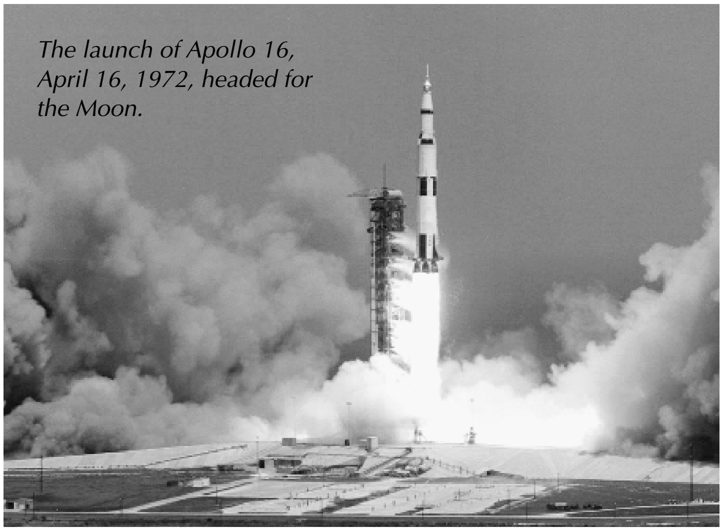


The launch of Apollo 16, April 16, 1972, headed for the Moon.

Apollo Project Archive

The technologies for creating and harnessing new "natural" resources are already known today. We need the political will to mobilize them now, for the benefit of mankind.

Nuclear Medicine Research Council

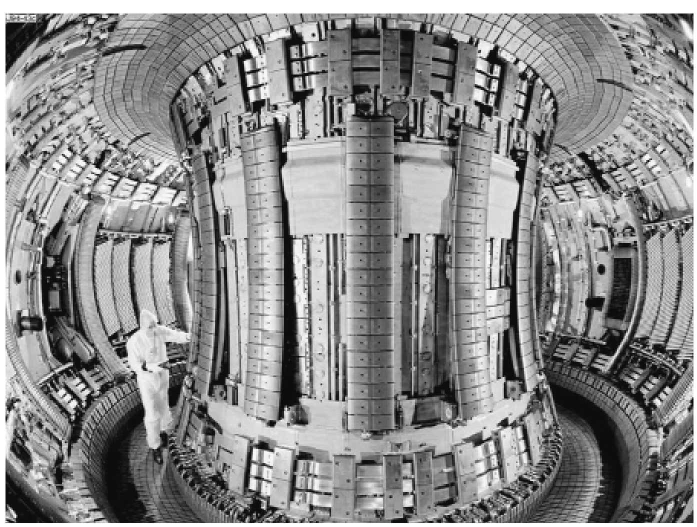
A robot manipulator holds a vial of yttrium-90, a radioactive isotope used in medicine. Although radioactive substances are used widely in medicine today, the United States must import 90 percent of its medical isotopes.

The Isotope Economy

by Dr. Jonathan Tennenbaum

South African Nuclear Energy Corporation

Technicians working with nuclear medicine radioisotopes in a hot cell.



EFDA-JET

A full-scale Isotope Economy will require the development of controlled thermonuclear fusion power. Here, the Joint European Torus (JET), an experimental reactor which produced over 16 megawatts of power in 1997.

Prologue

The subject of this essay is a crucial component of the economic mobilization which must be launched in the immediate future, if the world is to be saved from a physical and socio-political collapse of a severity comparable only, on a global scale, to what occurred in Europe in the period leading to the outbreak of the "Black Death" of the 14th Century. The essential problem, addressed here, is how to overcome the effects of the savage destruction of in-depth industrial and scientific-technological capabilities, and of the educational level, skills, and cognitive powers of the labor force, which has occurred in the major industrial nations of both the East and West under recent decades' policies of globalization, deregulation, privatization, "shock therapy," and "the postindustrial society."

