Announcements

My lectures on D2L under L01

Past lectures are indicated by their date. They include slides which were discussed on that date.

There is always one lecture dated in the future with slides which are subject to change. The first slide for this lecture indicates that it is under construction.

Last time

- Comparison of the gravitational and electromagnetic forces between two electrons
- Strong and weak *nuclear* forces
- Structure of matter
- Fundamental particles

This time

- More on structure of matter and fundamental particles
- Mass and charge
- Transfer of charge
- Conductors and insulators
- Coulomb’s law

Structure of matter

Matter is composed of molecules and atoms.

Molecules are composed of atoms bound together by chemical bonds.

Atoms are composed of fundamental particles.

Characteristics
Of fundamental particles

All fundamental particles can be classified according to two observable parameters: mass and charge.

This simplified model of the Universe (reductionism) which breaks matter into its simpler parts (matter → molecules → atoms → fundamental particles) is incredibly effective at explaining a wide range of physical phenomena.

Reductionism: To understand nature of complex things by reducing then to interactions of their parts. We then study each component and learn everything about it and finally put the parts back together to produce the original object.

All models are wrong, but some are useful. - G. Box

A model is a representation of reality and not reality itself.

What is mass?

High school definition:
The amount of matter in an object.

Better definition :
Mass is inertia to motion. Objects show higher inertia to motion at higher speeds (relativistic effects).

Rest mass (mass at rest) is always smaller than relativistic mass (mass at a non-zero speed).

What is an electric charge?

- An intrinsic property of particles: electrons (–) and protons (+)
- A quantity that determines the strength of the electric force between two objects.
- Can’t be created or destroyed (conservation of charge)
- Can transfer from one object to another
- Like charges repel, opposite charges attract

Quantization of electric charge

Electric charge is *quantized*.

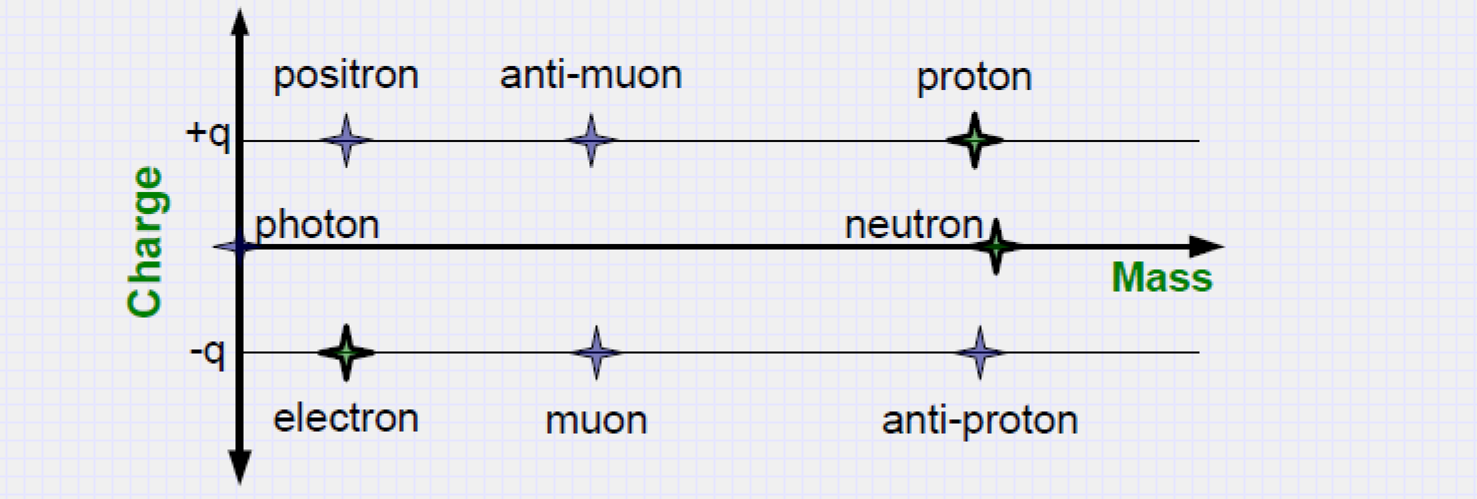
Charge always comes in some integral multiple of some fundamental charge e, which is the charge of electron.

Electric charge comes in discrete packets.

Light comes in discrete packets too, photons.

$$E = h\nu$$

Some examples of fundamental particles



All masses can be positive or zero.

Charge can be positive or negative.

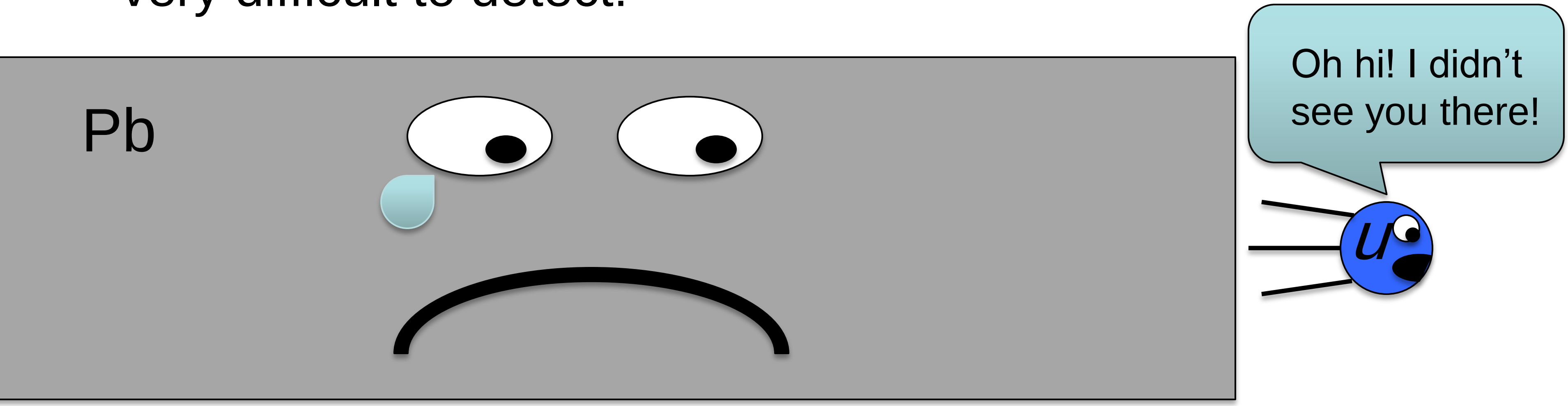
In this course will worry about three kinds of particles: electrons, protons and neutrons.

