (abbreviated) electron configuration, valence electrons, electron dot, and ion formed for sulfur, cadmium, hafnium, and radium.

	Z	Electron Configuration	Nobel Gas (abbr) e^- configuration	Valence e^-	Electron Dot	Ion
Hf	72	$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^6$ $6s^24f^{14}5d^2$	[Xe] $6s^24f^{14}5d^2$	$6s^2$	$\dot{\text{H}}\text{f}\cdot$	Hf^{2+}
Ra	88	$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^6$ $6s^24f^{14}5d^{10}6p^67s^2$	[Rn] $7s^2$	$7s^2$	$\dot{\text{R}}\text{a}\cdot$	Ra^{2+}

Hf:

1s ↑↓ **2s** ↑↓ **2p** ↑↓ ↑↓ ↑↓ **3s** ↑↓ **3p** ↑↓ ↓↑ ↑↓ **4s** ↑↓ **3d** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ **4p** ↑↓ ↑↓ ↑↓ **5s** ↑↓ **4d** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓

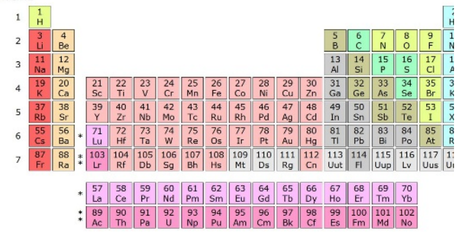
5p ↑↓ ↑↓ ↑↓ **6s** ↑↓ **4f** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ **5d** ↑ ↑ ___ ___ ___

Ra:

1s ↑↓ **2s** ↑↓ **2p** ↑↓ ↑↓ ↑↓ **3s** ↑↓ **3p** ↑↓ ↑↓ ↑↓ **4s** ↑↓ **3d** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ **4p** ↑↓ ↑↓ ↑↓ **5s** ↑↓ **4d** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓

5p ↑↓ ↑↓ ↑↓ **6s** ↑↓ **4f** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ **5d** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓

6p ↑↓ ↑↓ ↑↓ **7s** ↑↓



Group→ ↓Period	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1
1	1 H																		H
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	1 N
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	1 A
4	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	3 K
5	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	5 X
6	55 Cs	56 Ba	*	71 Lu	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	8 R
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	1 U
			*	57 La	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		
			**	89 Ac	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		

Atomic Theory
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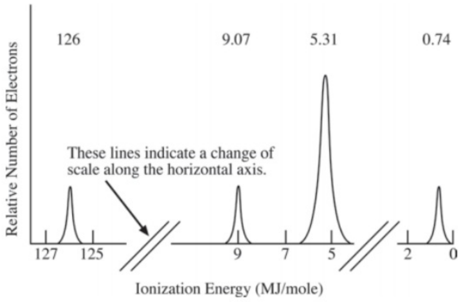
Photoelectron Spectroscopy

- **Photoelectron spectroscopy** is an experimental method used to determine the electronic structure of atoms and molecules.
- Photoelectron spectrometers ionize samples by bombarding them with high-energy radiation, such as UV or x-rays, and detecting the number and kinetic energy of ejected electrons.
- The frequency and energy of incident photons can be used to calculate the binding energy of the ejected electron using the following equation: $\text{BE} = h\nu - \text{KE}_{\text{electron}}$
  - In other words, $E_{(\text{x-ray photon})} = \text{PE}$ (BE; ionization E) + KE (energy of ejected electron; $1/2mv^2$)
- The PES spectrum is a graph of **electron count vs. electron binding energy**.
- The peaks in PES spectra correspond to the electrons in different subshells of the atom. The peaks with the lowest binding energy correspond to the valence electrons, while the peaks at the highest binding energy correspond to the inner-shell or core electrons.
- Ionization Energy - the energy needed to remove an electron from a gaseous atom
  - $\text{A}(g) + E \rightarrow \text{A}^+(g) + e^-$
    - $IE_n > \ldots > IE_3 > IE_2 > IE_1$