Any serious program of economic mobilization and reconstruction, must take account of the fact, that the largest single, organically interconnected repository of highest-level scientific research, technological and advanced-technology manpower, and industrial capability on this planet, is located in and around the nuclear energy sectors of the United States, Russia, Ukraine, Japan, Germany, France, India, China, South Africa, Argentina, Brazil, and some others; and in areas of astrophysics, space technology, geology, and biomedicine, most closely linked to research and applications of nuclear physics. By the very nature of nuclear science, its roots and history, and the needs of the world over the coming 50 years, a mobilization of the world's nuclear sector, as a vanguard and locomotive for a generalized economic mobilization of the world's leading nations, must take a specific form. After discussions with Lyndon LaRouche, with S. Subbotin of the Kurchatov Institute, and F. Gareev at the Joint Institute for Nuclear Research in Dubna, I have chosen to call it the "Isotope Economy."

* * *

Approximately a century ago, it was experimentally demonstrated that the naturally occurring chemical elements, whose harmonic ordering Dmitri Mendeleyev embodied in his periodic system, were not homogenous bodies, but rather mixtures of distinct species of atoms—isotopes—having nearly identical chemical behavior, but profoundly different physical properties.[1] The investigation of this "new dimensionality" of the periodic system, and of the processes of transformation of atoms underlying it, led eventually to the discovery of fusion, fission, and other nuclear reactions, the realization of the first nuclear fission chain reaction, and the first atomic weapons, during World War II. The creation of those devices depended upon the separation of the pure isotope U-235 from naturally occurring uranium, and upon the artificial generation, in nuclear reactors, of the first several kilograms of plutonium-239: a species of atoms hitherto virtually absent from the Earth's natural environment.

Today, 60-odd years after the first man-made nuclear chain-reaction, large-scale production of power from nuclear fission reactions has become a reality in 30 countries. Approximately 3,000 different isotopes are known, most of them artificially generated, and more than 200 are presently in commercial use. Modern medical care, and countless other vital activities of modern society, would be unthinkable without the daily use of a hundred-odd radioactive isotopes, produced in nuclear reactors and particle accelerators. Meanwhile, the creation of nuclear weapons profoundly changed the face of history, shaping the entire era of the "Cold War" and creating a situation, where the launching of large-scale warfare, in the form known up to World War II, were practically tantamount to an act of suicide. Certainly, very few even among nominally highly educated persons today, are fully conscious of the extent to which our world has been shaped by the implications of what initially appeared as "infinitesimal" nuances in the behavior of chemical elements.

And yet, the implications of what was set in motion by the discovery of radioactivity and the isotopes, growing out of Mendeleyev's "Keplerian" understanding of the periodic system, go far, far beyond anything the world has seen up to now.

As Vladimir Vernadsky and others recognized already a century ago, the discovery of new dynamic principles, transcending the chemistry of the periodic system and closely bound up with the origins of our Solar System and the elements themselves, meant unleashing a fundamental revolution in all aspects of man's relationship to nature. Science had delivered into man's hands a new power: the power to generate a "fire" millions of times more concentrated than the chemical combustion processes, which had been a chief basis of human civilized existence since the legendary gift of Prometheus. A new power sufficient to send a large ship 20 times around the Earth on 55 kilograms of fuel; sufficient, in principle, to support a thriving human population many times larger than that existing today; but also a power to create, on Earth, physical conditions found otherwise only in stars and centers of galaxies; a power that opens the way, in the not-too-distant future, for the expansion of human activity throughout the inner regions of the Solar System, and eventually beyond.

Man's beginning mastery of the power to transmute chemical elements, and to create new states of matter, not previously existing on the Earth and perhaps not even in the universe as a whole, demonstrates once more, that we are living in the universe of Plato, not of Aristotle. This is a universe in which *processes are primary;* in which "nothing is permanent, but change itself," and in which, in dealing with such things as atoms and so-called elementary particles, we must constantly speak, not of a "this" but of a "thus" (as Plato wrote in the *Timaeus*—see below). More than in any previous "phase state" of man's physical economy, the emergence of what I am calling the "Isotope Economy" signifies a condition, in which social practice must necessarily be oriented to *true ideas:* to the discoverable, universal principles that govern change and development of the universe, and not primarily to objects of the senses. This means the end of empiricism and materialism.