Neutrinos

Very light subatomic particles that are electrically neutral and only interact with other particles via the weak nuclear force. Emitted in radioactive decay and nuclear fusion.

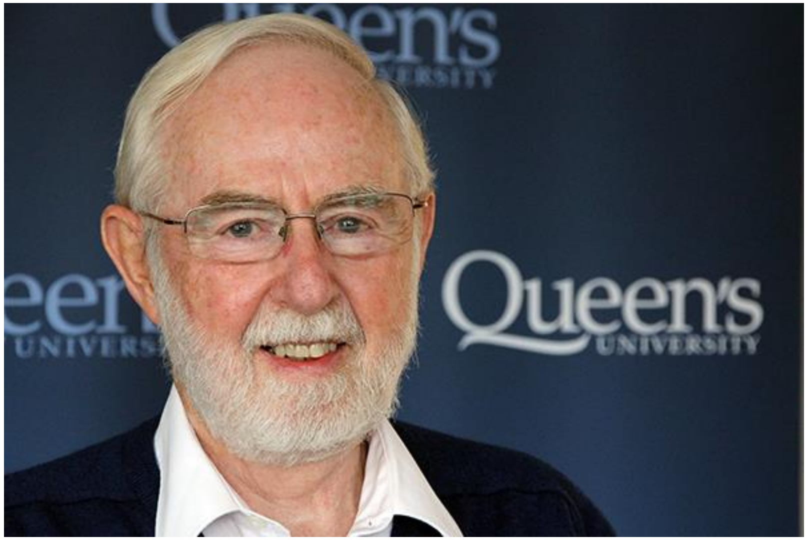
Trillions of neutrinos originating from the sun are passing through you at any given moment, day or night.

A neutrino can pass through a slab of lead that is one lightyear thick without hitting anything; this makes them very difficult to detect!



Nobel Prize in Physics 2015

For the experimental verification that neutrinos have mass



Arthur McDonald
SNO Lab

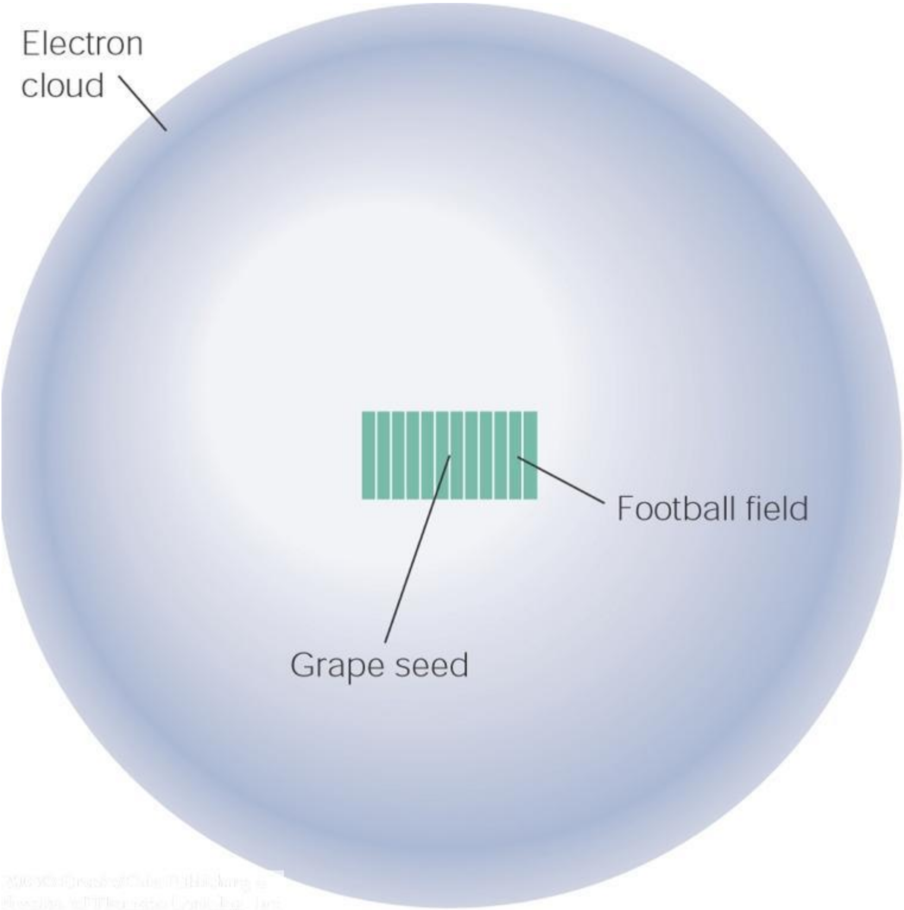
Takaaki Kajita
Super Kamiokande

image from http://queensu.ca

Atomic Structure

An atom consists of an *atomic nucleus* (protons and neutrons) and a cloud of electrons surrounding it.

