The Helium Story

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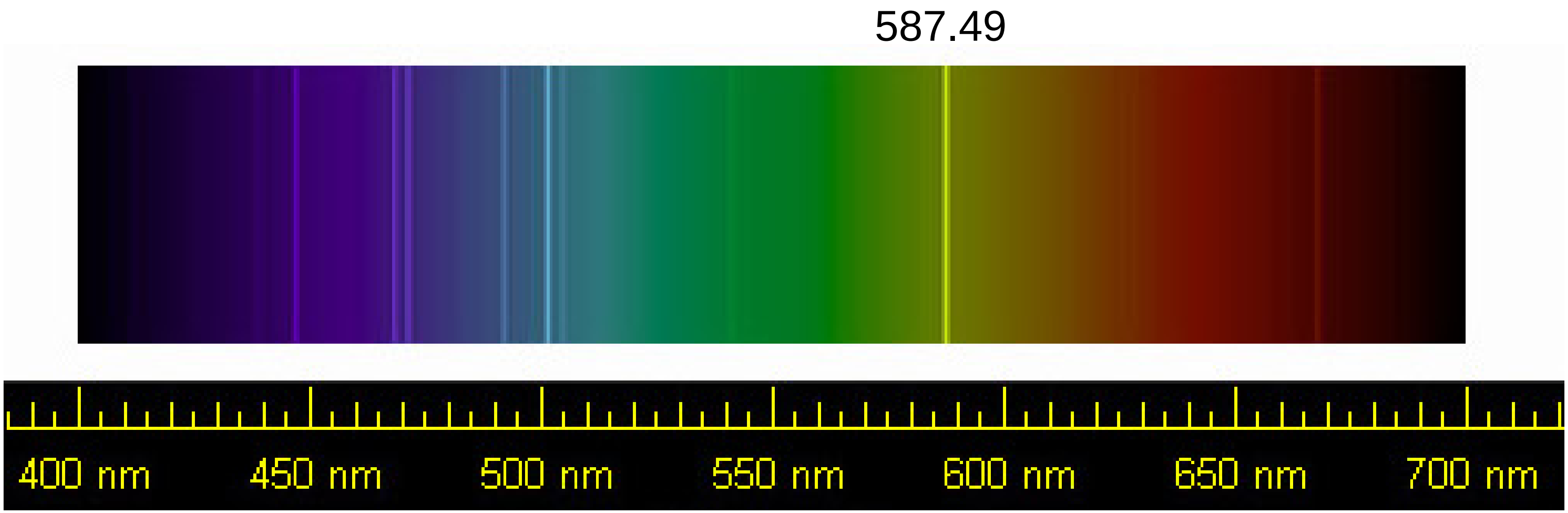
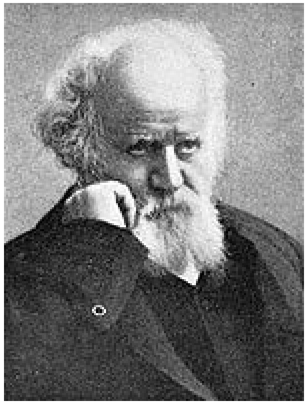
Spectrum of Helium



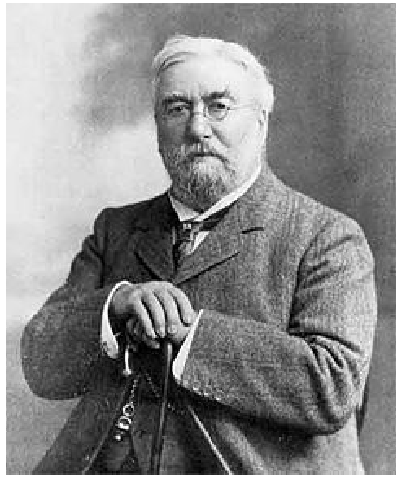
Named after ἥλιος (helios, the sun) because He was first discovered in the solar spectrum [yellow line D_3]

