Helium-3
Stealing the Sun's Fire

by Natalie Lovegren

The evolution of the science of chemistry has enabled us to achieve control over energy and matter by finer and finer degrees of precision and with greater density of power. Each discovery has afforded us new dimensions of knowledge which allow us to extend our curious reach out into the bigness of space, and down into the vast minuteness of matter with greater and greater power on a smaller and smaller scale. The degree to which we can advance such a power over nature, and utilize these myriad "gifts of Prometheus" defines our existence as a species.

Here we unravel the case of one singular substance, and investigate the change of its identity, and of its economic value throughout the advancement of physical chemistry.

The Strange Case of Dexter Gas

In May 1903, residents of Dexter, Kansas, were thrust into fits of sheer jubilation after a newly drilled well started spewing forth natural gas at the rate of 9 million cubic feet per day before it could be capped. With the promise of cheap fuel and lucrative industries coming to town firmly in mind, the people sprang into action, planning to celebrate the discovery of this "howling gasser" with games, speeches, music and a lighting ceremony that promised residents "a great pillar of flame" that would "light the entire countryside for a day and a night." Yet when the time came to light the well, the gas refused to burn. Mystification and dejection ensued.

Word quickly spread across the state, piquing the interest of University of Kansas geology professor Erasmus Haworth, who brought samples of the curiously nonflammable "Dexter gas" back to Chemistry Hall at the University. There, two chemistry professors, Hamilton P. Cady and David F. McFarland, began two years of extensive research and analysis of the strange gas.[1]

Finding huge pockets of "free" natural gas to be burned for fuel was an exciting prospect at this time in the United States. But that wasn't always the case.

1. John H. McCool, Department of History, University of Kansas kuhistory.com/articles/high-on-helium

It had been known since antiquity that invisible flammable gases could come out of the earth. The infamous Temple of Apollo at Delphi was built upon a fissure in a rock, whence seeped a burning gas, because they believed the flame to have a divine source. The oracle who resided at the temple was said to be inspired by the flame, which enabled her to make prophesies on behalf of the god Apollo.[2]

But this gas merely fueled the superstitions—and decline—of the Greeks.

The development of natural gas for commercial economic purposes required the firm establishment of modern chemistry. It first required going beyond the mere *observation* of fire, and of gases burning, to understanding what burning was.

Dmitri Mendeleev, discoverer of the periodic table of elements, wrote in his brilliant work, *The Principles of*

"The Oracle of Delphi Entranced" by Heinrich Leutemann

2. Both Aeschylus and Plutarch (who was one of the priests of Apollo, responsible for interpreting the oracle) attributed the oracle's powers of "prophesy" to her inhalation of gases coming from the ground. Ethylene, a component of natural gas, is known to have hallucinogenic properties. A 2001 study, published by *Geology*, corroborates the claims of the ancients by detailing the intersection of two geological faults directly beneath the temple, as the source for such fissures in the rock which emitted these natural gases. Natural gas during the collapse of this once great civilization, was thus, not a resource, but a symbol of a nexus of usurious money lending, sophistry, and superstition, as evidenced by the willingness to consider the euphoric delusions of an intoxicated woman as sacred political wisdom. See also: Humphreys, Colin J. *The Miracles of Exodus*. London, 2003. Papert, Antony. "Speaking of Delphi..." *EIR*, 21 October: 2005.

"An Experiment on a Bird in an Air Pump" by Joseph Wright of Derby, 1768.

Chemistry, that one of the reasons for the tardy progress of chemical knowledge was the pivotal importance of invisible gases in chemical reactions. We had to see beyond the faculty of sight to *weigh* these invisible substances, and understand the causes behind these processes. He wrote:

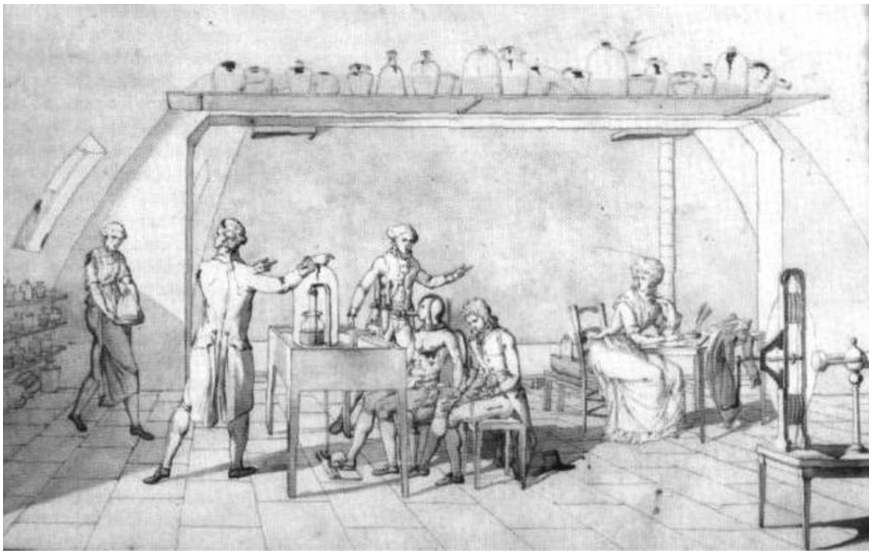
> The true comprehension of air as a ponderable substance, and of gases in general as peculiar elastic and dispersive forms of matter, was only arrived at in the sixteenth and seventeenth centuries, and it was only after this that the transformations of substances could form a science. Up to that time, without understanding the invisible, but ponderable, gaseous and vaporous forms of matter, it was impossible to obtain any fundamental chemical knowledge, because the gases formed or used up in any reaction escaped notice.[3]

On the eve of the French Revolution, Antoine Lavoisier would unravel this mystery. Contemporary theory held that when burned,substances, including metals, lost a substances known as phlogiston, the "fire principle."