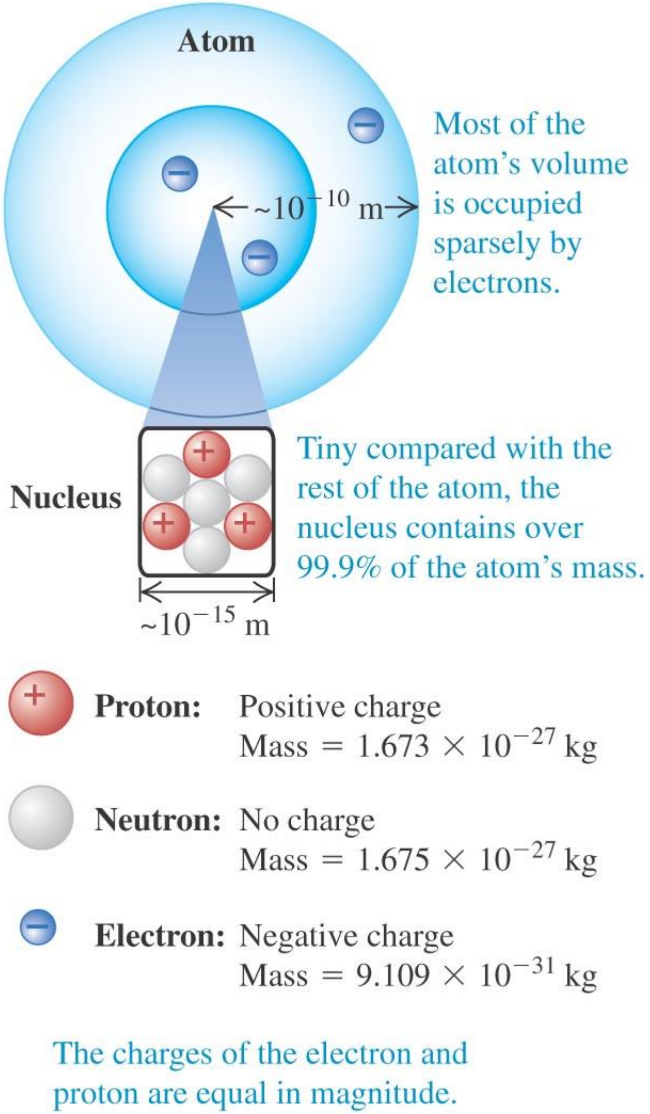
Almost all of the mass is contained in the nucleus, while almost all of the space is occupied by the electron cloud.



The diameter of a nucleus is much smaller than the diameter of the atom, by a factor of about 23,000 (uranium) to about 145,000 (hydrogen).

Atomic Structure

- Atoms are made up of the negative *electrons*, the positive *protons*, and the uncharged *neutrons*.
- Protons and neutrons make up the tiny dense nucleus which is surrounded by electrons.
- The electric attraction between protons and electrons holds the atom together.
- Electrons and protons have charges of opposite sign but *exactly* equal magnitude.



Most of the atom's volume is occupied sparsely by electrons.

Tiny compared with the rest of the atom, the nucleus contains over 99.9% of the atom's mass.

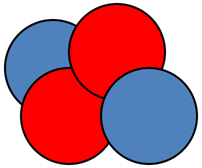
The charges of the electron and proton are equal in magnitude.

Different Kinds of Atoms

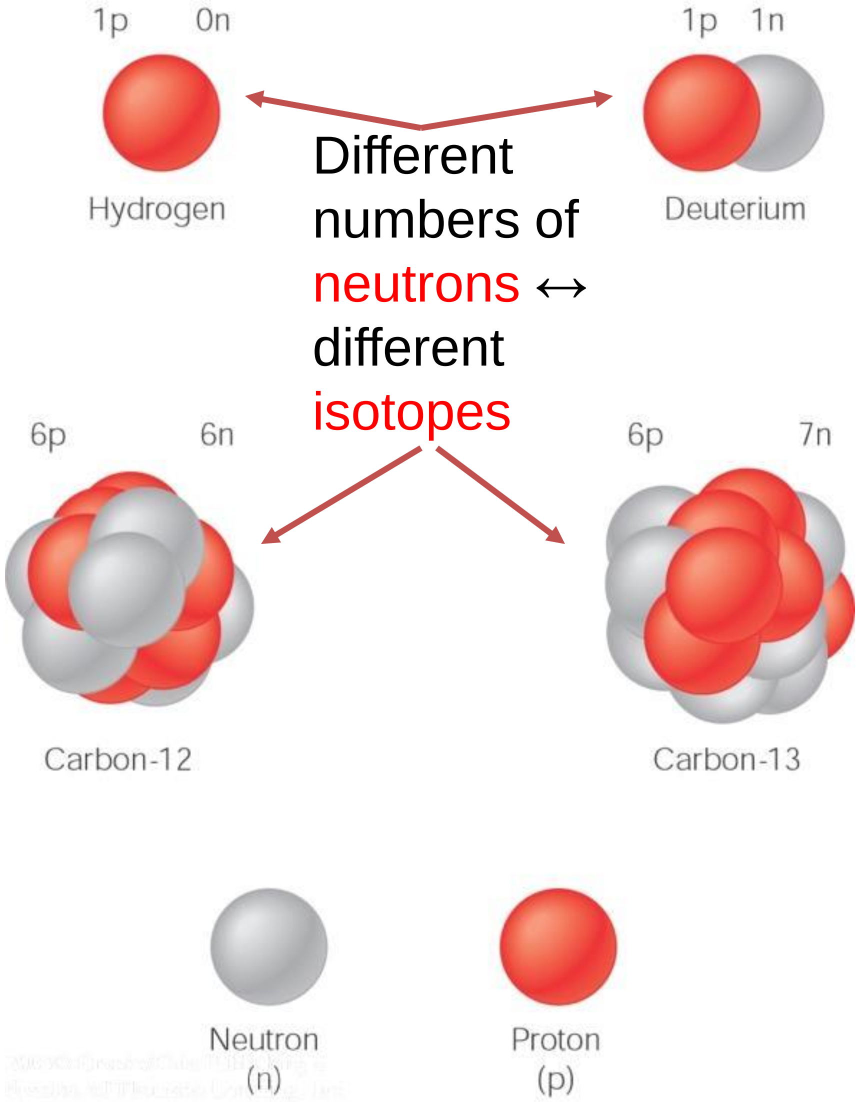
The kind of atom depends on the number of protons in the nucleus.

