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ALPHABETIC GLOSSARY

Names of major contributors to physics, chemistry, and astrophysics, following the thread of The Magic Furnace, by Marcus Chown

Alpher, Ralph 1921 - 2007, and **Herman**, Robert c 1948

American students of Gamow who carried out calculations that estimated the quantities of elements forged in the first five minutes in the life of the universe. They found, contrary to Gamow's inspiration, that only helium is created under these conditions, plus a tiny trace of lithium. Heavier nuclei could not be forged in the limited time scale of five minutes due to the absence of stable nuclei with 5 or 8 nucleons (protons or neutrons) to bridge the gap to carbon. This finding shot down the hope that the Big Bang was a unique magic furnace where all the elements were made.

Alpher also predicted the three degree microwave background, now the most fertile area of research into the early universe and cosmology in general.

Ampere, Andre-Marie 1775 - 1836

French mathematician and physicist, known best for his work on electricity, and for Ampere's Circuit Law. He found in 1814 that atoms of one element in a gas usually combine into diatoms (molecules with two atoms such as H₂, N₂, and O₂). This allows weight comparisons of molecular gasses to imply atomic weights.

Anaxagoras 500 BC - 428 BC

Greek philosopher who proclaimed that the sun is a hot, glowing ball of iron not much bigger than Greece.

Angstrom, Anders 1814 - 1874

Swedish physicist whose name defines the atomic scale distance, one Angstrom,

which is 10^{-10} m. He showed that a spectral line is in emission or in absorption relative to the adjacent continuum radiation of a background source depending on whether the line is formed in a gas which is hotter or cooler than the background source. One major consequence of this is that the relatively cool outer layers of a star produce absorption lines on the background continuum of black body radiation propagating up from the deeper and hotter layers of the star. Solar prominences rising above the photosphere, and seen against the background of space, will exhibit lines in emission.

Aston, Francis 1877 - 1945

British chemist and physicist. He started as assistant to JJ Thompson in 1910. In 1919 he built the first full, functional mass spectrometer. He discovered isotopes, and thereby explained non-integral atomic weights as isotopic mixtures. This resolved the problem of an element that strongly violated Prout's hypothesis, namely chlorine. But, in 1919 he also found that relative to oxygen, and other elements, hydrogen has too much mass ($1.008 \times 1/16$ of oxygen). Ultimately, this led to the modern theory of nuclear binding energy, which underpins all nuclear applications, including medical isotopes.

Atkinson, Robert 1898 - 1982, and **Houtermans**, Fritz 1903, 1966.

English experimentalist, and German theoretician, grouped together here due to their fruitful collaboration. Both worked with Gamow on alpha emission via quantum tunneling. Then, in 1919, after reading Eddington's book, *Internal Constitution of the Stars*, Atkinson informed Houtermans of the problem of nuclear burning at the relatively low temperatures in the cores of stars that Eddington had newly calculated. Houtermans then came up with the idea that quantum tunneling might allow nuclear fusion of hydrogen into helium in the sun at these low core temperatures. This was done with no knowledge of nuclear physics, and therefore it did not include the essential transformation of a proton into a neutron in the brief instant of the collision of two protons. For this, it was necessary to understand the weak force.

Avagadro, Amedeo 1776 - 1856

Italian lawyer turned physicist who, in 1811 published Avagadro's Law: that a fixed volume of gas at STP has a fixed number of molecules independent of the

chemical ID of the gas. A volume of 22.4 liters at STP has what is defined as one mole of gas. One mole = 6.0221415×10^{23} . His law allowed others to compare the atomic weights of the various molecular and atomic gasses, without knowing the atomic makeup of the gas molecule in question.

Baade, Walter 1893 - 1960

German-American astronomer who recalculated and thereby doubled the size of the universe, who identified two distinct types of Cepheid variables, who identified two stellar population types based partly on chemical abundances, and who identified supernovae as a new category of astronomical object.