Such a revolution has profound political implications. Its realization is plainly incompatible with further toleration of an irrational, oligarchical organization of society, in which essential decisions, concerning the future of nations and the fate of humanity as a whole, are subject to the whims of a tiny number of influential families, while the vast majority of humanity lives in ignorance and servitude. The revolution, proclaimed

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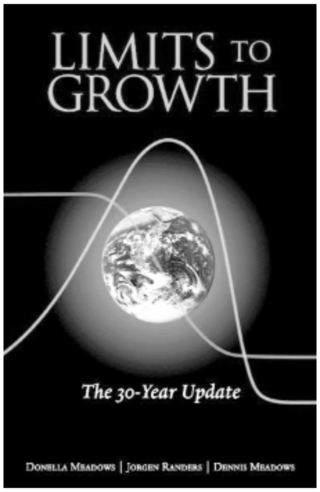
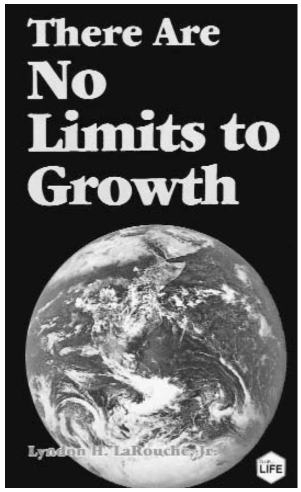
1. The sense of the distinction between "chemical" and "physical," referred to here, is historically specific and will become more clear as our discussion progresses. Briefly, the term "chemical" refers essentially to the circumscribed area of experimental and industrial practice which Mendeleyev (for example) dealt with in his influential textbook *General Chemistry.* There, elements are characterized, for example, in terms of the array of compounds they participated in, their mutual affinities and valences, and the geometrical type of crystals they form. Those properties turn out to be essentially identical for atoms belonging to the isotopes of one and the same element. "Physical" refers to all characteristics without restriction. In the historical context of the process leading to the discovery of isotopes, this meant above all the then-anomalous phenomenon of radioactivity, which fell outside the domain of "chemistry" as then understood.

Nowadays, textbooks generally try to "objectify" the distinction, by attributing the "chemical" properties to the structure of the electron shells of the corresponding atoms, and the differences between isotopes of a given element to differences in the composition of their nuclei. However, as we shall see later in this article, the attempt to treat the electron and nuclear structures as if there were hermetically separated worlds, introduces a crippling fallacy.





Since the mid-1960s, there has been an all-out assault against the very notion of scientific and technological progress. The Club of Rome's 1972 book Limits to Growth *(at left, in a new edition), was highly influential in the battle for population reduction. The LaRouche movement countered the Club of Rome with a pamphlet widely circulated on college campuses, and later with a 1983 book (right) by Lyndon H. LaRouche, Jr.*

by Vernadsky as the coming of the Noösphere,[2] and which he saw as inseparable from a coming era of nuclear power, means a society living the Promethean self-conception of man; it means a society whose activity would revolve around the principle of creative scientific discovery, like the planets around our Sun. It means a highly educated population, capable of deliberative self-government, and organized on the basis of a scientific understanding of the dynamic relationship between the sovereign creative individual, the sovereign nation, and the interests of humanity as a whole.

In a word, the image of society that Leibniz and the "American Prometheus" Benjamin Franklin had in mind, in the original design for a republic in the New World. This view of mankind's future inspired the enormous optimism that people all over the world attached to nuclear energy—"the atom in the service of man"—in East and West, North and South.

The Olympians' War Against Progress

The response to this challenge, from the oligarchical would-be "Gods of Olympus," was explicit and savage. From the mid-1960s on, an all-out psychological and political war was unleashed against the institutions of industrial society and against the very notion of scientific and technological progress. The assault, focussing on the United States, Britain, and Western continental Europe, was loudly proclaimed in advance by Bertrand Russell and his circles, and executed by leading Anglo-American financial institutions and intelligence agencies close to the British monarchy and to oligarchical circles on the European continent. It lay at the origin of the orchestrated spread of the rock-drug-sex youth "counterculture," the New Left movement, the 1968 student revolution, the Malthusian propaganda of the Club of Rome's *Limits to Growth,* and the "Green" environmentalist movement worldwide.