Most abundant (74% of the known universe):
Hydrogen (H), with one proton (+ 1 electron).

Second most abundant (24%) Helium (He), with 2 protons (and 2 neutrons + 2 electrons).

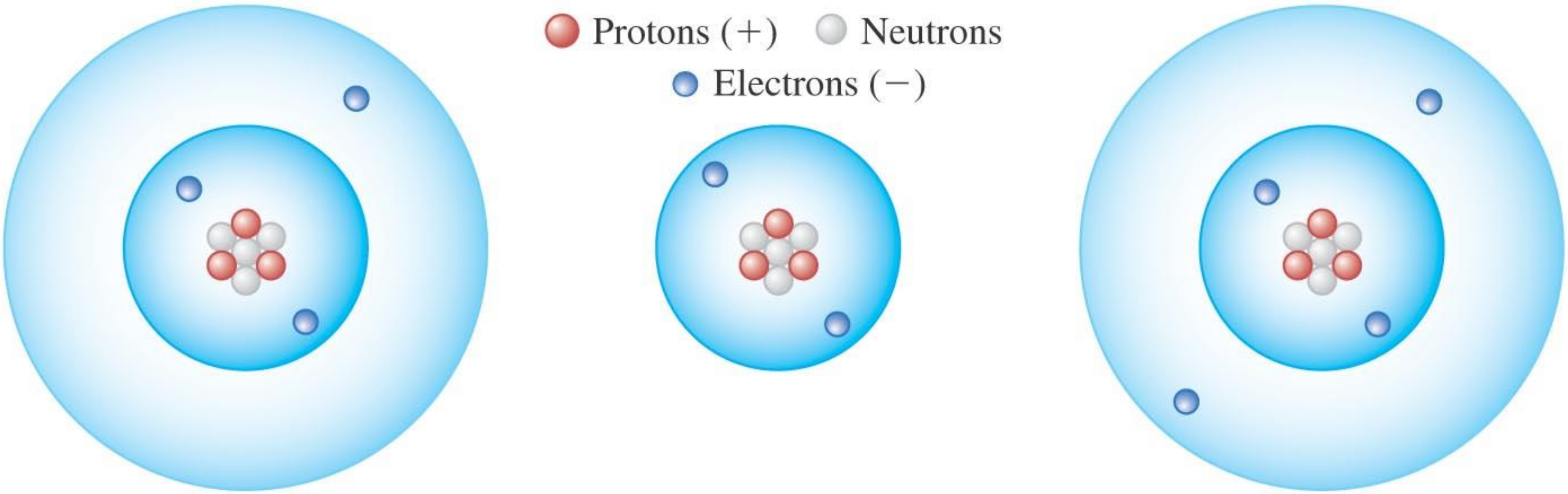


The nucleus of Helium 4 is called α particle.



Different numbers of neutrons ↔ different isotopes

Consider lithium as a cation, an anion, and a neutral



(a) Neutral lithium atom (Li):

3 protons (3+)
4 neutrons
3 electrons (3−)

Electrons equal protons:
Zero net charge

(b) Positive lithium ion (Li^+):

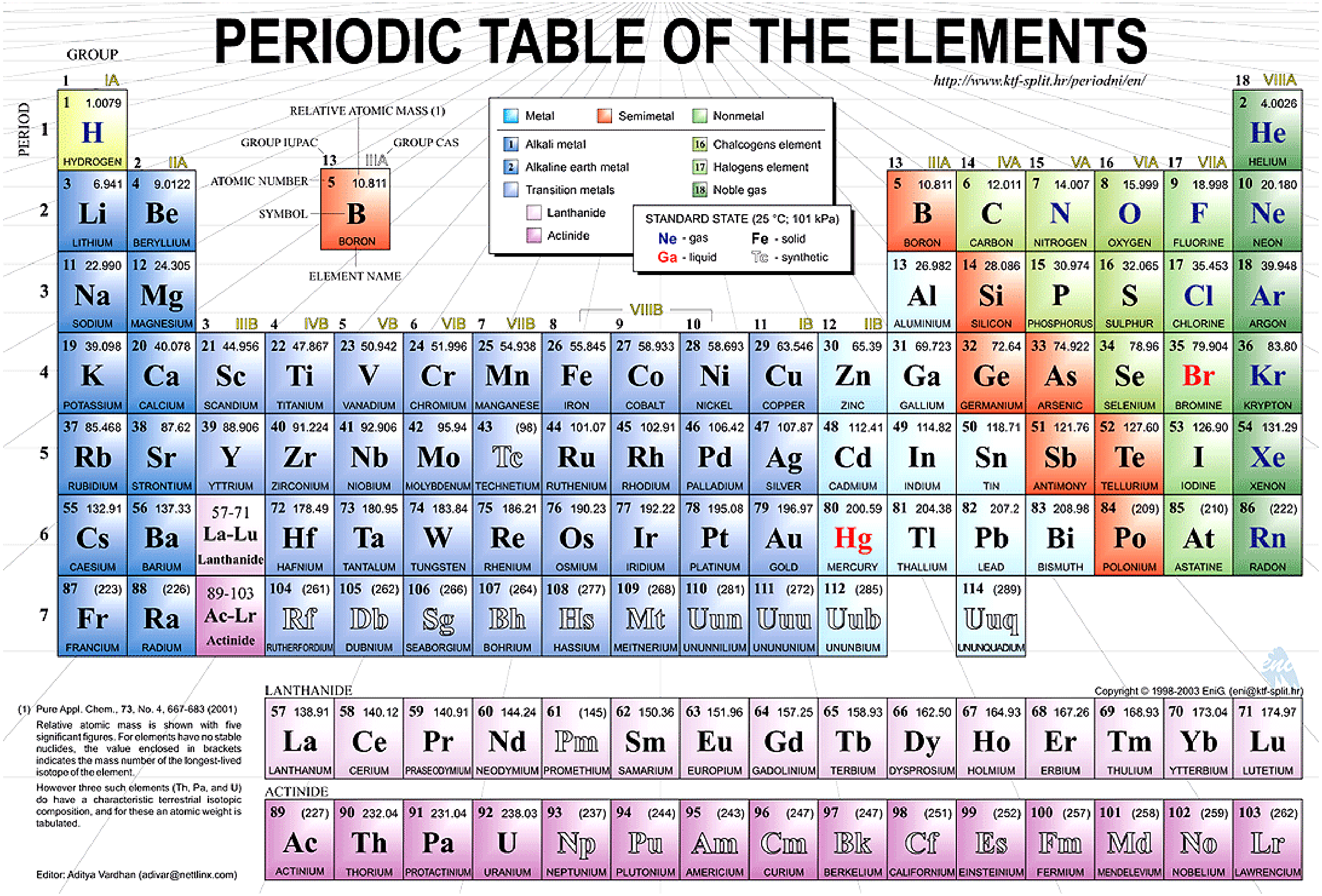
3 protons (3+)
4 neutrons
2 electrons (2−)