Changes in substances were explained by the addition or subtraction of phlogiston. In 1772, Lavoisier read the experiments of Guyton de Morveau, who showed that metals *increased* in weight when they were roasted in air. How could this be reconciled with the idea that burning was the removal of something? Although this did not bother the proponents of phlogiston theory, who explained it away by claiming that phlogiston can have "levity" which buoys up metals, it was a clear sign to Lavoisier that the theory was flawed. Lavoisier meticulously repeated the experiments, and found that when lead and tin were heated in closed containers their weights did not change; but when air was allowed to enter, the resulting product—the metal plus the burned ash—weighed *more* than the original metal.

He reasoned that some part of the air must be attaching itself to the metal. Soon thereafter, the chemist Joseph Priestley visited Lavoisier in Paris to tell him that he had found a new "dephlogisticated air" by heating up red calx of mercury (now called mercuric oxide, HgO). The new air seemed stronger and purer than regular air. Mice could live longer in the new air, than they would confined in an equal volume of regular air, and the new air

3. Mendeleev, Dmitri. *The Principles of Chemistry*, ed. A.J. Greenaway, trans. George Kamensky. London: Longmans, Green, and Co., 1891.



Monsieur and Madame Lavoisier and assistants experiment with respiration. Drawing by Madame Lavoisier, circa 1780.

allowed candles to burn with "an amazing strength of flame." Lavoisier repeated the experiment, and found the same result, but made a new hypothesis. Heating up the red calx of mercury had liberated something from it, and this substance was the same as that which was sticking to the heated lead and tin. Lavoisier identified this as an elementary substance, and later named it "oxygen."[4] He demonstrated that burning, rusting, and breathing were all types of oxidation—transformations in which oxygen combines with some other substance. Burning coal is rapid oxidation while rusting iron is slow oxidation.

Most gases burn, due to their ready combination with the oxygen in the air, in the presence of a flame. Hydrocarbons such as the methane in natural gas are eager to combine with oxygen, and burn quite well. After a tinsmith in Fredonia, New York in 1825 first observed bubbles forming in a creek, and decided to drill a well and sell the gas, the commercialization of natural gas as a fuel source took off.

So, what was the difference between these highly flammable natural gases, and the strange Dexter gas that refused to burn?

Return to Dexter

Using an air compressor and liquifier, the University of Kansas chemists were able to separate out the different gases. They found that it was only 15 percent methane, which was rendered non-flammable by 72 percent nitrogen. Along with the non-burning nitrogen was another 12 percent of a mysteriously "inert residue," out of which they were able to isolate, to their utter amazement—helium.

Helium wasn't supposed to be found in the Earth. At least not in the large quantities they had just discovered beneath the Great Plains. It was the Sun element, named from the Greek word for Sun—*helios*, where it was first observed, spectroscopically. Although it was quite a surprise to find helium on Earth, it was utterly useless as a fuel source since it did not burn, and for years, the entire U.S. supply of helium sat in three glass vials on a shelf at the University of Kansas.

Helium wouldn't burn, yet it was found in the Sun. Was the Sun not burning?

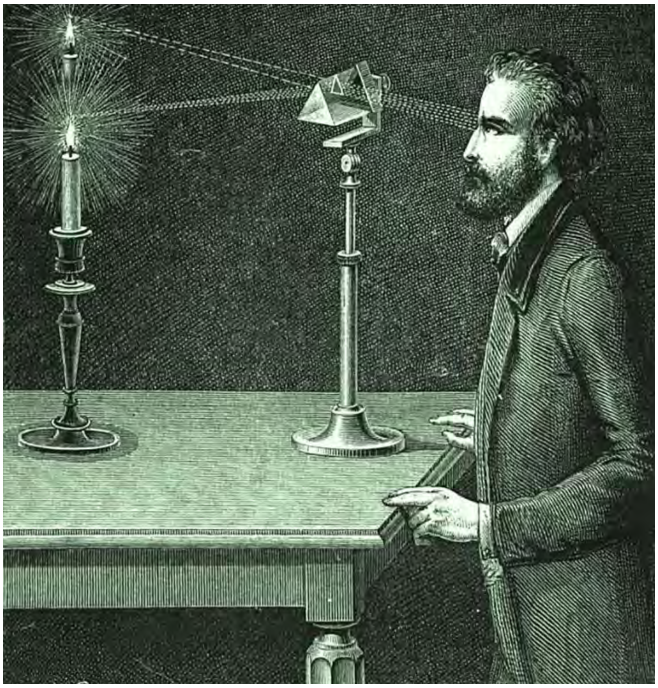
Helium was famous for being the first extraterrestrial element ever discovered. After the German physicist Gustav Kirchhoff figured out, in 1859, how to determine the chemical composition of stars by analyzing their light, astronomers eagerly anticipated the next total solar eclipse, so that they could analyze solar prominences. That opportunity came in 1868. French astronomer Pierre Jules César Janssen traveled to India with his spectroscope, and waited for the Moon to perfectly match the circumference of the Sun, blocking out the light of the bright orb, and leaving visible the protruding solar prominences.