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



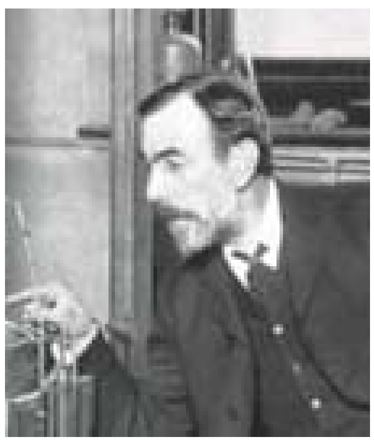
Norman Lockyer
1836-1920
1868

Also founded the journal Nature


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



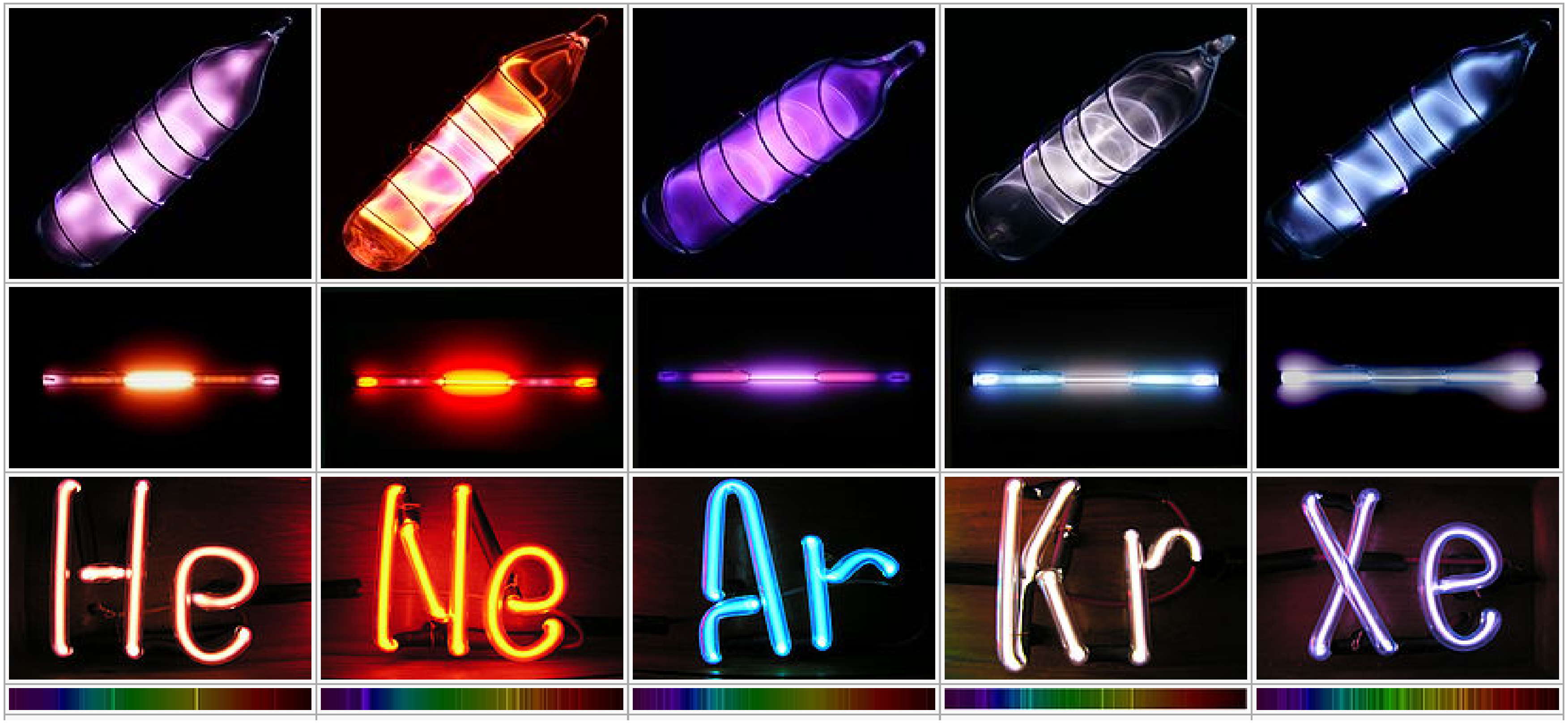
William Ramsay
1852-1916
Clevite 1895

Per Theodor Cleve
1840-1905
Clevite 1895

Adolf E. Nordenskiöld
1832-1901. Discovered
Clevite 1878

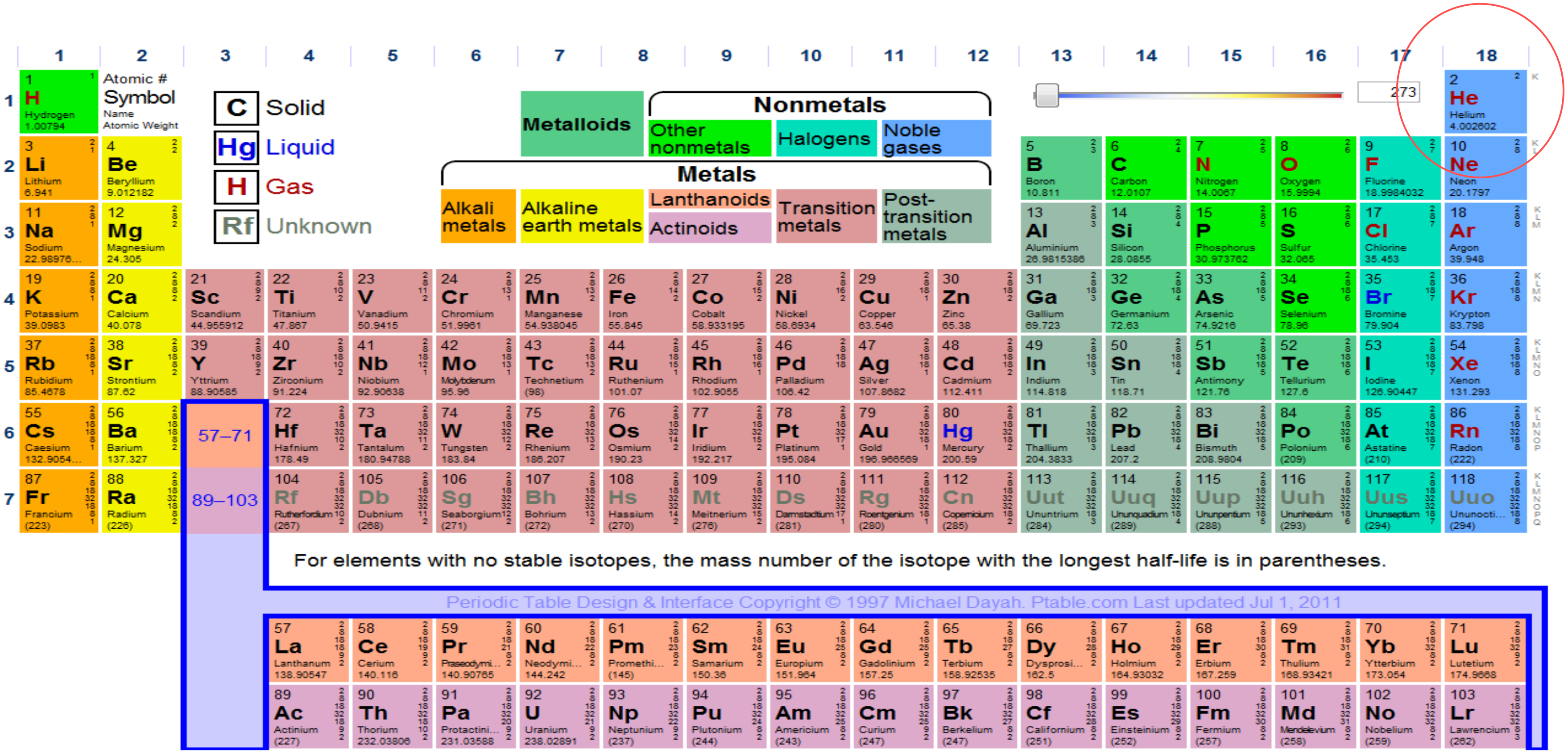
The Noble Gases

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



Although ‘noble’ [because of closed electron shells] most noble gases can [with some difficulty] form compounds with Flourine 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]**.