Fewer electrons than protons:
Positive net charge

(c) Negative lithium ion (Li^-):

3 protons (3+)
4 neutrons
4 electrons (4−)

More electrons than protons:
Negative net charge



PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

🟦 Metal	🟥 Semimetal	🟩 Nonmetal
1 Alkali metal		16 Chalcogens element
2 Alkaline earth metal		17 Halogens element
Transition metals		18 Noble gas
Lanthanide		
Actinide		

STANDARD STATE (25 °C; 101 kPa)

Ne - gas Fe - solid

Ga - liquid Tc - synthetic

GROUP IUPAC: 13 GROUP CAS: IIIA

ATOMIC NUMBER: 5 RELATIVE ATOMIC MASS (1): 10.811

SYMBOL: B

ELEMENT NAME: BORON

PERIOD	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE

57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YTTERBIUM	71 174.97 Lu LUTETIUM

ACTINIDE

89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

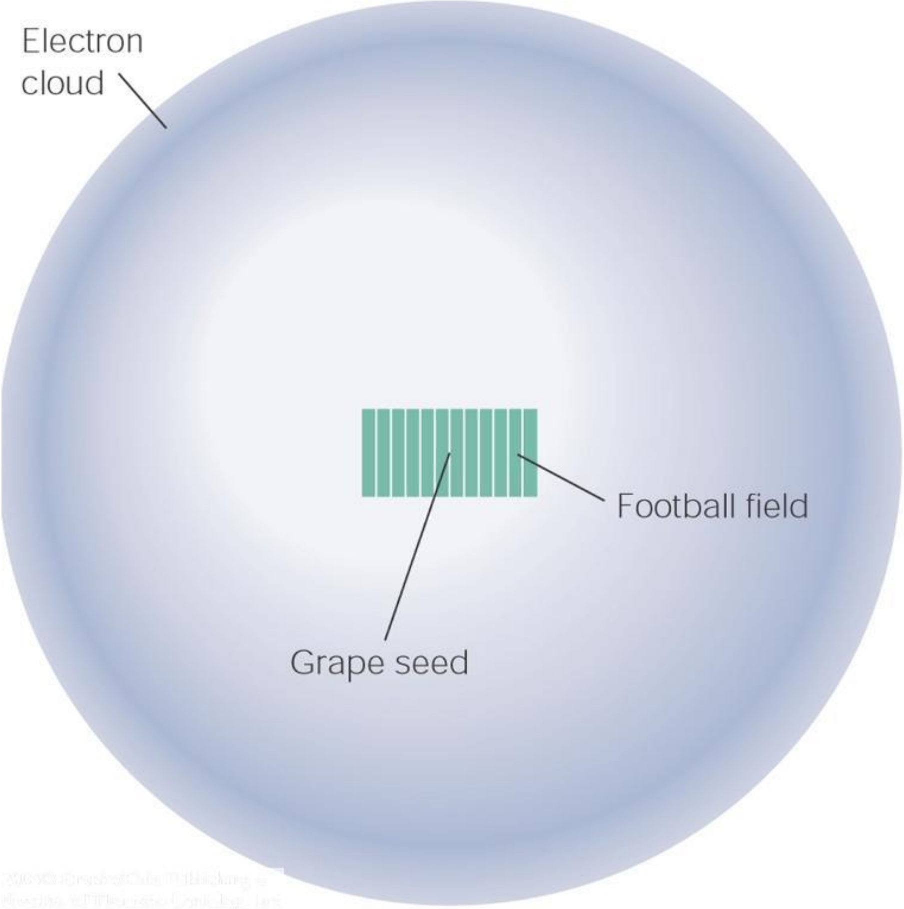
However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adivar@netllinx.com)

Nuclear Density

What happens when the electronic cloud is squeezed out of the atoms?