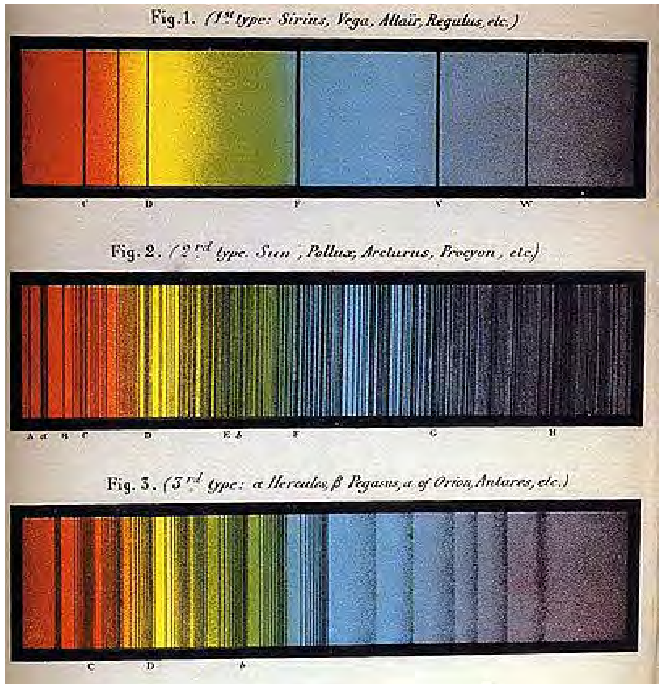
Janssen observed a distinct yellow line in his spectroscope that was similar to the signature of sodium. Other scientists on the scene wrote it off as merely sodium, but Janssen thought it was a new element.

Meanwhile, in England, the English astronomer Joseph Norman Lockyer had figured out how to observe solar prominences in regular sunlight, and had also observed the bright yellow spectral line of the new element. Even though these two scientists, working independently,

4. Lavoisier named *oxygen* from Greek words meaning "acid maker." In the preface to his famous *Elements of Chemistry*, Lavoisier credits his advances in the science to his intention to improve chemical nomenclature:

"Thus, while I thought myself employed only in forming a nomenclature, and while I proposed to myself nothing more than to improve the chemical language, my work transformed itself by degrees, without my being able to prevent it, into a treatise upon the elements of chemistry. The impossibility of separating the nomenclature of a science from the science itself, is owing to this, that every branch of physical science must consist of three things: the series of facts which are the objects of the science; the ideas which represent these facts; and the words by which these ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea, and the idea to be a picture of the fact. And, as ideas are preserved and communicated by means of words, it necessarily follows, that we cannot improve the language of any science, without at the same time improving the science itself; neither can we, on the other hand, improve a science, without improving the language or nomenclature which belongs to it. However certain the facts of any science may be, and however just the ideas we may have formed of these facts, we can only communicate false or imperfect impressions of these ideas to others, while we want words by which they may be properly expressed."





The spectroscope uses a prism to bend, or refract white light, which is made up of many different colors of light. Each color of light represents a unique wavelength and bends at a different angle, and the light spreads out, divided by color, into a broad rainbow. Joseph von Fraunhofer (1787-1826), a German telescope lens maker, used candle light to focus his lenses. A properly focused lens would not have a prismatic effect that spread the light out into distinct colors. One day, he used sunlight to focus his lenses, instead of a candle, and noticed some strange black lines in the spectrum. He figured out that the different lines represented different elements that were in the Sun. The black lines indicated certain wavelengths of light that were being absorbed by certain elements. Each element would absorb a series of wavelengths, which formed a pattern–a characteristic signature for each element. Depending on how this spectrum is observed, either a continuous spectrum of light can be seen, with breaks of black lines, where certain frequencies are absorbed, or the inverse–only lines of color, where those same frequencies are emitted.

5,000 miles apart, had come to the same conclusion, and were able to register their discoveries on the very same day at the French Academy of Sciences, they received little acclaim. The spectral results could not be reproduced in a lab, and no one believed that this new alien element existed.

They would not receive due credit until almost 30 years later, when helium would, again, emerge in a very mysterious process.

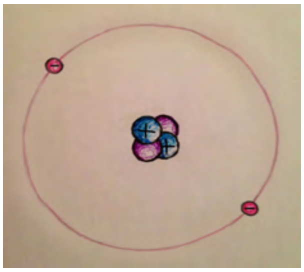
Alpha Particles

Marie and Pierre Curie spent endless hours investigating the strange properties of certain minerals that emitted a new form of energy. Henri Becquerel had previously found that uranium salts radiate a type of invisible light that can expose photographic plates. Marie Curie experimented with different compounds of uranium and thorium and noticed that no matter what type of minerals these special elements were found in, they all emitted the radiation in the same way.

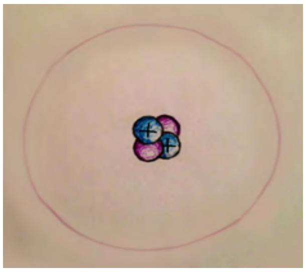
This did not fit the proper behavior of chemistry. Compounds of the same element often possess very different chemical properties. For example, one compound of uranium can be a dull black powder, while another can be a clear yellow crystal that glows green. Marie Curie found that the only thing that affected the amount of radiation emitted was the amount of uranium or thorium that the compound contained. She thus reasoned that this radiation was not the result of a *chemical* property, i.e., an effect of the different atoms' structural arrangement and relationship between each other. She hypothesized that radiation must originate from *inside the atom itself*.

After discovering radium, which was one million times more radioactive than uranium, the Curies put radioactivity to the test, poking and prodding these elements to figure out the nature of this new energy. The influence of a magnetic field revealed that the radiation was composed of different types of rays, some of which were affected by magnetism. When physicist Ernest Rutherford repeated the experiment, using an even stronger magnetic field, he was able to find three distinct rays.