Balmer, Jacob c1888

Swiss mathematician and physicist best known for discovering empirical formula for the wavelengths of the hydrogen in the visible spectrum, now known as the Balmer series. Wikipedia: Balmer's formula (for $n_1=2$) was later found to be a special case of the [Rydberg formula](#), devised by [Johannes Rydberg](#).

$$\frac{1}{\lambda} = \frac{4}{h} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Becquerel, Henri 1852 - 1908

French minerologist and physicist. In 1896, while studying phosphorescence in uranium salts, a non-nuclear phenomenon, he discovered nuclear radioactivity by accident and hunch.

Bernoulli, Daniel 1700 - 1782

Dutch-Swiss mathematician from a prominent family of mathematicians, best known for Bernoulli's Law of fluid mechanics, which explains why airplanes fly. He applied Newton's First Law to the concept of atoms (actually molecules) in a gas: When in motion a body tends to stay in motion. Thus the atoms in a gas will travel in straight lines until they collide with one another or with the walls of their container. From this, and the assumption that collisions are elastic, he predicted the three gas laws later known as Boyle's, Charles', and Gay Lussac's, which

combine into the perfect gas law, $PV = NRT$. Was way ahead of his time.

Bernoulli is also known for his work in mathematics and statistics.

Bethe, Hans 1906 - 2005

German-American theoretical nuclear physicist. Worked in several areas of physics, especially the theory of beta radioactivity, the most common action of the weak force. In 1934, he discovered the carbon cycle, a catalytic mechanism involving C, N, and O, for fusion of H into He in stars with hotter cores than in the sun. He found the temperature dependence of the carbon cycle reaction rate to be T^{17} . This extreme sensitivity to temperature is due to the temperature sensitivity of the high energy tail of the thermal velocity distribution, and the sensitivity of quantum tunneling probability to collision velocity. The carbon cycle was independently discovered at the same time by Carl Von Weizsacker.

In the P-P reaction Bethe found that one of the protons could decay into a neutron in the brief instant of fusion, transforming the highly tenuous PP pair into NP, which is the stable hydrogen isotope, deuterium. Deuterium then absorbs another proton, becoming He-3. Two He-3 nuclei can then combine into one He-4 plus two free protons. This is the proton-proton chain that transforms H into He in stars with less mass than 1.5 solar masses.

Bohr, Niels 1885 - 1962

Danish physicist who postulated quantized electron orbits to explain the Balmer series of spectral lines in hydrogen spectra. The Bohr Atom has orbits quantized by an integral number of de Broglie waves fitting around the orbit. The correct orbits, now found in every high school chemistry text, are spatially fuzzy orbitals calculated from Schrodinger's equation. Bohr was a key advocate of quantum theory, and argued extensively with Einstein, who felt strongly that his "God" would never allow nature to be fundamentally probabilistic. Einstein was convinced that quantum theory would some day be replaced by a non-probabilistic theory.

Brahe, Tycho 1546 - 1601

Danish astronomer who proved that the Church's "heavenly spheres" are not

immutable, that comets, supernovae (SN 1572), etc. lie outside them.

Bruno, Giordano 1548 - 1600

Italian friar, philosopher, mathematician, and astronomer. Rapidly oxidized by the Church for advocating the idea that the sun is a nearby star, and that the universe has an infinite number of worlds inhabited by intelligent beings.

Burbidge, Geoffrey 1925 - 2010

English-American astronomer. Wikipedia: In 1957 he and his wife were co-authors, together with [William Fowler](#), the American physicist, and [Fred Hoyle](#), the British astronomer, of a famous paper on [stellar nucleosynthesis](#), which was referred to as the [B²FH](#) paper, after the initials of the surnames of the four authors. This paper described the process of stars burning lighter elements into successively heavier atoms which are then expelled to form other structures in the universe, including planets.

In recent years Burbidge was known mostly for his [alternative cosmology](#) "[quasi-steady state theory](#)", which contradicts the [Big Bang](#) theory.

According to Burbidge, the universe is [oscillatory](#) and as such expands and contracts periodically over infinite time. This theory, due to its controversial nature, has brought a certain amount of fame (or even infamy) to Burbidge.

