The Periodic Table of the Elements

PHYS-107 Fall 2004 - Dr. Philip Edward Kaldon

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen **1.00794**																	2 He Helium **4.0026**
3 Li Lithium **6.941**	4 Be Beryllium **9.01218**											5 B Boron **10.811**	6 C Carbon **12.011**	7 N Nitrogen **14.0067**	8 O Oxygen **15.9994**	9 F Fluorine **18.9984**	10 Ne Neon **20.1797**
11 Na Sodium **22.9898**	12 Mg Magnesium **24.305**											13 Al Aluminum **26.9815**	14 Si Silicon **28.0855**	15 P Phosphorus **30.9738**	16 S Sulfur **32.066**	17 Cl Chlorine **35.4527**	18 Ar Argon **39.948**
19 K Potassium **39.0983**	20 Ca Calcium **40.078**	21 Sc Scandium **44.9559**	22 Ti Titanium **47.867**	23 V Vanadium **50.9415**	24 Cr Chromium **51.9961**	25 Mn Manganese **54.9381**	26 Fe Iron **55.845**	27 Co Cobalt **58.9332**	28 Ni Nickel **58.6934**	29 Cu Copper **63.546**	30 Zn Zinc **65.39**	31 Ga Gallium **69.723**	32 Ge Germanium **72.61**	33 As Arsenic **74.9216**	34 Se Selenium **78.96**	35 Br Bromine **79.904**	36 Kr Krypton **83.8**
37 Rb Rubidium **85.4678**	38 Sr Strontium **87.62**	39 Y Yttrium **88.9059**	40 Zr Zirconium **91.224**	41 Nb Niobium **92.9064**	42 Mo Molybdenum **95.94**	43 *Tc* Technetium **97.9072**	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 **121.76**	52 Te Tellurium **127.6**	53 I Iodine **126.904**	54 Xe Xenon **131.29**
55 Cs Cesium **132.9054**	56 Ba Barium **137.327**	71 Lu Lutetium **174.967**	72 Hf Hafnium **178.49**	73 Ta Tantalum **180.9479**	74 W Tungsten **183.84**	75 Re Rhenium **186.207**	76 Os Osmium **190.23**	77 Ir Iridium **192.217**	78 Pt Platinum **195.08**	79 Au Gold **196.9665**	80 Hg Mercury **200.59**	81 Tl Thallium **204.3833**	82 Pb Lead **207.2**	83 Bi Bismuth **208.9804**	84 Po Polonium **208.9824**	85 At Astatine **209.9871**	86 Rn Radon **222.0176**
87 Fr Francium **223.02**	88 Ra Radium **226.025**	103 Lr Lawrencium **262.11**	104 Rf † Rutherfordium **261.11**	105 Db Dubnium **262.114**	106 Sg Seaborgium **263.118**	107 Bh Bohrium **262.12**	108 Hs Hassium **265**	109 Mt Meitnerium **266**	110 Uun Ununnilium ***269***	111 Uuu Unununoium-? ***272***	112‡ Uud Ununduoium-? ***277***		114 Uuq Ununquadium ***"289"***		116 Uuh Ununhexium ***289***		118 Uuo Ununoctium ***293***

57 La Lanthanum **88.9059**	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 **151.965**	64 Gd Gadolinium **157.25**	65 Tb Terbium **158.925**	66 Dy Dysprosium **162.5**	67 Ho Holmium **164.93**	68 Er Erbium **167.26**	69 Tm Thulium **168.934**	70 Yb Ytterbium **173.04**	71 Lu Lutetium **174.967**
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 **247.07**	97 Bk Berkelium **247.07**	98 Cf Californium **251.08**	99 Es Einsteinium **252.083**	100 Fm Fermium **257.095**	101 Md Mendelevium **258.1**	102 No Nobelium **259.101**	103 Lr Lawrencium **262.11**

Revised: 31 August 2002

‡ New reports (1997-99) of elements 112, 114 (one event), 116 and 118 offer hope for an *island of stability* and *trans-300*. "Scientists discover 2 'superheavy' elements." *CHE*, June 18, 1999, p. A18. But… in 2002, there are now reports that some (not all) of these events could be the result of scientific fraud. "Atomic Lies." *CHE*, August 16, 2002, p. A16. Investigations continue.

† IUPAC's revised slated of element names and abbreviations as of early 1997. "New compromise offered on heavy-element names."*C&EN*, Feb. 24, 1997, p. 12. Names guessed for 111-118.

How to find a radius of an electron:

1.) Start with a nucleus with Z protons. A single electron in orbit around this nucleus undergoes Uniform Circular Motion, with the Coulomb Force as the centripetal force.

$$F_E = \frac{kZe^2}{r^2} = m\frac{v^2}{r}$$

2.) Simplifying, we get:

$$\frac{kZe^2}{r} = mv^2$$

or

$$v^2 = \frac{kZe^2}{mr}$$

Note that r and v are now locked together.