These forces chose *nuclear power,* the clearest embodiment of scientific and technological progress, and the single most crucial technology for world development in the postwar period, as a main focus of their assault. Parallel with the buildup of the anti-nuclear scare campaign, institutional measures were enacted to stop the spread and development of nuclear energy worldwide: The Administration of Jimmy Carter initiated a 180-degree reversal of President Eisenhower's wise "Atoms for Peace" policy. It attempted to impose a virtual moratorium on nuclear exports to developing countries under the pretext of "nonproliferation," worked to dismantle the in-depth nuclear research capabilities of the United States itself, and to delay or halt, if possible, the realization of controlled fusion as a power source of the future.

The ambitious nuclear power programs of developing countries such as Brazil, Argentina, Mexico, and others, and the kinds of North-South cooperation exemplified by the long-term German-Brazilian nuclear agreement, were crushed by the opposition of the Carter Administration and its successors. Amidst the mass-media-orchestrated anti-nuclear hysteria of the 1980s, the nuclear program of Germany, once world leader in export and technology-transfer of nuclear technology, was shut down, along with the smaller, but qualitatively significant programs of Sweden, Italy, and a number of other nations. With the collapse of the Soviet Union and the subsequent, savage looting and destruction of the scientific-technological and industrial capacities of that nation, the single largest nuclear sector in the world outside the United States nearly went out of existence, only to be partly revived in the most recent period.

All of this destruction, and more, was already promised to the world by Bertrand Russell in his vehemently anti-science tracts during the 1940s and 1950s. Russell went so far, in 1946, as to propose dropping nuclear bombs on the Soviet Union, in case the Soviets refused to submit to a world government having an absolute monopoly on nuclear technology. Russell's essential argument—that the existence of truly sovereign nations was "too dangerous" to be tolerated in an age of nuclear weapons—remains the basis for the use of so-called "nonproliferation" as a pretext for denying the right of all nations and peoples to full and unhindered use of the fruits of scientific and technological progress. It remains the basis for a de facto regime of "technological apartheid," directed above all against the majority of humanity living in the so-called Third World.

But the oligarchical attempts to snuff out the nuclear revolution began long before the discovery of fission in 1934-1938. They revealed themselves in the orchestrated persecution of Marie Curie in France, in the bitter opposition to Max Planck's discovery at the turn of the century, and in the mafioso-like, bullying behavior of Niels Bohr and others toward Schrödinger and Einstein at the 1927 Solvay

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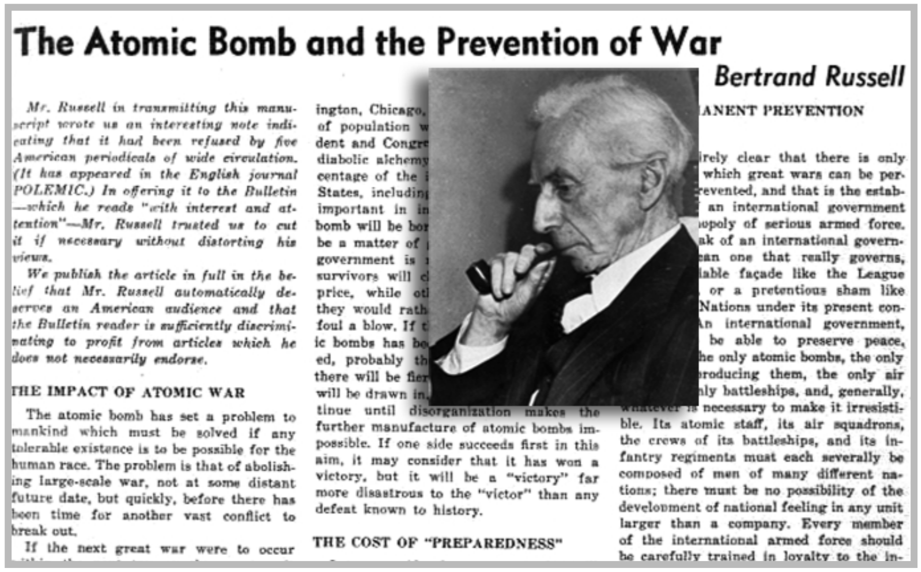
2. See Vladimir Vernadsky, "The Biosphere and the Noösphere," excerpted in *Executive Intelligence Review,* Feb. 18, 2005, http://www.larouchepub.com/eiw/private/2005/2005_1_9/2005_7/pdf/30_33_7_featnoosphere.pdf
See also, the book review of Vernadsky's "Essays on Geochemistry" by William Jones, *Executive Intelligence Review,* June 16, 2006, http://www.larouchepub.com/other/2006/book_reviews/3324_vernadsky.html.