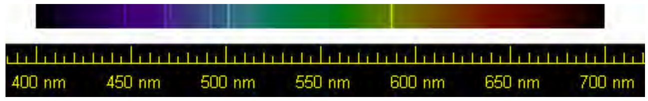
The first type of rays were clearly and narrowly bent. The second type were more strongly bent and spread out



Model of a helium-4 atom.



Doubly ionized helium-4.



Helium emission spectrum.

in a broad band. The third type was not affected at all by the magnet, and kept on its straight and narrow course. These rays were called alpha, beta, and gamma rays, respectively. Alpha were electrically positive, beta negative, and gamma neutral.[5] Rutherford found that the beta rays were electrons, and the alpha rays were a stream of oppositely charged, much heavier particles. Based on their weight and charge, he hypothesized that alpha particles were doubly ionized helium atoms—i.e., they were helium atoms which had lost both of their electrons, leaving no electrons, and only a bare, positively charged nucleus.

This hypothesis was corroborated by the then-recent discovery that most radioactive mineral ores contained helium atoms.

In 1895, the Scottish chemist William Ramsay heard that a Norwegian mineral called cleveite[6] emitted a gas similar to nitrogen when it was heated. Having discovered argon the year before, which had also been mistaken for nitrogen by other scientists,[7] Ramsay decided to treat the cleveite with sulfuric acid, to find out if argon would be liberated from it. When he examined the gas, Ramsay was so surprised by the bright yellow line that appeared on his spectroscope, that he thought he must be misreading it, and proceeded to clean his instrument. He then sent the gaseous emanation to Lockyer to identify. It was not argon, but a new terrestrial element, which matched the same yellow signature of Janssen and Lockyer's alleged Sun element, helium.

5. See "The Nuclear Era: Man Controls the Atom" in this report.

6. Cleveite is a radioactive variety of uraninite, with composition UO_2, where about 10% of the uranium is replaced by rare earth elements.

7. In 1892, Lord Rayleigh could not make sense of the very slight discrepancies in his measurements of nitrogen in the air, and wrote a plea to other scientists in *Nature*: "I am much puzzled by some recent results as to the density of nitrogen, and shall be obliged if any of your chemical readers can offer suggestions as to the cause." Mendeleev's periodic table had been established in 1869, and there were no empty spaces for an element of this type. William Ramsay made the bold hypothesis that there might be a whole new *family* of elements, and that the discrepancy was due to a heavier element of this new family, hidden in the air. He was correct. His discovery of argon was the first element of a new column of inert elements—the noble gases.
Lord Rayleigh, "Density of Nitrogen," *Nature* 46, 512 (1892).

How strange that a substance that did not form molecules could be found inside so many minerals.[8] How did it get inside these minerals, if it does not like to bond with anything? Why was this chemically useless element found in radioactive minerals? Was the Sun somehow implanting radiation in rocks?

William Ramsay and Frederick Soddy observed the radioactive gases with a spectroscope over time to see if they could figure out the nature of the transformations occurring.

They collected gaseous emanations from radium, and sealed them in a tube, through which a current was passed. The gas emitted light, whose spectrum they could observe, and to their surprise, over time, the spectral lines changed. The lines of radium emanation glowed with less intensity, and as they faded, a new bright yellow one emerged. The radium emanation was actually being transformed into another element. Helium was being created from radium. This confirmed Marie Curie's hypothesis, that this was not a chemical process, but a change occurring, inside the atom, on a nuclear level—i.e., the generation of new elements came out of the transformation of the atomic nucleus.

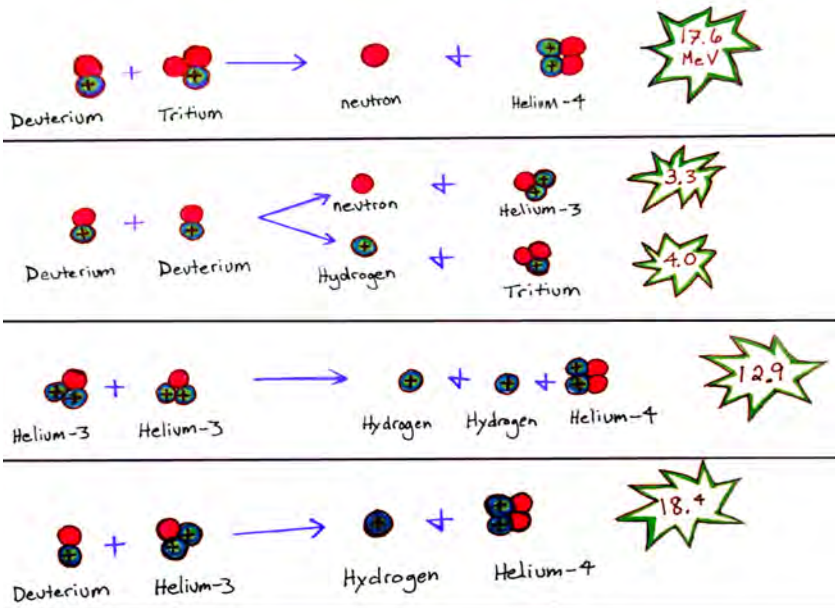
Helium would not partake in chemical reactions because it had a different identity—an identity as a future artifact of the nuclear era, and beyond.

Beyond Chemistry

This odorless, colorless, tasteless, chemically worthless lighter-than-air element was useless before the advent of modern science. But as we made the societal advances that allowed for the development of the native resources of the mind, the inherent qualities of this element would begin to manifest themselves.