3.) deBroglie said that matter has waves:

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

4.) The Bohr atom quantizes the states – in this case, we can think of the electron deBroglie matter wave as a standing wave:

$$2\pi r = n\lambda$$

5.) Solve (4) for r and substitute (3) for λ, and we see that the angular momentum (L = mvr) is quantized.

$$mvr = n\frac{h}{2\pi} = n\hbar$$

6.) Square (5) and then substitute v^2 from (2):

$$m^2v^2r^2 = n^2\hbar^2$$

$$\frac{m^2kZe^2r^2}{mr} = n^2\hbar^2$$

$$mkZe^2r = n^2\hbar^2$$

$$r = \frac{n^2\hbar^2}{mkZe^2}$$

7.) Note that the mass here is the mass of the electron, ($m_e = 9.11 \times 10^{-31}$ kg), so that the only variables in this equation are n and Z.

$$r_n = \frac{n^2\hbar^2}{m_e kZe^2} = \frac{n^2}{Z}\left(\frac{\hbar^2}{m_e ke^2}\right) = \frac{n^2}{Z}a_0$$

8.) The stuff in the parentheses represents the radius of the $n = 1$ orbit of hydrogen ($Z = 1$):

$$a_0 = \frac{\hbar^2}{m_e ke^2} =$$

$$= \frac{\left(1.0538\times10^{-34}\,J\cdot s\right)^2}{(9.11\times10^{-31}\,kg)(9\times10^9\,{}^{N\cdot m^2}/_{C^2})(1.602\times10^{-19}\,C)^2}$$

$$= 0.528\times10^{-10}\,m$$

9.) The Three-Body Problem says that we can't do this same kind of analysis with any atoms that have more than one electron. But… we can create a *hydrogenic* (means hydrogen-like) ion for all other elements by stripping off all but one of the electrons, and putting in the correct Z for the nuclear charge.

How to find the Energy of an electron:

10.) The kinetic energy is ½ mv². We can find this using (2) and (7):

$$\tfrac{1}{2}m_e v^2 = \frac{kZe^2}{2r_n} = \frac{kZe^2 m_e kZe^2}{2n^2\hbar^2} = \frac{k^2Z^2e^4m_e}{2n^2\hbar^2} = \frac{Z^2}{n^2}\left(\frac{k^2e^4m_e}{2\hbar^2}\right)$$

$$= \frac{Z^2}{n^2}\left(\frac{(9\times10^9\,{}^{N\cdot m^2}/_{C^2})^2(1.602\times10^{-19}\,C)^4(9.11\times10^{-31}\,kg)}{2\left(1.0538\times10^{-34}\,J\cdot s\right)^2}\right)$$

$$= \frac{Z^2}{n^2}2.18\times10^{-18}\,J = \frac{Z^2}{n^2}13.6eV$$

(since 1 electron volt = 1 eV = 1.602×10^{-19} J).

11.) The total energy of the electron is the sum of the P.E. plus K.E. terms. The P.E. for Coulomb's Law is:

$$PE = -W = -Fd = -\frac{kZe^2}{r_n}$$

Or P.E. = -2K.E. This form has the advantage that the P.E. is zero at infinity, and is always negative. The total energy, E_n = K.E. + P.E. = K.E. - 2K.E. = - K.E. Thus we can write the total energy as a function of n and Z as:

$$E_n = -\frac{Z^2}{n^2}2.18\times10^{-18}\,J = -\frac{Z^2}{n^2}13.6eV$$

So for Hydrogen (Z=1), the first three levels are:

n	r_n	E_n
1	0.528 Å	-13.6 eV
2	2.11 Å	-3.40 eV
3	4.75 Å	-1.51 eV

(1 Å = 1×10^{-10} m)

How to find a transition photon:

12.) In hydrogen, for an $n=3$ electron to drop to the $n=2$ state, this is:

ΔE = 3.4 eV - 1.51 eV = 1.89 eV = 3.03×10^{-19} J = hf.

$$f = \frac{E}{h} = \frac{3.03\times10^{-19}\,J}{6.626\times10^{-34}\,J\cdot s} = 4.57\times10^{14}\,Hz$$

$$\lambda = \frac{c}{f} = \frac{2.998\times10^8\,{}^{m}/_{s}}{4.57\times10^{14}\,Hz} = 6.56\times10^{-7}\,m = 656nm$$

This is red light.

NOTE: Don't confuse the wavelength λ here in (12) with the deBroglie wavelength λ in (3).