Supplement for Chapter 1: The Structure of Matter

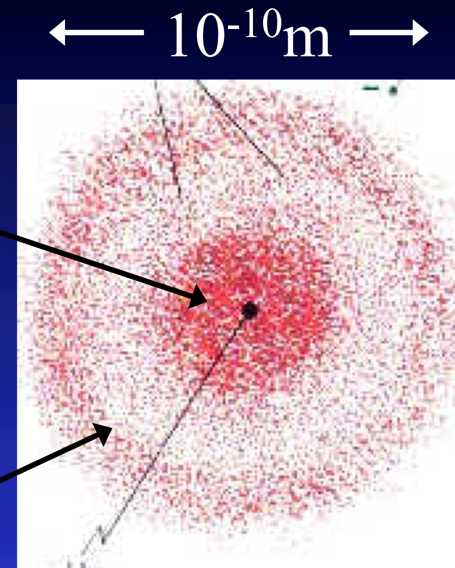
PHY2250 - Electronics & Circuit Theory

Dr. Hawley

Atoms

- All the matter we'll be dealing with consists of combinations of different kinds of atoms.
- For a long time, people believed that an atom was the smallest, indivisible instance of an element -- some natural "essence" (e.g., "earth", "air", "fire", "water").
- There are over 100 different kinds of atoms/elements, and they're actually not indivisible, they have parts, i.e. "subatomic particles."

Atomic Structure



- Nucleus: Heavy, almost entire mass of atom is here. Size ~10^{-15}m
- Electron(s): Tiny waves/ particles, around the nucleus in a "cloud"

(Do not "orbit" like planets," no "centrifugal force" on electrons!)

- Atom is over 99.9% empty space!
- Nucleus itself has constituents: protons & neutrons.

Electric Charge

- Protons & electrons have equal and opposite electric charge.
- Like charges repel, opposites attract.
- (“Strong” & “weak” forces overcome repulsion of protons, to hold nucleus together)

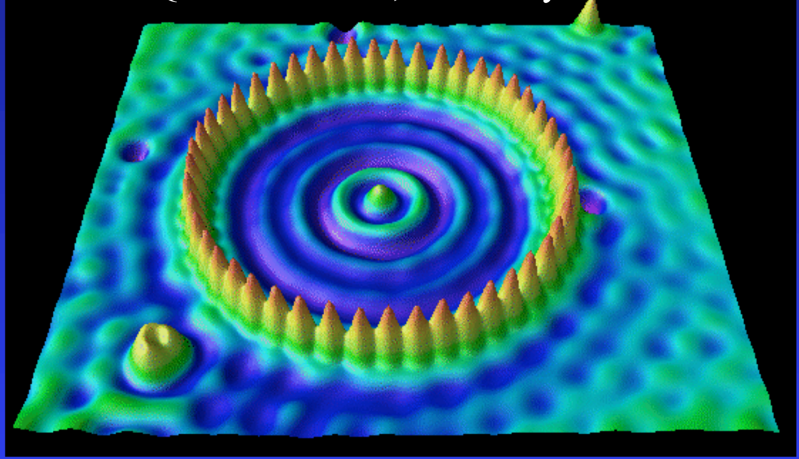
Particle	Mass in AU*	Charge in AU*
Proton	~1	+1
Neutron	~1	0
Electron	very small	-1

*1AU of mass = 1.67×10^{-27} kg, of charge = 1.602×10^{-19} C

Imaging Atoms

- Atoms are too small to “see” (smaller than wavelength of visible light), but they can be imaged, e.g. through Scanning Tunneling Microscopy.

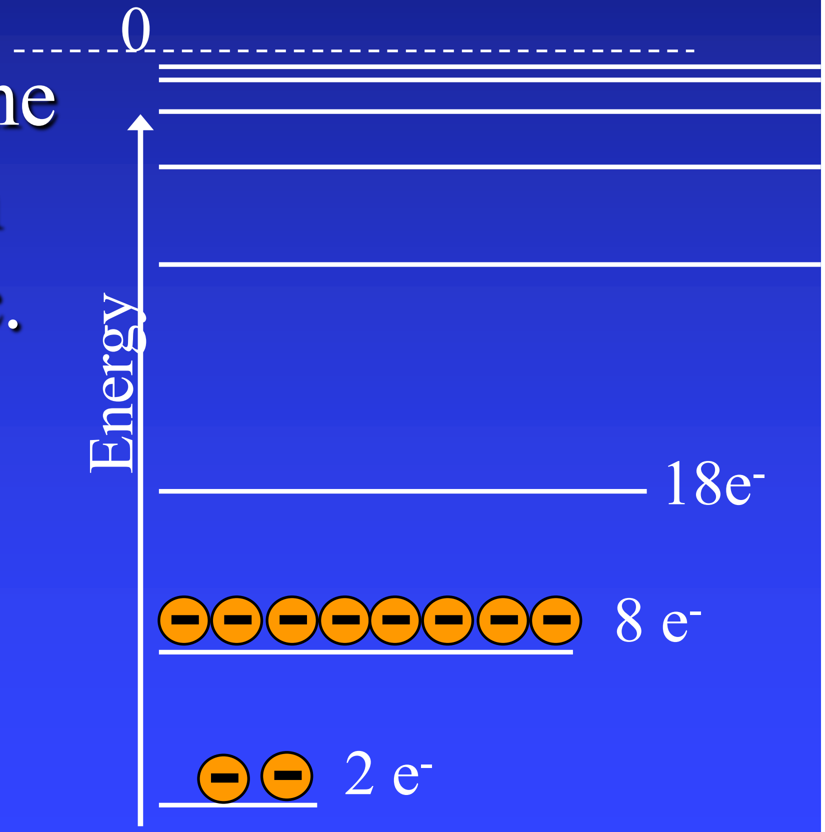
“Quantum Corral,” Courtesy IBM



- What you “see” is the electric field from the outer electron “shell.”