Atomic Theory
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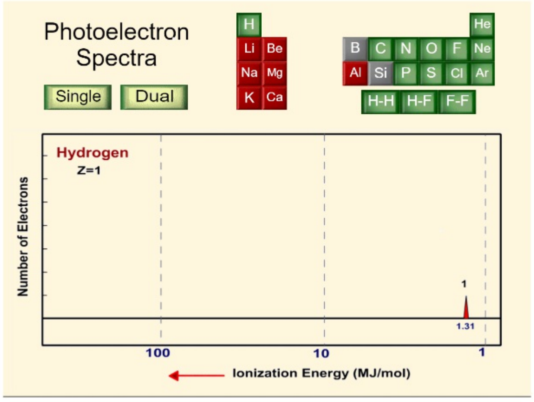
Photoelectron Spectroscopy



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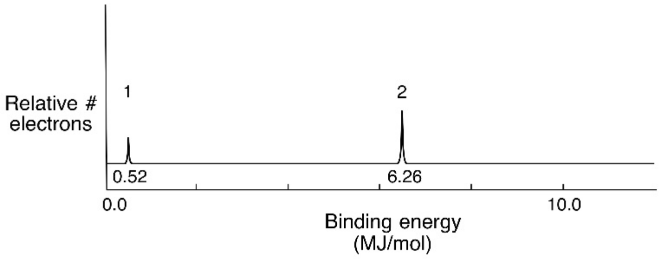
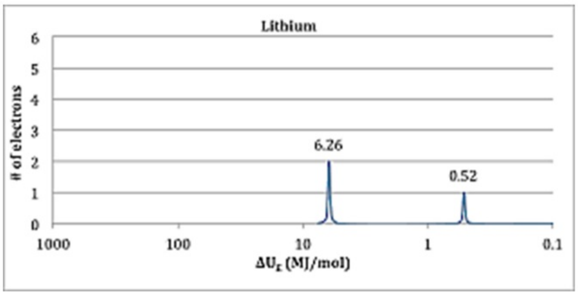
Photoelectron Spectroscopy

Because electrons in a particular subshell of an atom have approximately the same binding energy, each peak in a PES spectrum corresponds to a subshell. To illustrate, let's first look at a simulated PES spectrum for lithium,Li. As we look at the spectrum, it will be useful to keep in mind the ground-state electron configuration for lithium, which is $1s^2 2s^1$.





Atomic Theory
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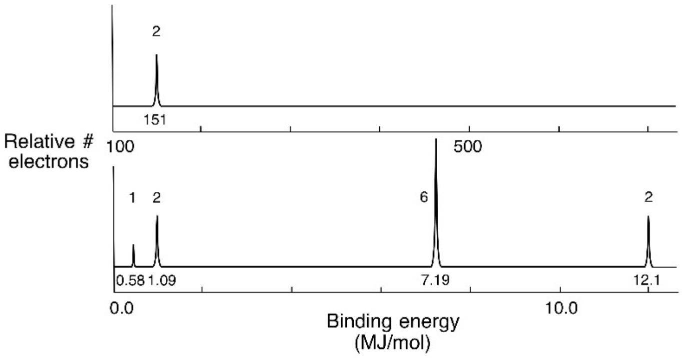
Photoelectron Spectroscopy

Sample WS#2 - Atomic Frequency of EM Radiation

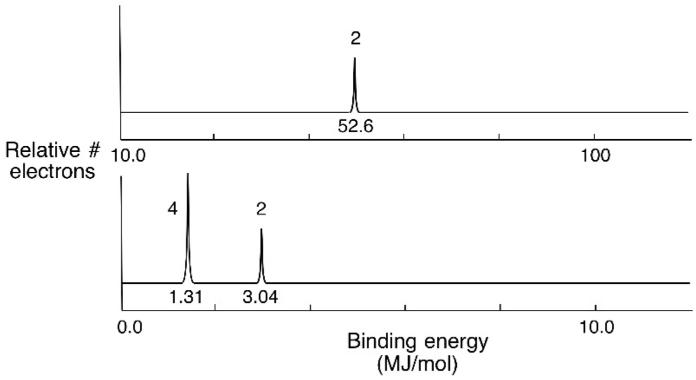
1. Identify the element represented by the PES spectrum. Write the electron configuration of the element. What is the first ionization energy for this element?



Photoelectron Spectroscopy

Sample WS#2 - Atomic Frequency of EM Radiation

2. Identify the element represented by the PES spectrum. Write the electron configuration of the element. What is the first ionization energy for this element?