The belief that helium was an extraterrestrial element was more prescient than those nineteenth-century astronomers—who named it after the Sun—understood at the time.

8. Helium does not form molecules, burn, or chemically react with other elements because it does not share outer electrons with other atoms. The sharing of outer electrons is what constitutes chemical change. Helium only has two valence electrons, which is considered a full, stable shell, and it is not inclined to share.



Four different fusion reactions, involving deuterium (D), tritium (T) and helium-3 as fuels. Output products are shown, along with energy released per reaction, expressed in MeV. The D-D reaction has two possible outputs. Neutrons cannot be affected by a magnetic field, although the other (charged) particles can. Helium-3 fuel makes it possible to have reactions without neutrons. Note that combining D and He-3 fuel will also result in D-D fusions, and will therefore produce some neutrons.

This second most abundant element in the universe, which escaped our grasp until almost the twentieth century, also almost escaped from the planet, until legislation was introduced in 1958 to capture and conserve it. The helium that is created from the radioactive decay of heavy elements deep in the earth's crust makes its way out of the ground, and being lighter than air, has nothing to keep it in the atmosphere, so it escapes into space. That recognition, scientifically and politically, would allow helium to take us off the Earth,[9] and all the way to the Moon. Its very low freezing point would make it the only thing that could be used as a refrigerant for liquid oxygen and hydrogen rocket fuels. During the Apollo program, helium would determine how long the astronauts could stay on the Moon. Once the helium had boiled away, there would have been nothing left to keep the return fuel in liquid form, and the spacecraft would have been stranded.

It would continue to prove its worth in advanced technologies due to its ability to be cooled almost to absolute zero while still remaining a liquid,[10] and is therefore used for superconducting magnet technology, magnetic resonance imaging, and advanced cryogenic research.[11]

But helium has an even nobler mission in advanced sciences—and the future of human civilization—that is yet to be met. The even more extraterrestrial identity of helium's special isotope, helium-3 will be vital for helping us achieve our own extraterrestrial imperative.[12]

Helium-3 Fusion: A New Type of Energy

The hidden potential of this ethereal isotope currently resides in a domain beyond the chemical, beyond nuclear fission and beyond even many nuclear fusion reactions. Fusion reactions involving helium-3 are considered advanced, third generation reactions due to the relative difficulty in achieving them with current magnetic confinement technologies. Helium-3 fusion reactions are truly advanced due to the qualitative power increase that they represent, compared to all other current forms of energy production.

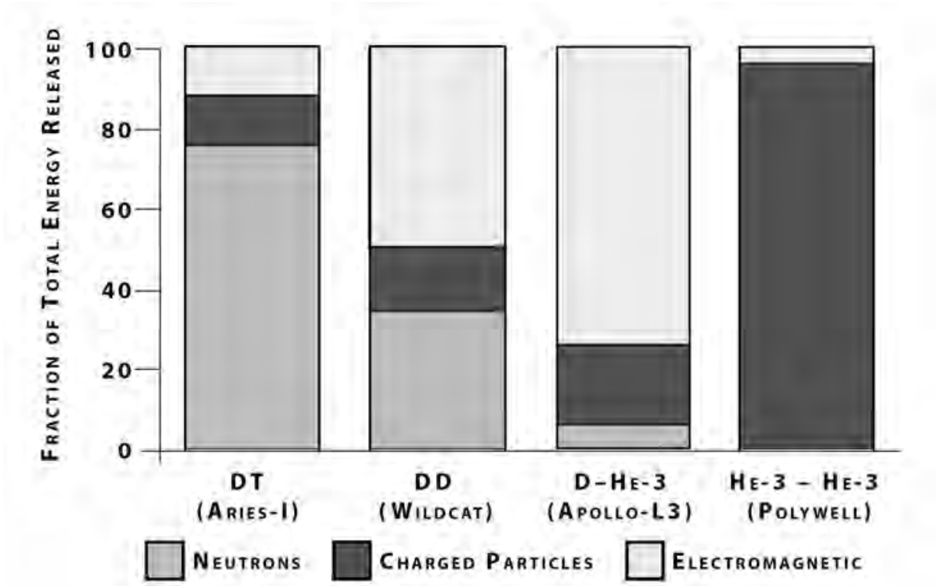
Since the modern era of electricity production began with the advent of the steam powered turbine in 1884, the primary source of energy has been based on rotary motion to drive an electrical generator. Today, approximately 90% of all electricity generation in the United States is by use of a steam turbine. Each successive stage of higher energy-flux density fuel sources—coal, natural gas, nuclear fission, and nuclear fusion—represent advances in the potential of that fuel, as measured in the relative quantity of the material to its energy output. Although the density of energy innate to each of these fuel sources is different, the *type* of energy generated remains the same: heat. In each of these processes, we are merely using a

9. Its lighter-than-air, non-flammable properties would make it a key resource to the U.S. Navy during WWII for its use in surveillance blimps to detect German submarines. The Germans' lack of helium forced them to use highly flammable hydrogen in the unfortunate *Hindenburg*.

10. Helium boils at 4.22 Kelvin or –452 degrees Fahrenheit.

11. Helium-4 also has a very strange "quantum state," that defies the laws of classical physics. Once it reaches a special liquid state at 4.2 K, it gains properties such as zero viscosity, which allows it to literally crawl up walls, and imitate the properties of sound. What new principles lie dormant, awaiting us to uncover them? What future potential does this hint at? See Alfred Leitner's 1963 video demonstrating these properties at alfredleitner.com

12. German rocket propulsion engineer and space pioneer Krafft Ehricke (1917–1984) believed that human creativity possessed no limits, and that as a uniquely creative species we have an "extraterrestrial imperative" to explore and develop space in order for the species—and that creative quality—to progress.