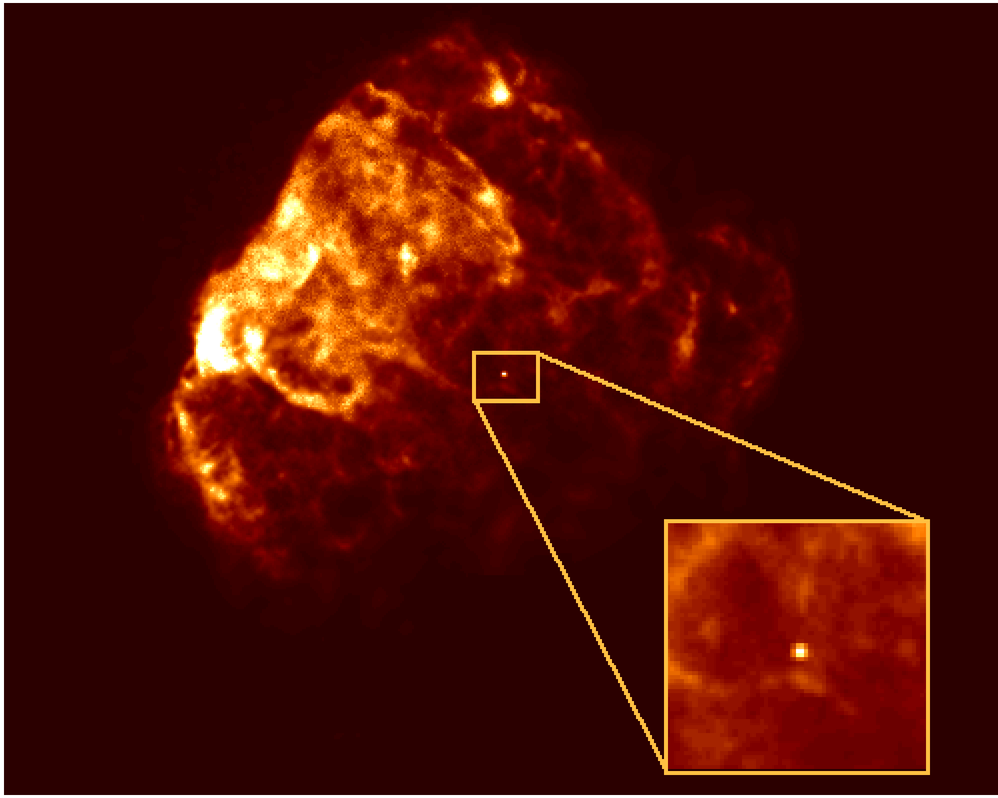
We form a neutron star.



Nuclear Density

If you could fill a 4L milk jug with material as dense as an atomic nucleus, it would have the mass of Mount Everest

- Neutron Stars are the end point of a massive star's life.
- When a massive star runs out of nuclear fuel in its core, the core begins to collapse under gravity. When the core collapses the entire star collapses. The surface of the star falls down until it hits the now incredibly dense core. It then bounces off the core and blows apart in a supernova.
- All that remains is the collapsed core, a Neutron Star or sometimes a Black Hole, in case a very massive star.



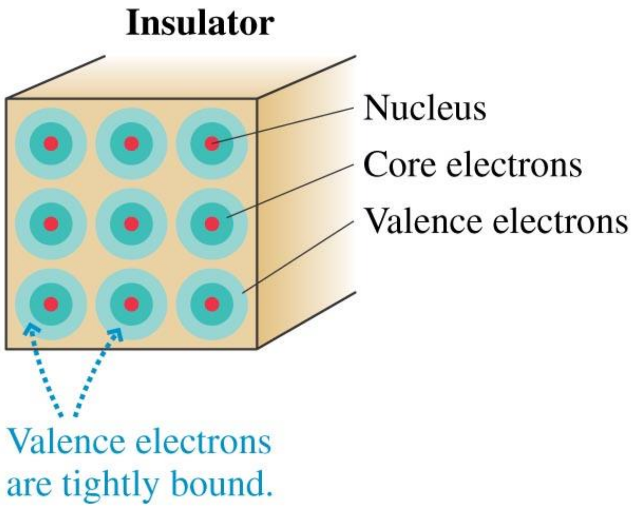
A supernova flash in a galaxy

Neutron star

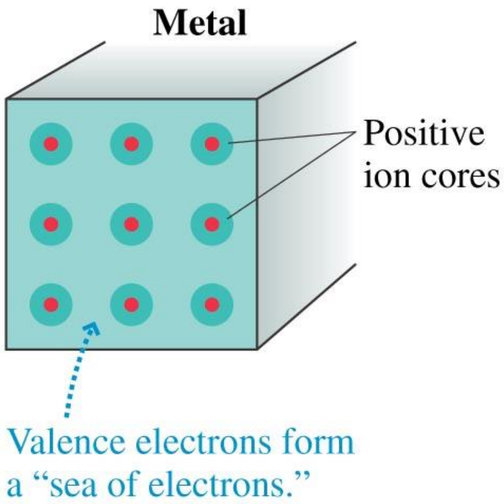
A typical neutron star is the size of a small city, only 10 Kilometers in diameter but it may have the mass of as many as three suns. It is quite dense.

Broad categorization of materials according to their electrical properties

Insulators do not conduct electricity, because the electrons are **not** free to move. Wood, Styrofoam, glass



Conductors do conduct electricity, because the electrons **are** free to move. Metals



Transfer of charge

- Typically, electrons are the charge carriers that are transferred. Why? Why not protons?