Periodic Table

Periodic Table

- History
  - Johann Dobereiner (Triads) < John Newlands (octaves) < Dmitrii Mendeleev & Julius Lothar Meyer (atomic mass) < Mosley (atomic number)
  - Group I (alkali metals, most reactive metals), Group II (alkaline metals), Group 17 (halogens, most active nonmetals), and Group 18 (noble gases, inert (unreactive))
  - Transition metals - fill *d* orbitals (NEVER use half filled sublevels as a reason for stability or energy, SAY instead the half-filled subshell MINIMIZES electron-electron repulsions which LOWERS the energy state of the atom!)
  - Rare Earth Metals (Inner transition metals) - fill *f* orbitals

Atomic Theory

Topic#10

Periodic Trends

Periodic Trends (ALMOST always a FRQ question!)

Arguments

1. Effective nuclear charge (Z_{eff}) - equal to group # (Group 1, Z_{eff} is 1) for groups 1 and 2. For groups 13-18, Z_{eff} is equal to group # - 10 (Group 13 is 13-10 = +3 for core charge), the higher the Z_{eff}, the more positive the nucleus, the greater the positive (attractive) force is on electrons (coulombic force). (the higher the Z_{eff}, the more energy it takes to remove an electron or the smaller the atom's radius due to the nucleus pulling the outer electrons in closer). Used for **ACROSS** a period comparisons.

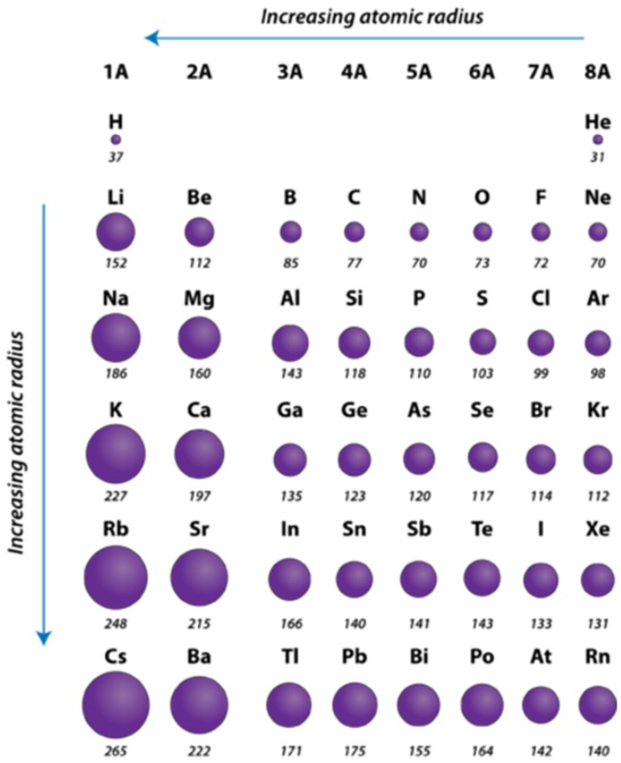
2. Distance - increased distance from the nucleus weakens the attractive coulombic force on the electron (need a lower amount of energy to remove). Used for **UP/DOWN** a group comparisons.

3. Shielding - the "shielding" of outer electrons from the nucleus by inner electrons. (Use only GOING UP OR DOWN a group NEVER across a period, use Z_{eff} and coulombic force for this).Used for **ACROSS** a period comparisons.

4. Minimize electron-electron repulsions - puts atom at a lower energy state (More stability).

Periodic Trends

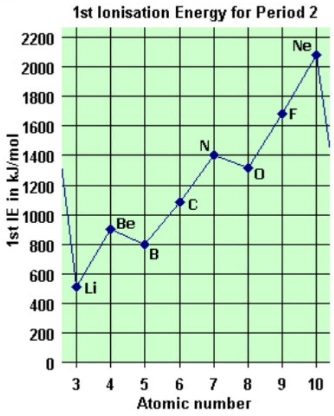
- **Atomic Radius -** the distance from center of nucleus to outer electron.
  - **Across -** increase in Z_{eff} results in a more positive charge in the nucleus which attracts electron cloud more strongly and "shrinks" atom (until electron-electron repulsion can overcome the attraction).
  - **Down -** an additional principal (n) energy level is added (attractive force on valence electrons decreases).