Adapted from: Kulcinski, G.L. and Schmitt, "Nuclear Power Without Radioactive Waste—The Promise of Lunar Helium-3" (2000)

Fusion reactions release energy, and that energy can come in three forms: the motion of neutrons, the motion of charged particles, and in electromagnetic radiation (forms of light). This diagram indicates energy release breakdowns for several proposed fusion designs.

different fuel source to generate energy of motion (kinetic energy), which heats up water to create steam, to spin a turbine in a magnetic field, to induce an electric current.

Helium-3 fusion reactors offer the potential to liberate us from this 130-year old technology, and move us into the next era.

When the nuclei of light atoms are forced together in the process of controlled thermonuclear fusion, they make different products. Among those products can be positively charged particles, neutral particles, and different types of electromagnetic radiation. These charged particles, neutrons, and photons serve different purposes for energy production.

A *first generation* fusion reaction involves two isotopes of hydrogen—deuterium and tritium (DT). When these isotopes fuse, the reaction creates 80% neutrons, along with photons and some charged helium nuclei (alpha particles). The energy from this reaction is taken from the kinetic motion of the high-energy neutrons. Although the energy density of this fusion fuel is higher than in fission reactions, the same physical process is at play. High energy neutrons create heat, which must be converted into electricity. Furthermore, because neutrons are neutral,i.e., they have no charge, they do not respond to a magnetic field, and are thus very hard to control. These factors, combined, give the DT reaction an electrical conversion efficiency of 45%, not much better than a fission reaction (40%), or any heat-based form of electrical energy for that matter.

A *second generation* reaction, using helium-3 and deuterium, generates very different fusion products. In this case, depending on factors such as plasma temperature and the ratio of helium-3 to deuterium, hardly any neutrons (1-5%) will be produced, and the majority of the products will be in the form of charged particles (protons and alpha particles) and photons. Instead of having to convert the heat generated from neutrons into electricity, the charged particles and electromagnetic radiation are directly converted to electricity. Direct conversion methods yield efficiencies of 60-70%.

The main advantages of these products, as opposed to neutrons,[13] is the greater ease in directly converting them to electricity, and the fact that charged particles *do* respond to a magnetic field, and can thus be efficiently controlled and directed.[14]

Magnetohydrodynamics is one method for using this flow of charged particles to generate electricity directly. A moving charge under the influence of a magnetic field, will be deflected. By passing a charged particle plasma (which conducts current) through a magnetic field, the charge is deflected to one side by the magnetic field, creating a potential difference and the flow of current.

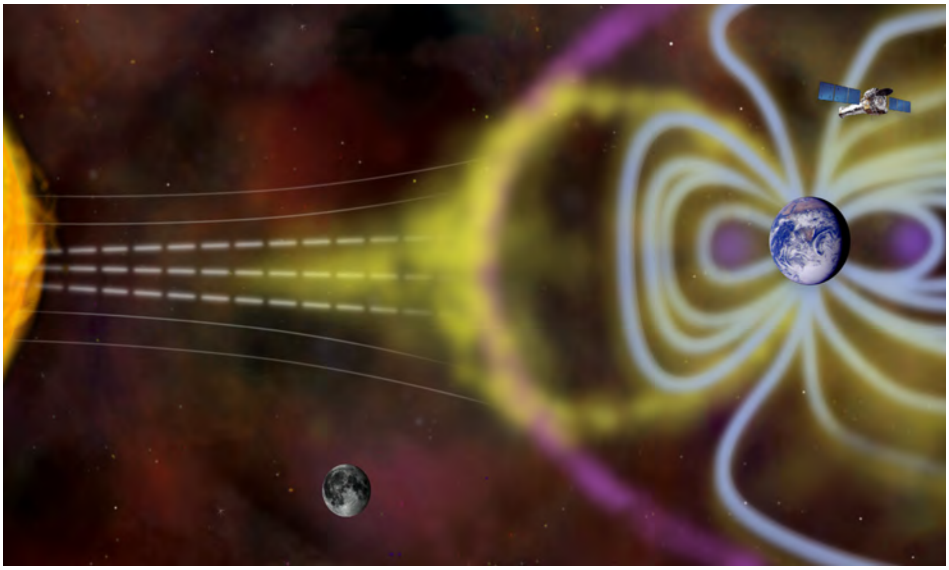
Electrostatic direct conversion makes electricity by creating voltage—the electrical potential difference between two points—from the motion of the charged par-

13. It should be noted that neutrons are not inherently bad things. They can be very useful for certain purposes, such as the production of life-saving medical isotopes, or for explosive detection technologies. In a process such as desalination, where heat may be used for evaporation, we may prefer a neutron-producing fusion or fission process that can both generate electricity, while using waste heat for the desalination process.

14. While first generation DT reactions are thus classified because they are considered the easiest to achieve in terms of the temperature, pressure and confinement times required for magnetic confinement fusion, this practical approach (often a response to budget cuts and bad economic policy) may not be the fastest way to achieve commercial fusion, after all. A side effect of using an aneutronic helium-3 reaction is that we will avoid the extra engineering, maintenance and fuel-processing challenges that come with the nuclear radiation of DT reactions. We will not have to deal with the high-energy, out-of-control neutrons that wreak havoc on reactor walls and other metallic components, and require radiation shielding and cooling towers. By eliminating the time and expenses required to develop these materials, we may concentrate our resources on plasma physics.

ticles. While a particle accelerator uses voltage differences to induce motion in particles, this process works in reverse, using the motion of the charged particles created by the fusion reaction to drive the voltage. In effect, the charged particle is slowed electrostatically, during which process it drives a current.

