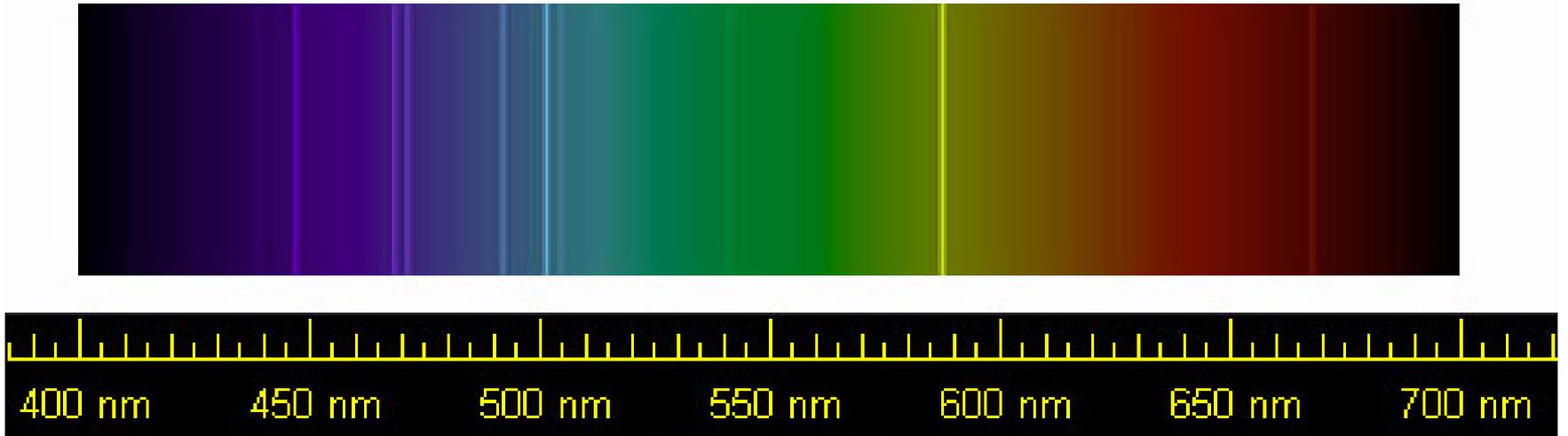


The Helium Story

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Stanford University
July 22, 2011

Spectrum of Helium

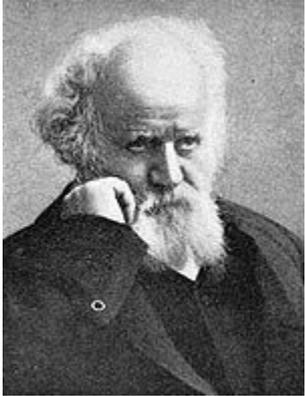
587.49



Named after ἥλιος (helios, the sun) because **He** was first discovered in the solar spectrum [yellow line D₃]

Helium is misnamed, as '-ium' is normally used with metals. The gas should perhaps better have been named 'helion', cf. Argon, Neon, Krypton, Radon

Discovery of Helium



Jules Janssen
1824-1907
1868

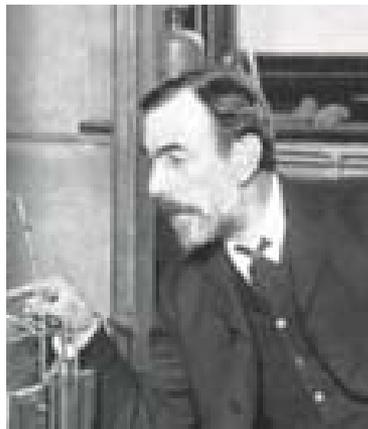


Norman Lockyer
1836-1920
1868
Also founded
the journal
Nature

Janssen and Lockyer observed the D_3 line in the chromosphere and Lockyer proposed to some ridicule that the line was due to a new element not yet found on Earth



Luigi Palmieri
1807-1896
Lava D_3 1882



William Ramsay
1852-1916
Clevite 1895



Per Theodor Cleve
1840-1905
Clevite 1895



Adolf E. Nordenskiöld
1832-1901. Discovered
Clevite 1878

The Noble Gases

Colors and spectra (bottom row) of electric discharge in pure noble gases



It is hard [and dangerous] to collect enough Radon for a discharge tube

He's place in the Periodic Table

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 4.002602																												
3 Li Lithium 6.941	4 Be Beryllium 9.012182																												
11 Na Sodium 22.98976...	12 Mg Magnesium 24.305																												
19 K Potassium 39.0983	20 Ca Calcium 40.078																												
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62																												
55 Cs Caesium 132.9054...	56 Ba Barium 137.327																												
87 Fr Francium (223)	88 Ra Radium (226)																												
		Metals										Nonmetals																	
		Alkali metals		Alkaline earth metals		Lanthanoids		Actinoids		Transition metals		Post-transition metals		Metalloids		Other nonmetals		Halogens		Noble gases									
		C Solid		Hg Liquid		H Gas		Rf Unknown																					
		57-71		89-103																273									
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																													
Periodic Table Design & Interface Copyright © 1997 Michael Dayah. Ptable.com Last updated Jul 1, 2011																													
57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodym... 140.90768	60 Nd Neodymi... 144.242	61 Pm Promethi... (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosi... 162.5	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 Protactini... 231.03688	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)															