Atomic Theory
Topic#10

Periodic Trends

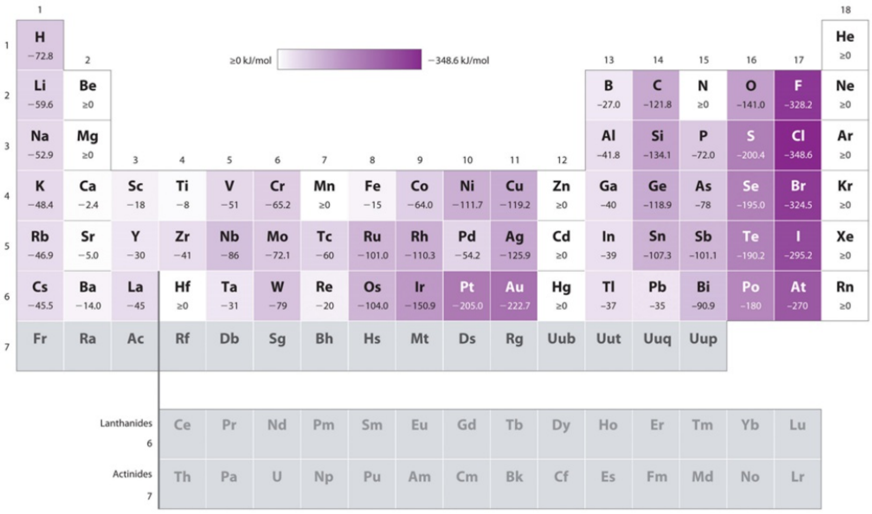
- **Ionization Energy (*IE*) -** energy needed to remove an electron (atom in gas phase!), each electron removed needs more energy.
  - **Across -** increase in Z_{eff} results in a more positive charge in the nucleus which attracts electron cloud more strongly resulting in more energy needed to remove electron (increase of coulombic force of attraction).
  - **Down -** increased distance from nucleus and increased shielding means less energy needed to remove and electron (inner electrons shield outer form nucleus) (decrease of coulombic force of attraction).
  - When electron pairing first occurs in an orbital there is an **increases** electron-electron repulsion which results in a lower energy needed (I_E) to remove an electron. (Look at oxygen vs. nitrogen)
  - Look at s^2 vs p^1, even though Z_{eff} is greater for the *p* electron, the removal of a *p* electron takes less energy than an *s* electron (Be vs. B).
    - ▪ *p* held less tightly because *p* electrons do not penetrate the electron cloud as well as an *s* electron.



Atomic Theory
Topic#10

Periodic Trends

- **Electron Affinity -** energy released when a gaseous neutral atom gains an electron (A(*g*) + e^- → A^-(*g*) + *E*)
  - **across -** increases (energy released becomes MORE negative). An increase in Z_{eff} results in a more positive charge in the nucleus which attracts the electron cloud more strongly (stonger columbic force of attraction), resulting in more energy released when an electron is accepted.
  - **down -** due to increased distance from nucleus and shielding of inner electrons with the addition of another energy level (*n*), the energy released is LESS negative.