Cameron, Alistair 1925 - 2005

Canadian nuclear physicist who discovered the source of neutrons for building heavy elements in stars with less than eight solar masses. It is the rare isotope C-13, a by product of the carbon cycle (see Bethe). C-13 combines with an alpha to produce O-16 and a free neutron. For stars with more than eight solar masses he discovered another neutron source, namely Ne-22 combining with an alpha to produce Mg-25 and a free neutron.

Chadwick, James 1891 - 1974

English physicist who discovered the neutron. In 1932, James Chadwick proved that the atomic nucleus contained a neutral particle which had been proposed and named more than a decade earlier by Ernest Rutherford. He found the neutron to be about 0.1% more massive than the proton.

Chamberlain, Thomas 1843 - 1928

American geologist who anticipated a radioactively self-heated earth, discovered CO₂ in the earth's atmosphere, introduced the concept of climate change, and challenged Lord Kelvin's gravitational contraction theory for the energy output and age of the sun, 30 MY. Geologists and Darwinian biologists at that time, not yet enlightened by radio dating, were estimating 100 MY.

Comte, Auguste c 1835

French philosopher who asserted that the chemical composition of the stars will never be known because we cannot travel to the stars.

Copernicus, Nicolaus 1473 - 1543

One of the greatest polymaths of the Renaissance, and the first person to formulate a comprehensive heliocentric cosmology. Copernicus, living before the invention of the telescope, reasoned that absence of parallax (that he could measure) implied the stars were very distant. From this he came up with a far simpler paradigm than that of Ptolemy.

Curie, Marie 1867 - 1934

French chemist born in Poland, often called "the greatest woman scientist". Working with husband Pierre Curie, in 1898, she discovered radium and polonium in pitchblende ore through their anomalous high radioactivity. They isolated and worked extensively with radium, revealing the enormous store of energy latent in this isotope, and by implication, in the nuclei of other elements. After working to find therapeutic uses of radium, she died of cancer, probably due to her high exposure to this dangerous element.

Dalton, John 1766 - 1844

English chemist, physicist, and meteorologist. In 1803, he noticed that elements always combined in fixed proportions by weight, and saw this as evidence that atoms were combining in fixed number ratios, now known as stoichiometric ratios. The "Dalton", one unit of chemical mass, is now defined as 1/12 of the mass of the atomic and nuclear ground state of the common isotope C-12.

Five main points of Dalton's atomic theory (obviously dated in the light of today's knowledge)

1. Elements are made of extremely small particles called atoms.
2. Atoms of a given element are identical in size, mass, and other properties;
3. Atoms cannot be subdivided, created, or destroyed.
4. Atoms of different elements combine in simple whole-number ratios to form chemical compounds.
5. In chemical reactions, atoms are combined, separated, or rearranged.

de Marignac, Jean-Charles 1817 - 1894

Swiss chemist who, in 1861, published a paper claiming that his mass deficit measurements proved Prout's rule to be inexact: that all elements are composites of hydrogen. He was ahead of his time when he attributed this mass deficit to lost energy, thereby predicting the equivalence of mass and energy, beating Einstein to the punch by 44 years. But, it was Einstein who derived the quantitative relation $E = Mc^2$.

Democritus 470 B.C.

He was the first to come up with idea that all matter is composed of atoms (meaning they cannot be split, often referred to as "elementary" in today's lingo). He reasoned that water is atoms plus void, otherwise fish could not swim through it, nor could salt dissolve in it. His conclusion, "In reality, there are only atoms and the void."

Eddington, Sir Arthur 1882 - 1934

English astrophysicist who did structure calculations of stars, starting with the easy case of red giants (with their cool cores). These pioneering computations improved on previous work by Martin Schwartzchild with the inclusion of radiation as the dominant store of energy relative to the heat energy of the plasma, but assumed incorrectly that atoms in the stellar regime are not ionized. Much of the pressure to support a star against its own gravity comes from the electrons liberated by ionization.