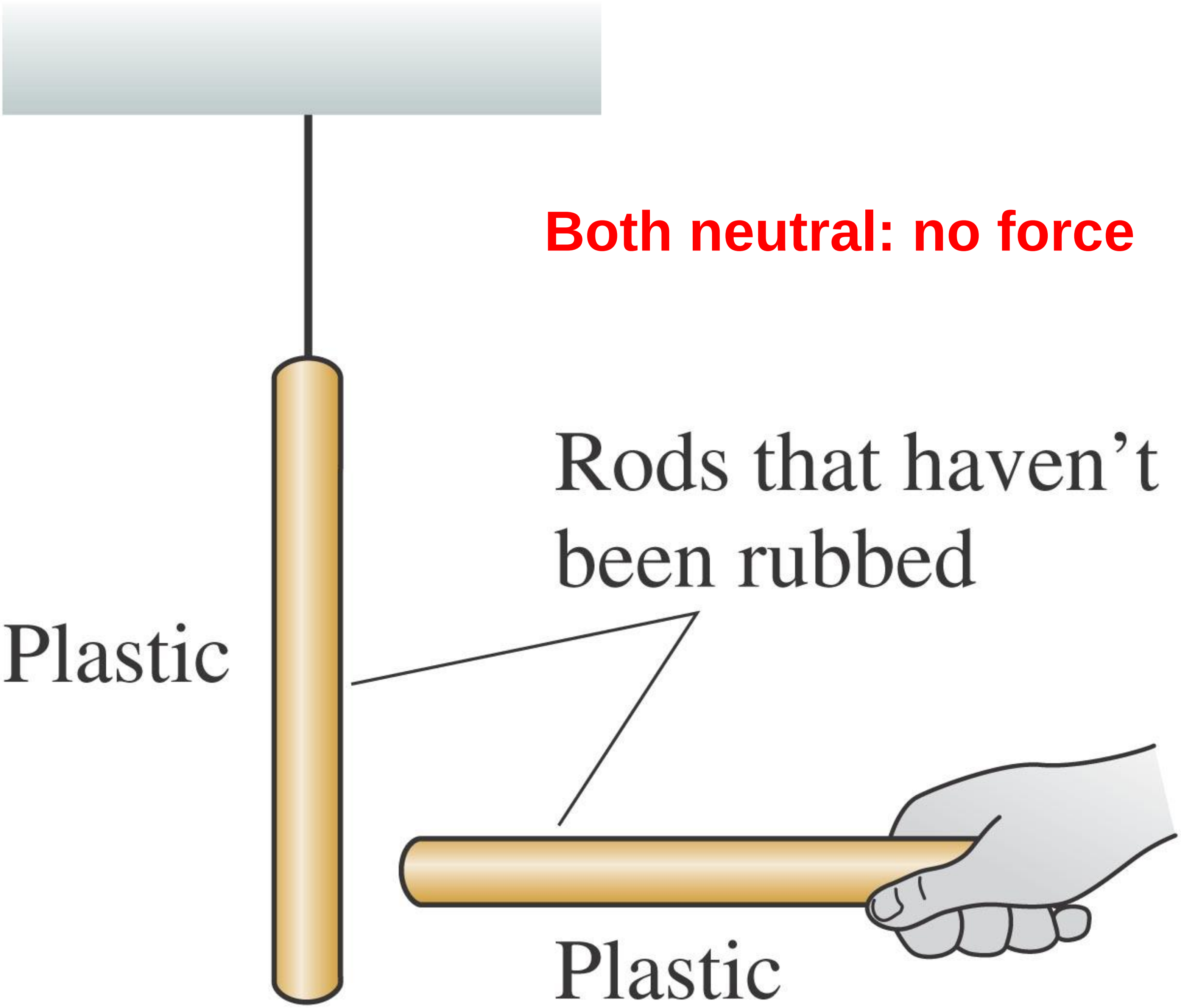
- Different materials have different affinities for electrons.

- When put into contact, one material gives up its electrons and the second material will draw those electrons onto itself.

- Rubbing increases the amount of surface area which is brought into contact, thereby increasing the amount of charge transfer.

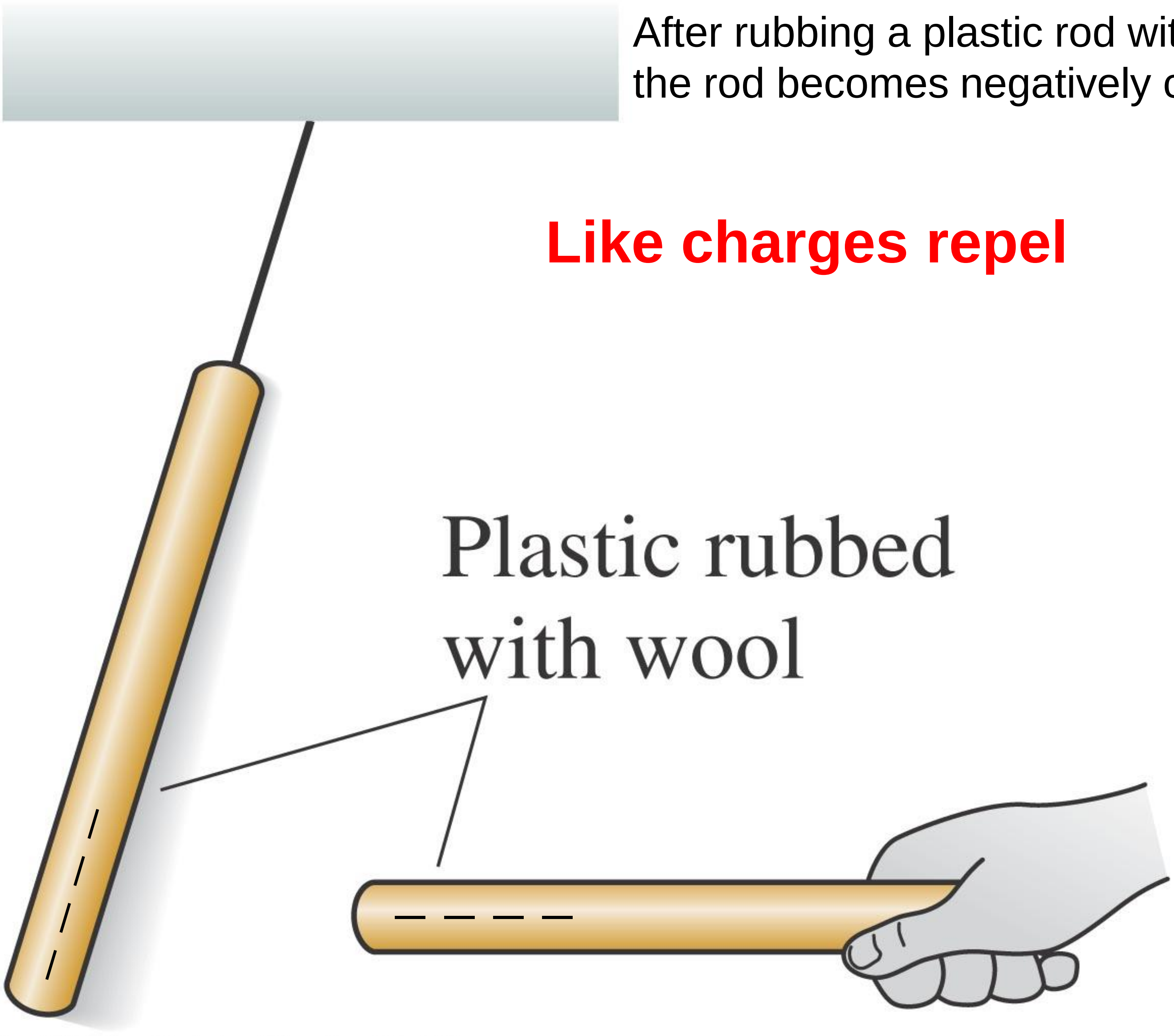
- Rubber has a much greater attraction for electrons than animal fur. As a result, the atoms of rubber pull electrons from the atoms of animal fur, leaving both objects with an imbalance of charge.