Although 'noble' [because of closed electron shells] most noble gases can [with some difficulty] form compounds with Fluorine and Oxygen. I don't know of any He-compounds, except **hydrohelium** HeH_n^+ , that are positively charged ions formed by the reaction of protons with a helium atom in the gas phase, first observed in 1925 and probably present in interstellar clouds and some white dwarfs. **It is the strongest known acid [with n = 1].**

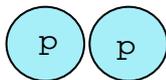
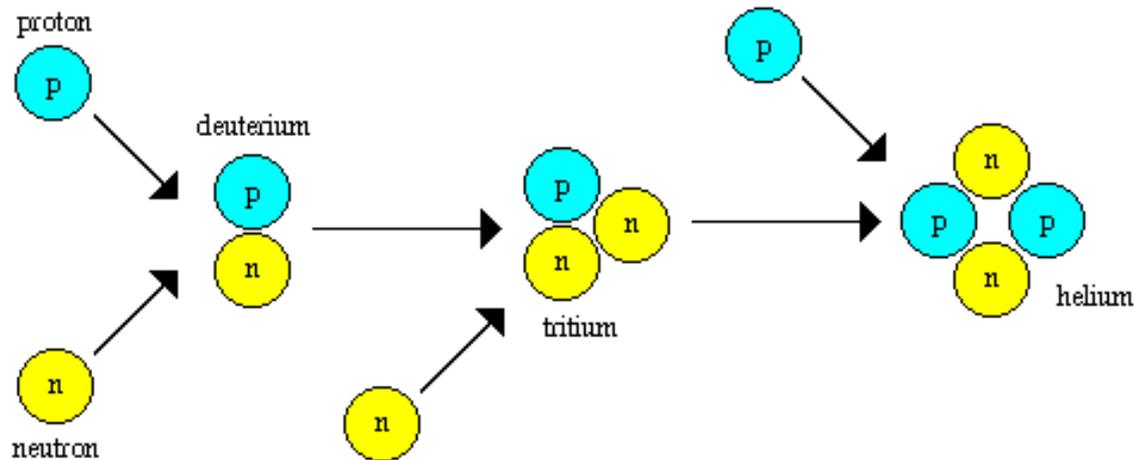
Where does the Helium come from?

- Helium is formed in stars, e.g. the proton-proton chains
- But largely stays in the stars as they die
- Because supernovae forming heavier elements actually burns the Helium
- So, 98% of He must be 'primordial', i.e. formed before the stars

Formation of Helium in the Early (< 3 minutes) Big-Bang Universe

Nucleosynthesis

as the Universe cools, protons and neutrons can fuse to form heavier atomic nuclei



← Cannot [and does not] exist, so to build Helium we need to add neutrons as above, so the number of neutrons is the controlling factor in the above reactions

Estimating the number of neutrons, I

The average energy of a particle at temperature T is $E_{\text{avg}} = 3 kT / 2$, where k is Boltzmann's constant. If a neutron and proton with that energy collide, the total energy in the rest-frame of the collision is $E_{\text{col}} = 2 E_{\text{avg}} = 3 kT$. The binding energy of Deuterium is 2.225 MeV, so the temperature T_D at which Deuterium begin to form from collisions of protons and neutrons can be estimated by equating its binding energy to E_{col} : $kT_D = 2.225 \text{ MeV}/3$, so, since $k = 8.617 * 10^{-11} \text{ MeV/K}$, $T_D = 8.6 * 10^9$ degrees K. The probability of finding a particle with energy $E = mc^2$ at a temperature T is determined by the Boltzmann factor $\exp(-E / kT)$.

Estimating the number of neutrons, II

So the number of neutrons, N_n , available to form Deuterium at T_D would be proportional to $\exp(-m_n c^2/kT_D)$, and the number of protons, N_p , to $\exp(-m_p c^2/kT_D)$, so the neutron fraction would be $N_n/N_p = \exp(-(m_n c^2 - m_p c^2)/kT_D) = 0.175$, using the mass difference $m_n c^2 - m_p c^2 = 1.293$ MeV. Thus $N_p = N_n / 0.175 = 5.7N_n$ and $N_n + N_p = N_n + 5.7N_n = 6.7N_n$, so that $N_n/(N_n + N_p) = 1/6.7 = 0.15$. Thus 15% of the number of nucleons formed in the Big Bang will be neutrons. These will combine with an equal number of protons to form Deuterium which eventually combines in pairs to form ${}^4\text{He}$, so that the ${}^4\text{He}$ abundance will be roughly 30% by mass.

Taking into account that neutrons decay with a half life of only 886 seconds lowers that estimate to about 24% which is, in fact, what is observed.

John W. Draper, first president of the American Chemical Society declared in 1876 in his inspiring presidential address:

“And now, while we have accomplished only a most imperfect examination of objects that we find on the earth, see how, on a sudden, through the vista that has been opened by the spectroscope, what a prospects lies beyond us in the heavens! I often look at the bright yellow ray emitted from the chromosphere of the sun, by that unknown element, Helium, as the astronomers have ventured to call it. **It seems trembling with excitement to tell its story**, and how many unseen companions it has. And if this be the case with the sun, what shall we say of the magnificent hosts of the stars. [...] Is not each a chemical laboratory in itself?”

Indeed, the stars and the whole Universe are chemical laboratories and we can now tell that story.