In the 1920s, he introduced the idea that proton-proton reactions were the basic principle by which the Sun and other low mass stars fuse hydrogen into helium, releasing binding energy in the process. Working without knowledge of nuclear quantum tunneling he wrongly concluded that his stellar core temperatures would

not sustain a P-P reaction.

Eddington is also known for his expedition of 1919 to observe an eclipse of the sun and the angle deflection of star images near the occulted solar disk due to gravitational curvature of space and time. This resulted in a rough quantitative confirmation of general relativity.

Einstein, Albert 1879 - 1955

Wikipedia: German-born [theoretical physicist](#) who developed the theory of [general relativity](#), effecting a revolution in [physics](#). For this achievement, Einstein is often regarded as the father of [modern physics](#) and one of the most prolific [intellects](#) in human history. He received the [1921 Nobel Prize in Physics](#) "for his services to theoretical physics, and especially for his discovery of the law of the [photoelectric effect](#)".^[4] The latter was pivotal in establishing [quantum theory](#) within physics.

For the thread of this glossary, Einstein is most important for establishing the equivalence of mass and energy, $E = Mc^2$, a basic principle underlying the transmutation of the elements, and the luminosity of the stars.

He also confirmed the atomic hypothesis through his explanation of Brownian motion in pollen grains floating on water. But, he did more than explain. He built a quantitative theory which led to the first determination of the size of atoms by Perrin.

Fowler, William (Willi) 1911 - 1995

American nuclear experimentalist at Cal Tech who started a program to study the nuclear reactions in the carbon cycle discovered by Bethe in 1934. He correctly concluded that this catalytic mechanism cannot work in the sun due to the relatively low temperature in the sun's core. His work on stellar nucleosynthesis culminated in his collaboration with Hoyle and the Burbidges. His name is the "F" in B^2FH , which explained the nucleogenesis of all the elements except the lightest ones.

Friedmann, Aleksandr 1888-1925

Russian cosmologist who pioneered the use of Einstein's general theory to model the geometry of the universe. He advocated the Big Bang idea seven years before Hubble found evidence for an expanding universe. He is known for the Friedmann Equation, an energy conservation equation whose solution is the time dependent rate of expansion of space-time. He categorized cosmological models into those with space which is positively or negatively curved, or flat. Universes with positive curvature are closed and eventually collapse. Those with negative curvature are open and expand forever. The flat ones lie on the mathematical borderline.

Gamow, George 1904 - 1968

Russian born physicist, cosmologist, and science writer. He conjectured the original explosive expansion of the universe, derisively named the "Big Bang" by Fred Hoyle. Early in his career he solved the mystery mechanism for alpha radioactivity: quantum tunneling through the potential force barrier of the strong force. Working with his student Alpher, he pursued the rational but incorrect idea that all the elements, in their modern proportions, were forged in the Big Bang, all in one furnace. From the Big Bang model Alpher predicted the three degree cosmic background radiation, now considered perhaps the most fertile area of research into cosmology. Gamow suggested that the sun produces its luminous energy by fusing H into He, but failed to see that quantum tunneling can work to facilitate fusion as well as fission, which solves the mystery of how H-to-He fusion events can occur at Eddington's relatively cool temperatures in the cores of low mass stars. Highly creative and imaginative, Gamow wrote the popular books: "Creation of the Universe", "Birth and Death of the Sun", and "One Two Three Infinity". His last years were spent here at the CU Physics Department. He is buried in the Columbia Cemetery, in Boulder.

Hauksbee, Francis 1666 - 1713

English physicist who in 1709 invented a discharge tube that would later be engineered into the neon light. He isolated "electricity", which was previously encountered in, and confused with the properties of, a copper wire, by placing electrodes in a blown glass tube with reduced air or gas pressure. Voltage on the electrodes produced sparks zig zagging between them. See Plucker and Hittorf, who picked up this thread much later.

Herschel, John 1792 - 1871

English mathematician, chemist, and astronomer well known for his observations in the southern hemisphere. He measured the heat output from the sun, which emphasized the question, What powers the sun?