The Atomic Bomb and the Prevention of War

Bertrand Russell

Mr. Russell in transmitting this manuscript wrote us an interesting note indicating that it had been refused by five American periodicals of wide circulation. (It has appeared in the English journal POLEMIC.) In offering it to the Bulletin—which he reads "with interest and attention"—Mr. Russell trusted us to cut it if necessary without distorting his views.

We publish the article in full in the belief that Mr. Russell automatically deserves an American audience and that the Bulletin reader is sufficiently discriminating to profit from articles which he does not necessarily endorse.

THE IMPACT OF ATOMIC WAR

The atomic bomb has set a problem to mankind which must be solved if any tolerable existence is to be possible for the human race. The problem is that of abolishing large-scale war, not at some distant future date, but quickly, before there has been time for another vast conflict to break out.

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tinue until disorganization makes the further manufacture of atomic bombs impossible. If one side succeeds first in this aim, it may consider that it has won a victory, but it will be a "victory" far more disastrous to the "victor" than any defeat known to history.

THE COST OF "PREPAREDNESS"

ANENT PREVENTION

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An international government,
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nly battleships, and, generally,
is necessary to make it irresistible. Its atomic staff, its air squadrons, the crews of its battleships, and its infantry regiments must each severally be composed of men of many different nations; there must be no possibility of the development of national feeling in any unit larger than a company. Every member of the international armed force should be carefully trained in loyalty to the in-

Bertrand Russell's infamous call for nuclear war against the Soviet Union was published in The Bulletin of the Atomic Scientists, *Oct. 1, 1946. If war were to take place soon, before Russia gains nuclear weapons, he wrote ,America would surely win, "and American victory would no doubt lead to a world government under the hegemony of the United States—a result which, for my part, I should welcome with enthusiasm."*

Conference. Bohr et al. explicitly forbade any kind of thinking which conflicted with the chosen occult-empiricist doctrine of "complementarity" and with the claim, that microphysical processes are intrinsically statistical-indeterminate in character.

In opposition to Einstein, Schrödinger, and others, who sought to conceptualize the *higher principle* underlying the apparently *discontinuous character* of quantum phenomena, Bohr, Max Born, Wolfgang Pauli et al. arbitrarily asserted that reality on the microphysical scale is *intrinsically* beyond the conceptual powers of the human mind! This explicit, savage attack on the principle of scientific creativity, backed up by the growing oligarchical takeover of the financing of scientific research, especially in the wake of World War I, served the obvious underlying purpose, to break what remained of the Promethean spirit of physical science, reawakened during the Renaissance, and to enslave science to the oligarchical agenda. Insofar as the fruits of scientific research were needed, for military and other "practical" purposes, scientists would be allowed to work; but they would not be allowed to think in a truly creative way. This repeated the tactic that had once deployed Laplace et al. to crush the circles of Monge and Carnot, and convert the Promethean École Polytechnique into a tool of Napoleon's imperial drive.

In the sequel, theoretical nuclear physics was elaborated, in the hands of a "kindergarten" of admittedly very brilliant and capable young scientists, into what it still largely remains today: a Ptolemaic mixture of mutually contradictory models, mathematical formalisms, and calculational procedures, that can be extremely useful and even indispensable in certain specific domains of application—such as building bombs!—but embody no intelligible conception of the universe. It is not surprising, that in the stormy developments leading to the discovery of nuclear fission, so-called "theory" lagged far behind the experimental work, which was the real "driver" of development. The discovery of fission was itself held back for four years, because this process was regarded by the theorists as "impossible."[3] The subsequent rapid development of nuclear physics and technology, from the wartime bomb projects, up to and including the realization of civilian nuclear power and the vast complex of medical and other applications of

Masked terrorists assault a nuclear plant in Germany in 1986. The anti-nuclear hysteria succeeded in shutting down Germany's nuclear program; Germany was once the world's leader in the export of nuclear technology.