An advantage of electromagnetic products is that this radiative energy can be tuned to make use of specific wavelengths. Microwaves, gamma rays and X-rays may be selected and used for various applications aside from electricity. There are also methods for converting radiative energy into electricity.



Artist's vision of the Earth's magnetic field, protecting our planet from the charged particles in solar wind, while the exposed Moon is subject to the full brunt of solar emissions, including the beneficial fuel helium-3.

One method uses a rectifying antenna called a "rectenna" to convert microwave energy into direct current electricity. The inventor of this device, William C. Brown reported to NASA's Second Beamed Space-Power Workshop in 1989 that he had demonstrated an 85% electricity conversion efficiency.[15]

A *third generation* fusion reaction uses helium-3 as both agents in the reaction. In an electrostatic device,[16] 99% of the resulting energy is in charged particles, which can be directly converted into electricity, yielding an electrical conversion efficiency of 70-80%. There are no neutrons or radioactivity produced in a He-3–He-3 reaction.[17]

Finding Helium-3

When fusion scientists at the University of Wisconsin's Fusion Technology Institute realized the value of helium-3 for nuclear fusion reactions, they wondered where it could be obtained. Unlike the regular helium-4, which was discovered to be common by the Kansas chemists, helium-3 was still believed to be quite rare—at least on Earth. Then, they remembered that the Sun, a giant nuclear fusion reactor, was pumping out quite a bit of helium-3, as a product of fusing hydrogen. The Sun spews out helium-3 along with other charged particles and plasma into the solar system, in the form of solar wind and coronal mass ejections. On Earth, we're largely shielded by an atmosphere and a strong magnetic field. But our less fortunate Moon is completely exposed to all of the Sun's tantrums. The Wisconsin fusion scientists made the hypothesis that helium-3 could be found on the Moon. In 1986, they made a trip down to NASA's Johnson Space Center in Houston, to scour the records of Apollo lunar samples.

Indeed, records showed helium-3 to be present in every lunar sample.

Lunar scientists whom they queried about the rare isotope were puzzled. They said that they had known since 1970 that there was an abundance of helium-3 on the Moon, but were not aware that it was useful for anything. Of course, it was not useful for anything in 1970, because the discovery of its vital importance as a fusion fuel had not yet been made. The helium-3 lunar samples had been destined to sit, useless, on shelves at NASA, as had the Dexter gas at the University of Kansas. And it will remain seated on the lunar shelves of our natural satellite, the Moon, until there is a significant breakthrough made here on Earth.

A serious step in that direction has been made by the Chinese with their December 14, 2013 landing of a spacecraft on the Moon. While we do not have full access to the plans of the Chinese, we do know something about their intentions, and the technical capabilities that have been made possible by the pioneering work of scientists at the Fusion Technology Institute of the University of Wisconsin, and the Department of Earth and Planetary Sciences, at the University of Tennessee, since the U.S last visited the Moon, in December 1972. Research-

15. Freeman, Marsha, "Mining Helium on the Moon to Power the Earth" *21st Century Science & Technology*, Summer 1990.

16. Kulcinski, G.L. and Schmitt, H.H., "Nuclear Power Without Radioactive Waste—The Promise of Lunar Helium-3," 2000.

17. Kulcinski, G.L. "Helium-3 Fusion Reactors—A Clean and Safe Source of Energy in the 21st Century," 1993.

ers found that the helium-3 is held very loosely in the dust on the surface of the moon and could be extracted relatively easily. Scientists at the Wisconsin Center for Space Automation and Robotics have designed vehicles to separate helium-3 from the lunar soil. If it is heated to 600-700°C, it can be released from the dust and re-cooled into a liquid during the cold lunar night. This can be done by concentrating solar energy with mirrors, or by using microwave energy, which has a very unique coupling effect with lunar soil, that allows it to be heated very efficiently with microwave energy. The potential reserves of helium-3 are estimated at one million tons, which could power the Earth in fusion reactors for 1,000 years. It also has been shown that there is ten times more energy in He-3 on the Moon than there ever was in fossil fuels (i.e., coal, oil, and gas) on the Earth. This fossil of the Sun is magnitudes more energy dense than any petroleum product, such that one shuttle load could supply the entire U.S. with electricity for one year.[18]

Chinese Moon goddess, Chang'e. Chinese President Xi Jinping, in a speech to space scientists and engineers who participated in the research and development of the Chang'e-3 mission, said that innovation in science and technology must be put in a "core position" in the country's overall development: "Dare to walk the unwalked paths. Constantly seek excellence through solving difficulties, and accelerate the shift to innovation-fueled development."

18. This was measured in 1988, when the U.S. still operated the Space Shuttle. Our electricity consumption is not much higher than 1988 terms, due to economic collapse, and the resulting reduction of industry.

The development of helium-3 fusion reactors on the Moon would give us a unique power for industrial and agricultural applications that could take advantage of the low gravity, near vacuum, extreme temperature changes, and other conditions. This is an ideal fuel for use on the Moon and other space applications, because it is available on site, and because the direct conversion to electricity mitigates any thermal losses.