Hittorf, Johann 1824 - 1914

German physicist, student of Plucker. Applying the laws of EM, he used magnets to deflect the ray in a discharge tube, showing it to be electrically charged. He created shadows of objects in its path to confirm it was traveling in straight lines. These results opened the path to a major discovery by J.J. Thompson.

Hoyle, Fred 1915 - 2001

British nuclear physicist and astrophysicist. Pioneer of stellar nucleosynthesis, and advocate of the "steady state hypothesis" in cosmology. With Fowler and the Burbidges he published a lengthy paper, B^2FH , explaining how all the elements aside from helium and the other lightest elements are forged in stars and supernovae. This paper, the most well known in astrophysics, details seven out of eight processes by which atomic nuclei can be forged, starting from an early universe of protons and neutrons. For the "X" process, see **von Weizsäcker**.

- 1) P-P chain
- 2) CNO
- 3) triple-alpha
- 4) S-process
- 5) R-process
- 6) P-process
- 7) Hot Big Bang
- 8) X-process

Huggins, William 1824 - 1910

Wealthy English amateur astronomer who spent his life laboriously recording the line spectra of hundreds of stars, repeatedly encountering the laboratory line spectra reported by Bunsen. The combined work of Kirchoff and Huggins made it clear that the stars are made of the same chemical elements as found on the earth, but the relative abundances in stars were still unknown. This was due to the

complicated relationship between line profiles and the detailed physics of the atmospheres in which the lines are formed.

Kirchoff, Gustav 1824 - 1887

German physicist well known for his work on electric circuits, spectroscopy, and black body radiation, which he named. He suggested to Bunsen that a prism should replace Bunsen's awkward use of glass light filters to determine the precise wavelengths of spectral lines. This led to a collaboration that revealed that Bunsen's emissive flame spectra was identical to Fraunhofer's absorption spectra in the sun, and stars. The important implication of this is that the sun and stars are composed of the same chemical elements as those found in the earth. He reasoned from the work of Angstrom that the sodium lines in the sun were in absorption because they were formed in the cool outer layers of the sun's atmosphere, which is illuminated by the hotter layers below.

Lavoisier, Antoine 1743 - 1794

French chemist. In 1789 he compiled a list of 23 elements as a basis for all compounds, a list which rapidly grew as more workers identified more elements. He also discovered the rule of conservation of mass in chemical reactions. A well connected aristocrat living at the time of the French Revolution, Lavoisier was guillotined in 1794.

Maxwell, James Clerk 1831 - 1879

Scottish mathematician and physicist who unified electricity and magnetism in four linear, differential equations known as Maxwell's Equations. This was the second greatest unification in physics, the first being that of Newton, who identified earth's gravity with the force acting on celestial bodies. Maxwell's wave propagation solution demanded that the speed of light be independent of moving reference frames, meaning that the speed of light is constant. This highly counter-intuitive result became the central axiom of Einstein's special theory of relativity.

Maxwell also helped develop the Maxwell-Boltzmann distribution, the statistical spread of velocities found in every gas in thermal equilibrium.

Mendeleev, Dimitri 1834 - 1907

Siberian chemist who discovered repeating properties in the 67 elements known in

his time, from which he organized them into his well known Periodic Table of the Elements. Many as yet undiscovered elements were found as missing entries in his table. His work was empirical; understanding chemical properties and reactions in terms of electron shell structure, valences, and the Exclusion Principle, would have to come later.

Newton, Isaac 1614 - 1727

English physicist, one of two mathematicians to independently invent calculus, and one of the foremost intellects of all time. Newton achieved the first great unification in physics by identifying earthly gravity with the force acting on celestial bodies. He confirmed the Galilean idea that a body's motion persists until a net force acts on it, and he extended this to $F = MA$, and the law of action and reaction. His work with telescopes, including the invention of the reflector telescope, and on the spectrum of light, laid groundwork for all future astronomy and optics. He was the first person to raise the question, What powers the sun?