3. See my article "How Nuclear Fission Was Really Discovered," *21st Century*, Spring 1991.

isotopes, was driven forward largely by people who were trained in the tradition of physical chemistry, geochemistry, and related industrially oriented fields of natural science. These people, exemplified by William Harkins, the Noddacks, or Vernadsky, often despised the mathematical sophistry of theoreticians who had been elevated to the stature of "high priests of science."

But the state of nuclear physics today is no less a product of the enormous external pressures imposed on science, and on many of the most brilliant scientists in the context of the wartime atom bomb projects and the ensuing Cold War. The subservience to military aims, of some of the most revolutionary areas of fundamental research in the physical sciences, and the imposition of strict regimes of secrecy, both in the West and East, preventing the free exchange of scientific ideas and experimental results, were virtually unprecedented in the millennia-long history of science. These circumstances had a devastating effect upon the intellectual integrity of many among the most brilliant scientists, and upon the organic development of science as a whole. Although the military relevance of advanced scientific areas such as nuclear physics, caused enormous resources to be devoted to their pursuit, the managed environment within which many scientists worked, became a powerful barrier to fundamental scientific progress.

Courtesy of Robert J. Moon

Chemist William Draper Harkins, who taught at the University of Chicago, was trained in industrially oriented fields of natural science and despised the mathematical sophistry of the science establishment. In the 1920s and early 1930s, Harkins investigated the relationships of the isotopes.

This was no mere incidental side-effect. Under the strategic policies promoted initially by Russell, Leo Szilard, and others—which later became known as the "balance of nuclear terror" and "Mutually Assured Destruction (MAD)"—the *suppression of fundamental breakthroughs* became more and more a *deliberate feature* of the management of scientific research. The essential argument of the Russell faction was, that once the United States and Soviet Union possessed sufficient numbers of nuclear warheads and delivery systems to inflict catastrophic damage on the other side, even after having suffered a first strike, a certain "stability" in the form of mutual deterrence had been achieved, which should not be disturbed at any cost. Accordingly, both sides should agree, not to pursue certain directions of research and development that might overturn the rules of the game. This had as a necessary consequence, however, that the *very possibility of fundamental scientific revolutions, would be seen, increasingly, as a potential threat to the strategic balance, and thereby to national security!*

Chaining Prometheus

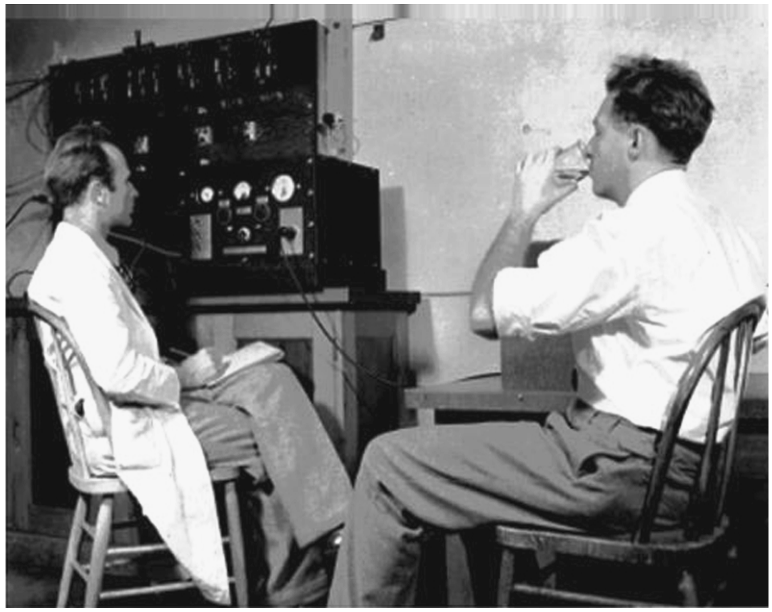
The view, that Prometheus had to be chained down in the interests of preserving strategic stability, was institutionalized in certain understandings reached between the U.S. and Soviet governments, through Bertrand Russell's Pugwash Conferences and other "back channels," going back to the post-1957 Khrushchov period, and later exemplified by the ABM Treaty negotiated under Henry Kissinger. Superpower competition was thereby supposed to be limited to a narrow range of "permitted" directions—with a certain amount of cheating on both sides, of course—while at the same time the two sides cooperated to prevent any third country from developing "dangerous" scientific and technological capabilities. The active suppression of fundamental scientific breakthroughs, through bureaucratic and other means, applied not only to nuclear physics and areas directly connected with nuclear weapons, their delivery systems, and possible means of defense against them, but also to revolutionary areas in biophysics (bioelectromagnetism) and many other fields of science.