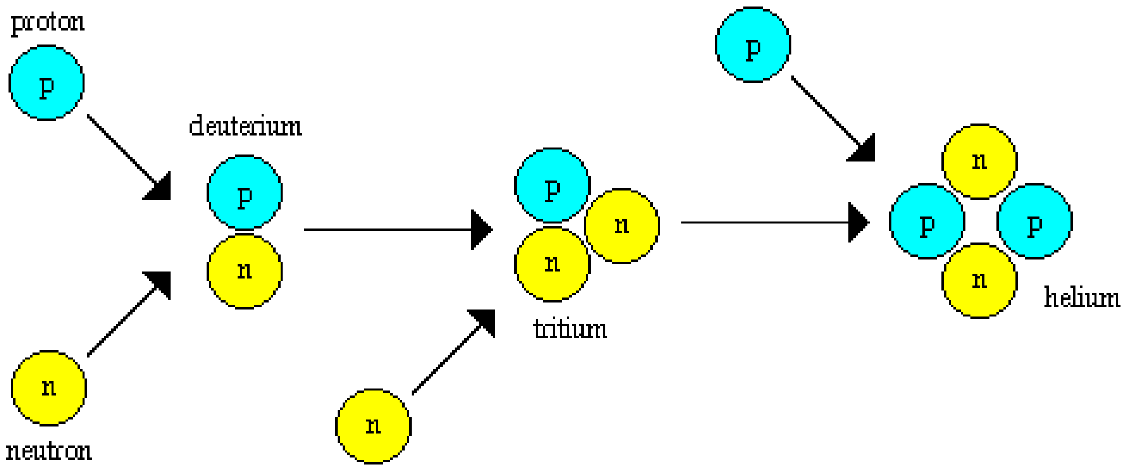
Where does the Helium come from?

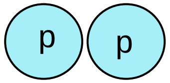
- Helium is formed in stars, e.g. the proton-proton chains
- But largely stays in the stars as they die
- Because supernovae forming heavier elements actually burns the Helium
- So, 98% of He must be ‘primordial’, i.e. formed before the stars

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 $E_{avg} = 3\,kT / 2$, 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 $E_{col} = 2\,E_{avg} = 3\,kT$. 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 Mev/3, so, since $k = 8.617 * 10^{-11}$ 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 $\exp(-m_\mathrm{n}c^2/kT_D)$, and the number of protons, N_p, to $\exp(-m_\mathrm{p}c^2/kT_D)$, so the neutron fraction would be $N_\mathrm{n}/N_\mathrm{p} = \exp(-(m_\mathrm{n}\mathrm{c}^2\text{-}m_\mathrm{p}\mathrm{c}^2)/kT_D) = 0.175$, using the mass difference $m_\mathrm{n}\mathrm{c}^2\text{-}m_\mathrm{p}\mathrm{c}^2 = 1.293$ MeV. Thus $N_\mathrm{p} = N_\mathrm{n} / 0.175 = 5.7N_\mathrm{n}$ and $N_\mathrm{n}+N_\mathrm{p} = N_\mathrm{n}+5.7N_\mathrm{n} = 6.7N_\mathrm{n}$, so that $N_\mathrm{n}/(N_\mathrm{n}+N_\mathrm{p})= 1/6.7 = 0.15$. 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}He, so that the ^{4}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.