Both neutral: no force

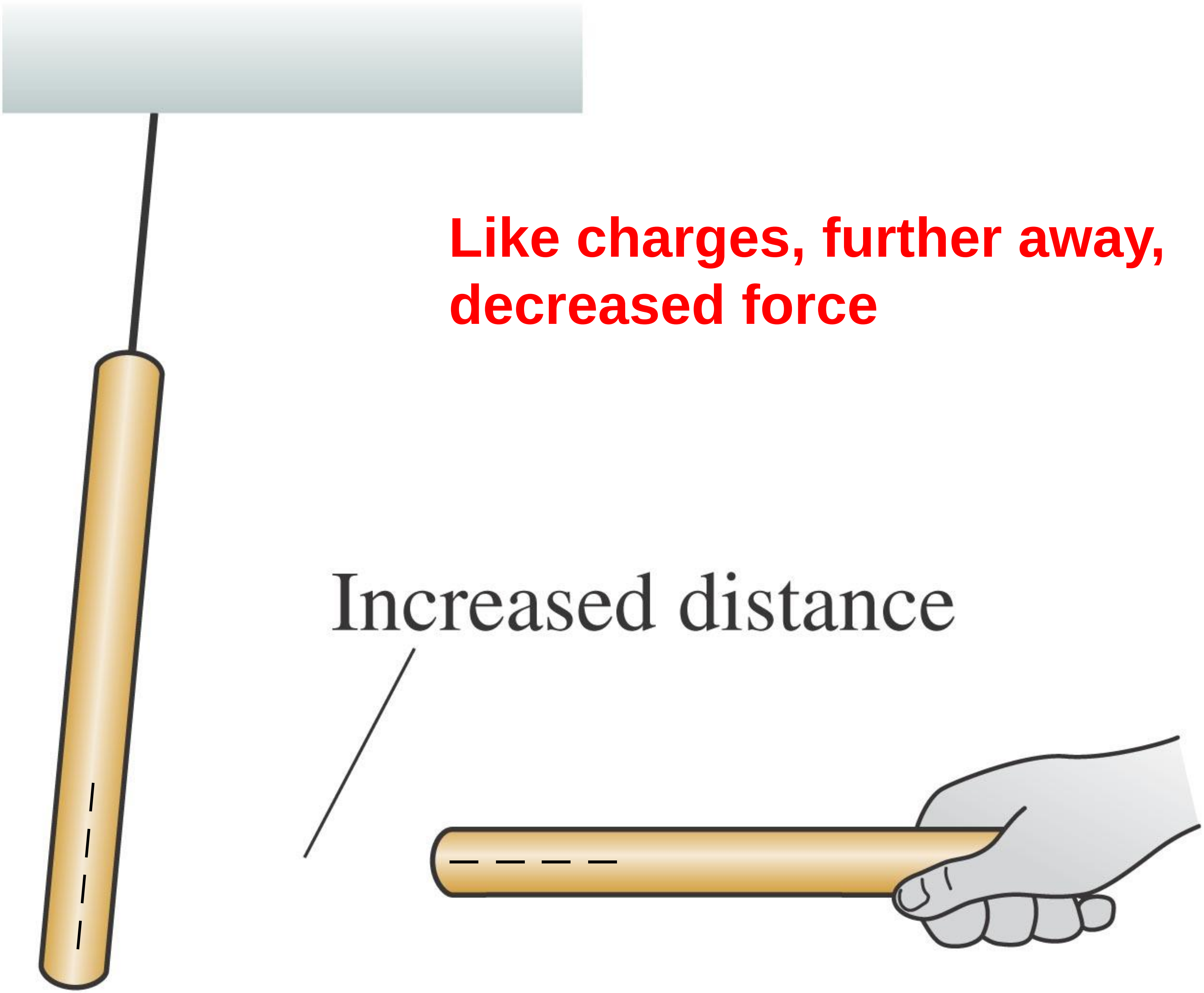


After rubbing a plastic rod with the fur, the rod becomes negatively charged.

Like charges repel



Like charges, further away, decreased force



After rubbing a glass rod with the silk, the rod becomes positively charged.

Opposite charges attract