These U.S.-Soviet government understandings shaped world events for the entire period up to the collapse of the Soviet Union. Their effects even reached into school classrooms. They cleared the way, for example, for the 1960s liberal educational reforms in the United States and other NATO countries, which degraded the role of "hard physical science" in general education, in favor of the so-called social sciences, and for the subsequent assault upon the concept of scientific and technological progress. With the founding of the International Institute for Applied Systems Analysis (IIASA) as a joint project of top elements of the Anglo-American establishment and the Soviet *nomenklatura,* the oligarchical conception underlying the long-standing "condominium" arrangements between the two sides came out into the open: to manage the world by methods intrinsically opposed to the Promethean impulse of science. Many on the Soviet side failed to realize that the elimination of the Soviet Union, and especially of its advanced scientific-technological potentialities, was high on the list of priorities.

The only substantial attempt to break the world free from these policies, was Lyndon LaRouche's fight to cause a fundamental change in strategic relations between the two nuclear superpowers, centered on a jointly agreed commitment for both to develop and deploy antiballistic-missile defense systems based on "new physical principles" (sometimes called directed-energy or beam weapons). This would have eliminated the doctrine of "Mutually Assured Destruction" and thereby the whole game of Bertrand Russell and Szilard, and at the same time permitted both nations to move into a "science-driver" mode of economy, in which the revolutionary civilian spinoffs of research into "new physical principles" would pay back investment into defense systems many times over.

Unfortunately, Soviet General Secretary Yuri Andropov refused the proposal, which LaRouche had communicated and explored in "back-channel" discussions with the knowledge of the Reagan Administration. Six years later, the Soviet Union collapsed, as LaRouche had warned it would, if his proposal were rejected. The policy of destroying the U.S.S.R.'s in-depth scientific-industrial capability went into full gear. But with the end of the Cold War, the need to continue large-scale state investments into advanced science and technology in the United States and Western Europe, from an oligarchical standpoint, no longer existed.

Nor was there any "need" to maintain an all-around industrial base. The floodgates were opened for savage deindustrialization and "outsourcing" of production to "cheap labor" nations, accompanied by the creation of a gigantic speculative bubble in the financial system. To most of the youth growing up in the formerly industrialized nations, true scientific and technological progress is at best a distant, secondhand memory.



Lawrence Berkeley Laboratory

One of the first isotope metabolism studies, during the 1930s, at what was then called the Lawrence Radiation Laboratory.

We have come to the end of the cycle. The destruction of large parts of the total scientific-technological potentials of mankind, the loss of much of its best-qualified labor force, and the stupefication of the population in formerly industrialized countries, if not reversed soon, would doom the world economy to inevitable physical collapse. There is no way that the nations of the developing world, including China and India with their oceans of poor people, could generate the technologies they need for their long-term survival, without a revival of the kinds of scientific and industrial capabilities in the United States, the former Soviet Union, and Europe, that were typified by the first decades of development of nuclear energy. The world is faced with a simple choice: either to launch an economic mobilization, rejoining the track of development of the "nuclear age" that Vernadsky and others had foreseen, or to fall back into a murderous dark age. Prometheus must be set free! Human civilization cannot survive without scientific revolutions.