Electron Shells

- Electrons in an atom can only exist at discrete energy levels, and each level only supports a certain number of electrons.
- The electrons fill up the lowest level first, then the next-to-lowest, etc.
- Often the symbol "e^-" is used to denote electrons



Periodic Table of Elements

Atomic # / Symbol / Name / Atomic Mass

C Solid · Hg Liquid · H Gas · Rf Unknown

Metals: Alkali metals · Alkaline earth metals · Lanthanoids · Actinoids · Transition metals · Poor metals
Nonmetals: Other nonmetals · Noble gases

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050											13 Al Aluminium 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57–71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (208.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)
7	87 Fr Francium (223)	88 Ra Radium (226)	89–103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Ptable.com

Atomic Number & e^- Shells

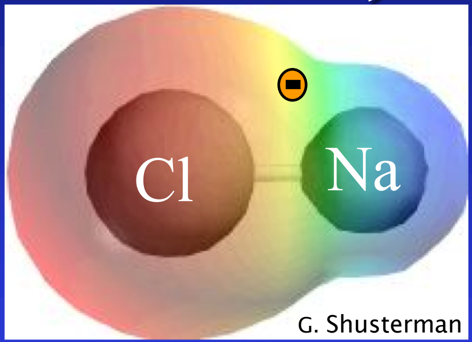
- The number of protons in an atom -- called the atomic number -- determines how many electrons an (electrically) neutral atom can “hold.”
- This determines how many shells are filled and to what extent.
- The # of electrons in the highest energy shell (often called the “valence” shell) is largely responsible for the chemical properties of the atom or element, i.e. how the atom combines with other atoms...

Shells & Properties

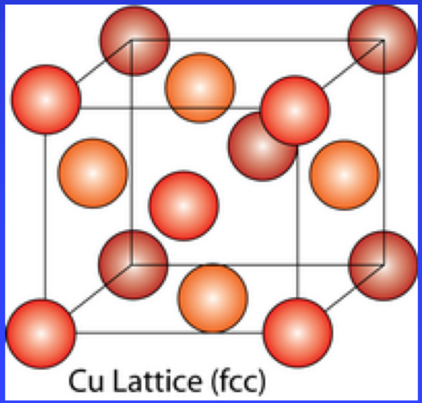
- Filled shells tend to correspond to chemically <u>inert</u> (non-reacting) elements, e.g. noble gasses (Helium, Neon...)
- Almost-filled shells "prefer" to get another e^- to fill them, & tend to produce a negative <u>ion</u> (charged atom), e.g. Chlorine: Cl^-
- Shells w/ only one e^- tend to lose it easily, producing positive ions, e.g. Sodium: Na^+
- *Semi*conductors possess valence shells which are "half full," with 4 electrons.

Electron Sharing

- Atoms can share electrons, forming chemical bonds and becoming a molecule. e.g., sodium & chlorine can share 1 e^-, becoming NaCl -- salt.



- In a metallic conductor like copper (Cu), atoms are arranged in a crystal or lattice, and electrons are easily shared throughout the entire metal



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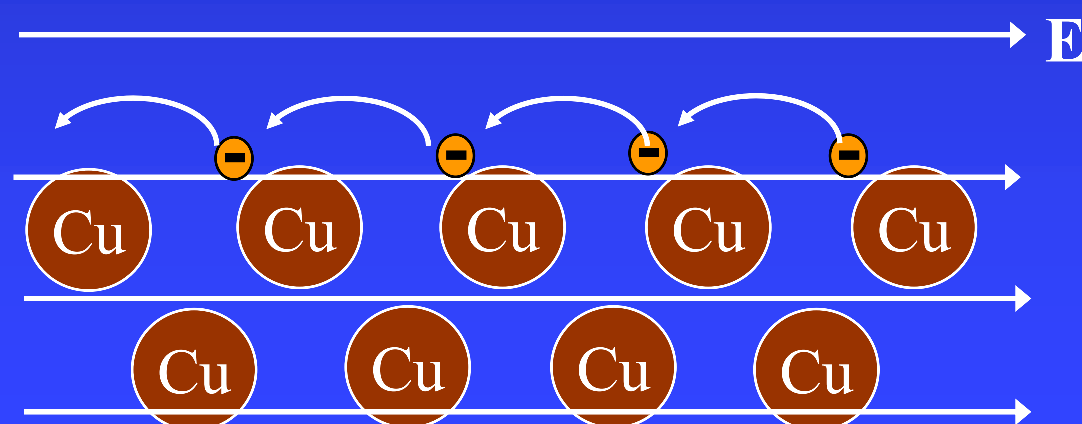
Electron Gas Model of Conductors

- In fact, the electrons are so easily shared between atoms in a conductor, they can actually be modeled as an "electron gas" in the conductor.
- Electrons will jump freely from atom to atom in the presence of an applied electric field.



…Voltage and Current!

- A difference in electric potential across opposite sides of a conductor will produce such an electric field in the conductor. An electric potential difference is called voltage, measured in Volts.
- This will cause electrons to jump from atom to atom, resulting in an electric current!
- Current is defined as charge per unit time.
- 1 Coulomb (C) flowing in 1 second (s) is a current of 1 Ampere (Amp or A)

$$1 \text{ Amp} = 1 \text{ C/s}$$

The End