Payne-Gaposhkin, Cecilia 1900 - 1979

English astronomer who, when disallowed, due to her gender, from an academic program in England, went to Radcliff and proceeded to make a major breakthrough. First, she studied the spectra of many stars in the Harvard catalogue, attempting to determine chemical abundances. Then, in 1925, after learning of Saha's method to determine per-cent neutral hydrogen in the sun, she did so and found that almost all the hydrogen in the sun's photosphere is ionized. She concluded from this and the strong hydrogen absorption lines in the solar spectrum, that the sun must be composed mainly of hydrogen, but also helium, the other elements being present in trace abundances. This basic paradigm shift was hard for even her to believe. But, it finally killed the idea which started with Anaxagores in pre-socratic Greece, that the sun is a hot glowing ball of iron. One implication of Cecilia Payne's basic finding is that the sun has enough hydrogen fuel to burn (into helium) for many BY.

Perrin, Jean Baptiste 1870 - 1942

French physicist. Using lab data and Einstein's quantitative theory for Brownian motion he calculated the size of water molecules, about 10^{-10} m, or one Angstrom. This was the first time the size of an atom or molecule had been

calculated.

He also suggested that the sun is powered by some unknown sort of sub-atomic energy released in the conversion of H to He.

Plucker, Julius 1801 - 1868

German mathematician and physicist. In 1858 he continued Hauksbee's early work, using more highly rarified gasses. At lower gas density, Hauksbee's jagged lightning bolts became a continuous glow. Further pumping down of the gas pressure resulted in blackness, with only a faint glow near the termination of the ray at the end of the glass tube.

Prout, William, 1785 - 1850

English chemist, physicist, and natural theologian, he is remembered today mainly for what is called Prout's hypothesis. Using the results of Ampere and others, he stumbled upon the remarkable discovery that all the atomic weights he measured are near multiples of the weight of hydrogen. Based on this, he theorized that all elements were composites of hydrogen. Not quite right, but on the right track, and useful as a standard of comparison for others.

Röntgen, Wilhelm Conrad 1845 - 1923

Wikipedia: German physicist, who, in 1895, produced and detected electromagnetic radiation in a wavelength range today known as X-rays or Röntgen rays, an achievement that earned him the first Nobel Prize in Physics in 1901.

Russell, Henry Norris 1877 - 1957

American astronomer who, with Hertzsprung, introduced the Hertzsprung-Russell (H-R) Diagram, which allows a scatter plot of the stars over luminosity and surface temperature, and a convenient way of tracking their evolution. Russell extensively studied red giants and catalogued their surface temperatures. The H-R Diagram is universally employed to visualize the evolutionary "tracks" for stars of all masses.

Rutherford, Ernest 1871 - 1937

British physicist born in New Zealand, the "father of nuclear physics".

In 1899, soon after Becquerel discovered radioactivity and Roentgen produced X-rays, he identified alpha and beta rays in natural radioactivity, and some of their properties. He discovered the tiny size and strong electrical repulsion of the atomic nucleus by suggesting that Marsden and Geiger, who were exposing a thin sheet of gold foil to alpha particles, look for alphas bouncing back at large deflection angles. When they revised their detector, they found that most of the alphas missed their heavy target nuclei in the foil, but one out of about 8,000 hit and bounced back at wide angles, indicating the tiny size and large electrical repulsion at close range of the positively charged, heavy atomic nucleus of gold. In earlier work he showed that radioactivity involves nuclear transmutation: He transformed nitrogen-14 into oxygen-17, by bombardment with alpha rays, discovering that the proton can be spit out as a particle of radioactivity. He had performed the first act of artificial nuclear alchemy. He discovered and named half-life, and worked on the application of half lives to geologic dating, concluding that the age of the earth is 4.6 BY.

Saha, Meghnad 1893 - 1956

Indian physicist who combined Bohr's theory of the quantized atom with thermodynamics to derive the Saha formula for the relative number densities of the ionization stages of an atom. This is important to spectral analysis and structure computations in astrophysics, as several different stages of ionization might be simultaneously present in various regimes of temperature and density in the deep interior, or in the line forming atmosphere of a star. The Saha Equation, used together with Boltzmann's Equation, can determine the populations (particles per cubic centimeter) of every atomic excitation level of every ion stage of every element in a gas or plasma in local thermodynamic equilibrium (LTE) with a known temperature and density at the point in question.