For every ton of helium-3 extracted, there are 6,000 tons of hydrogen, 500 tons of nitrogen, 5,000 tons of carbon-containing molecules, and over 3,000 tons of the heavier helium-4 isotope, all of which will be extremely valuable for atmospheric control, life support, and chemical fuels during the construction of a lunar base.

Fusion rockets far exceed the energy-flux density of chemical rockets, allowing for much less fuel mass, and, crucially, making it possible to fly missions that simply could not be undertaken with chemical propulsion, such as one-week transit time to Mars (instead of many months), and an effective strategy for planetary defense.[19]

Among fusion fuels, helium-3 is by far the best, because the products of helium-3 fusion reactions are mostly charged particles, creating a magnetically controlled exhaust to propel the rocket. As stated by fusion scientist John Santarius, "Fusion will be to space propulsion what fission is to the submarine."

While the isotope helium-3 is much more rare on Earth than helium-4, we do have access to a small amount that could be used to build test facilities. Although using the natural helium-3 left over from the formation of the Earth would require extracting all natural gas in the planet, and would only yield 200 kg, there is another source. Both the United States and Russia have about 300 kg worth that could be collected from the radioactive decay of tritium in thermonuclear weapons. This would be more than enough to fuel test facilities to develop the proper fusion engineering to get us started.

How to Find Helium-3 on the Moon: A New Spectroscopy

In order to begin a proper mining expedition, we will need to create a map of the Moon, which shows the locations of the higher concentrations of helium-3. Unlike on Earth, where there are veins of ores which have been concentrated by efficiently active forms of life, the resources on the Moon are more diffuse. However, since it is the Sun that is implanting the helium-3, we can know that there will be more helium-3 in the places where the Sun has been able to reach more easily, i.e., the surface. This is a very fortunate situation, since it means we will

19. See the Planetary Defense issue of *21st Century Science & Technology*, Fall/Winter 2012–2013.

not have to embark on complex drilling missions deep below the surface of the Moon.[20] Because the Sun does not affect the Moon's surface uniformly, the distribution of helium-3 is also non-uniform. We can use this non-uniform behavior of the Sun to detect where there will be greater amounts of helium-3.

We can do this using gamma ray spectroscopy to detect when the Sun creates changes in the helium-3 that is embedded in the surface of the Moon. Researchers at the Fusion Technology Institute, propose to use very large solar proton flares, to take advantage of the increased flux of solar cosmic-ray–induced neutrons.[21] When neutrons from these solar flares reach the surface of the Moon, they can react with helium-3, and that reaction can be detected.

The difference between helium-3 and helium-4 is that fourth thing, the extra neutron. When helium-3 is bombarded with a neutron and is transformed into helium-4, a little burst of energy is produced, in the form of a gamma ray.[22]

Gamma rays also have signatures like the distinctly colored spectral lines characteristic of elements that can be seen with a spectroscope. These signatures depend on the amount of energy that the gamma ray has. The gamma ray that is produced from a reaction between a helium-3 atom and a neutron is a very specific energy—20.6 MeV—which is such a different value than that produced in other reactions, that it is not easily confused. While these reactions are infrequent, the specificity of that particular 20.6 MeV gamma ray can be uniquely detected. "We are essentially 'looking for a needle in a haystack.' Fortunately, it is a different colored needle."[23]

A gamma ray spectroscope can thus be used in a satellite orbiting the Moon, which will wait for these solar flares to instigate gamma-ray-releasing reactions with the helium-3. This is only one proposal for creating a map of the Moon to mine this necessary new resource. With the international Apollo crash program to develop fusion energy that must be implemented before this decade is out, there will be many more.

20. The mining of this new resource, helium-3—magnitudes more energy-dense than petroleum—will be far easier in this respect than oil beneath the ocean floors, which must use NASA space technology to carry out increasingly complicated missions.

21. Karris, K.R., H.Y. Khater, G.L. Kulcinski "Remote Sensing of Astrofuel" 1993, Wisconsin Center for Space Automation and Robotics.

22. Remember, these were the third type of rays (alpha, beta, gamma) observed by Rutherford and the Curies, that constituted radioactive emanations. Gamma rays were the very high energy, fast, penetrating rays that were not swayed by the magnetic field.

23. Karris, K.R., H.Y. Khater, G.L. Kulcinski "Remote Sensing of Astrofuel" 1993, Wisconsin Center for Space Automation and Robotics.

Conclusion

It is estimated that as a result of fusion processes for the past four billion years, the Sun is now composed of about one-third helium, and has only two-thirds left of its original hydrogen.

As the Sun converts that remaining two-thirds hydrogen into helium and implants it into the Moon for storage, it is gradually losing its ability to create fusion reactions, and therefore losing its power as our Sun. The remainder of our Sun's life is estimated at approximately two billion years, which should give us enough time to recreate its processes. Retrieving from the Moon these helium fossils of the Sun's short life, and employing them to venture out into a new planetary system, so that we may survive to extend our creative reach into new worlds, is not a mission that can be delayed.

We must ask again, what is the value of helium, or any resource? Do resources exist independently of the human mind, and of a culture and economy that has chosen to discover and make use of them? Is economic value really a function of money? Would all the money gained through the imperial wars of Zeus, from the Temple of Delphi to the present day, have been sufficient to build a helium-3 fusion reactor in those times, under those systems? Does our species have the collective moral intelligence at this moment to cast off the Zeusian shackles of our slow development and soar, before it is too late?

NASA

"China has made no secret of their interest in lunar Helium-3 fusion resources." Former astronaut, geologist and U.S. Senator, Harrison Schmitt is one of the leading proponents for the mining of helium-3 on the Moon. He was on the last Apollo mission to the Moon.