≥0 kJ/mol — −348.6 kJ/mol

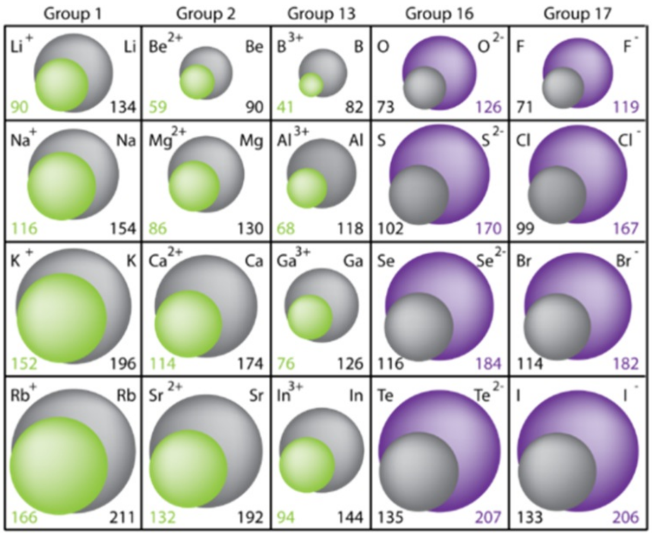
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H −72.8																	He ≥0
2	Li −59.6	Be ≥0											B −27.0	C −121.8	N ≥0	O −141.0	F −328.2	Ne ≥0
3	Na −52.9	Mg ≥0											Al −41.8	Si −134.1	P −72.0	S −200.4	Cl −348.6	Ar ≥0
4	K −48.4	Ca −2.4	Sc −18	Ti −8	V −51	Cr −65.2	Mn ≥0	Fe −15	Co −64.0	Ni −111.7	Cu −119.2	Zn ≥0	Ga −40	Ge −118.9	As −78	Se −195.0	Br −324.5	Kr ≥0
5	Rb −46.9	Sr −5.0	Y −30	Zr −41	Nb −86	Mo −72.1	Tc −60	Ru −101.0	Rh −110.3	Pd −54.2	Ag −125.9	Cd ≥0	In −39	Sn −107.3	Sb −101.1	Te −190.2	I −295.2	Xe ≥0
6	Cs −45.5	Ba −14.0	La −45	Hf ≥0	Ta −31	W −79	Re −20	Os −104.0	Ir −150.9	Pt −205.0	Au −222.7	Hg ≥0	Tl −37	Pb −35	Bi −90.9	Po −180	At −270	Rn ≥0
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup			
Lanthanides 6				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
Actinides 7				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Atomic Theory
Topic#10

Periodic Trends

- **Ionic Radii** (generally follows atomic radius trend, except transition from metal ions to nonmetal ions a BIG jump in radii occurs!)
  - Cations shrink respective to their atoms (nucleus now attracting fewer electrons, Z_{eff} equal for ion and atom)
  - Anions expand respective to their atoms (nucleus now attracting more electrons, Z_{eff} equal for ion and atom and more electron-electron repulsions)
  - Isoelectric - ions containing the same number of electrons.

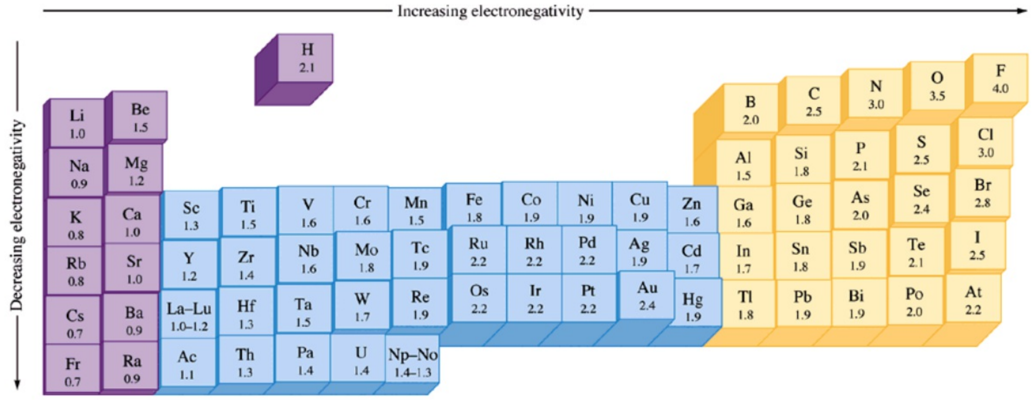
Size of Atoms and Their Ions in PM



Atomic Theory
Topic#10

Periodic Trends

- **Electronegativity -** the ability of an atom in a MOLECULE to attract shared electrons to itself. (generally follows the ionization energy trend)
  - F most (4.0)
    - Why? Highest Z_{eff} and smallest so nucleus is closer to the bound electrons in the bond
  - cesium/francium least (0.7)
    - Why? Lowest Z_{eff} and largest so nucleus is farther away from the bound electrons in the bond.
  - Critical when describing bonding!



Atomic Theory
Topic#10

8. The first ionization energy for phosphorus is 1060kJ/mol, and that for sulfur is 1005kJ/mol. Why?

9. Consider the atoms with the following electron configurations:

a) $1s^2 2s^2 2p^6$

b) $1s^2 2s^2 2p^6 3s^1$

c) $1s^2 2s^2 2p^6 3s^2$

Identify each atom. Which atom has the largest first ionization energy, and which one has the smallest second ionization energy? Explain your choices.

10. Predict the trend in radius for the following ions: Be^{2+}, Mg^{2+}, Ca^{2+}, and Ba^{2+}.