Salpeter, Edward 1924 - 2008

Austrian-American physicist who predicted the two-step process by which He-4 could be fused into C-12. See Hoyle.

Salpeter also estimated the distribution of stars over mass, called the "initial mass function". Later in his life he led a committee which investigated and shot down the claims of President Reagan's SDI (Star Wars) concept.

Schwartzchild, Martin 1912 - 1997

German-American astrophysicist, and son of Karl Schwartzchild, known for the Schwartzchild metric of general relativity from which we have the concept of the event horizon of a black hole. Martin Schwartzchild did early computer models of stellar structure and evolution, and applied his numerical techniques to problems like differential rotation (e.g. as seen in the sun) and pulsation (e.g. in Cepheid variables). He is known for his book, *The Structure and Evolution of the Stars*. Encouraged by Lyman Spitzer, a leader in infrared astronomy, he pioneered the use of balloons to send IR detectors above the earth's atmosphere.

Soddy, Frederick 1877 - 1956

Wikipedia: [English radiochemist](#) who explained, with [Ernest Rutherford](#), that [radioactivity](#) is due to the [transmutation](#) of elements, now known to involve [nuclear reactions](#). He also proved the existence of [isotopes](#) of certain radioactive elements. He received the [Nobel Prize for Chemistry](#) in 1921, and has a [crater](#) named for him on the [far side of the Moon](#).

Thompson, Joseph, John “JJ” 1856 - 1940

British physicist credited with the discovery of the electron, and of isotopes. In 1897, working with discharge tubes, he used opposing and balanced forces from magnetic and electric fields to determine the charge and mass of the electron. The first sub-atomic particle had been found, and had a mass of about 1/2000 the mass of the hydrogen atom, later found to be close to 1/1836.

The mysterious tube discharge was now seen as very light negatively charged particles (electrons) ripped off metal electrodes and accelerated across the tube by the applied electric field, and subject to magnetic fields which can be used to deflect them. Using the ability to discriminate on the basis of a particle's charge-to-mass ratio, Thompson pioneered the mass spectrograph, which is used to physically separate the isotopes of an element in an ionized beam.

Thomson, William (Lord Kelvin) 1824 - 1907

Most honored British scientist of all time. He devised the Kelvin temperature scale which we use universally in all physical science, discovered the first and second laws of thermodynamics, and wrote some 600 papers over a broad range of topics. He advocated Helmholtz' early and incorrect idea that the sun is powered by gravitational contraction which has been reducing it from a larger nebula for

some 30 MY.

Urey, Harold c 1932

In 1932, he discovered the hydrogen isotope deuterium (one neutron and one proton locked together by the attractive, short range "strong force"), an intermediate step in building He from H in the proton-proton chain in stars like the sun that are too cool for Bethe's carbon cycle to operate efficiently.

Von Fraunhofer, Joseph 1787 - 1826

German physicist who discovered the sharp, dark absorption lines in the spectrum of the sun, and a few bright stars. Further work later revealed about 25,000 of them. See Bunsen. He and a co-worker also did a lot of work on elemental abundances in stars, later used in B^2FH .

von Weizsäcker, Carl Friedrich Freiherr 1912 – 2007

German philosopher and physicist who did extensive research in nuclear physics, and discovered the carbon cycle independently of Bethe. He shot down the notion that all the elements could have been forged in one nuclear furnace by showing that each element had to be created at its own temperature and density. This led to the conclusion that only deep in stars could the full range of needed conditions be found. We now know that this notion is correct for all elements except He, Li, Be, and B. Almost all He and Li in today's universe was formed in the Big Bang, while Be and B are thought to be fragments of heavier cosmic ray particles which underwent collisions. This is the "X" process in Hoyle's list.

Young, Thomas 1773 - 1829

English polymath and physicist who discovered the wave nature of light, and measured its wavelength. This allowed Fraunhofer to pin down the precise wavelengths of the spectral lines he was observing in the sun and bright stars.