A Nuclear Revival

Presently, the world is witnessing the beginning stages of a revival of nuclear power, which encompasses not only major developing countries such as China, India, South Africa, Argentina, and Brazil, but also Russia and even advanced-sector Western nations such as the United States, which had virtually abandoned their once-ambitious nuclear energy programs, for foolish ideological reasons, some 30 years ago. If the world does not descend into a dark age of chaos and war, a period of large-scale construction of nuclear power plants is pre-programmed, if only by the sheer scale and rapidity of expansion of demand for electrical and other forms of power, and the need to renew large sections of existing power-production capacities, which are coming to the end of their service lives.

However, the world we are living in now is not the same as it was at the point that nuclear power development was aborted, three decades ago. Even an all-out commitment to a nuclear power plant construction program now could not possibly compensate for the severe damage the world economy, and human civilization generally, has suffered as a consequence of the sabotage of nuclear power development, and of the virtual war against industrial culture of which nuclear technology was a crucial vanguard element. Much of the science and engineering capabilities that once existed in the United States, Germany, Russia, Italy, Sweden, and other countries, is simply no longer there. They must be built up again in a process that will require a generation or more.

In the meantime, huge challenges facing mankind, which the early architects of nuclear energy development had recognized 50 years ago on the horizon of the future, stand today at our doorstep: the need to produce large quantities of fresh water by desalination or other artificial means; the need to replace the burning of petroleum products by a combination of electric power and synthetic, hydrogen-based fuels; the need to apply much larger power densities to the extraction, processing, and recycling of basic materials, and more.

To meet all these requirements, a revolutionary *new phase* in the development of nuclear energy must be launched now. I christen it, the "Isotope Economy."

What Is the Isotope Economy?

The immediate context for the emergence of the Isotope Economy is the now-beginning transition-process of the global physical economy, from the present, still-dominant role of fossil fuels, to nuclear power as the chief basis for the world's power production systems—both with respect to the generation of electricity, as well as, increasingly, industrial process heat and the production of hydrogen-based synthetic fuels to cover a growing percentage of total consumption of chemical fuels. The first stage of this process relies on nuclear fission reactors, with increasing emphasis on high-temperature reactors (gas-cooled as well as liquid-metal-cooled, slow- and fast-

Courtesy of General Atomics

The TRIGA research reactor was designed for training engineers and scientists and for producing nuclear isotopes for medical and industrial use. It was conceived by Edward Teller in 1956, and a working model was installed in 1958 in Geneva, at the Second Geneva Conference on the Peaceful Uses of Nuclear Energy. Today there are 65 TRIGA reactors in 24 countries.

neutron systems), and an integrated fuel cycle, with comprehensive reprocessing and recycling of fissionable materials, and employing thorium as well as uranium and plutonium.

The necessary inventory of fission reactors encompasses a large spectrum of different reactor designs, including small-sized, series-produced modular units, as well as standard large units; reactors optimized variously for use as electricity generators, as industrial heat sources, for desalination, for production of hydrogen and other synthetic fuels; for breeding of fission fuel and transmutation of nuclear waste products; for ship propulsion, etc. Reactors requiring little or no supervision and running for very long periods without refueling—the so-called "nuclear batteries"—may play a significant role in outlying and developing regions of the world.

This transition to nuclear energy as the basis for the world's power systems, necessitates a massive buildup of industrial capacities for isotope-separation and for the reprocessing of nuclear materials, with emphasis on use of revolutionary laser- and plasma-based technologies. The latter buildup, in turn, provides an immediate jumping-off-point for the emergence of the Isotope Economy.

The Isotope Economy is characterized by the combination of four main features:

First, the Isotope Economy means incorporating the entire open-ended array of individual species of atoms known as "isotopes," of which today 3,000 are known, into the economy as fully differentiated instruments of human activity. Thereby, the familiar system of the 92-odd elements of Mendeleyev's Periodic Table will be superseded, in broad economic practice, by an incomparably more complex and multifaceted System of Isotopes. At first, these developments will concentrate on a subset of 1,000 or so relatively longer-lived isotopes known today; later, however, this number will grow, as means are devised for extending the lifetimes of even very short-lived isotopes, modifying or even suppressing the radioactivity of unstable nuclei and rendering them economically usable, by "binding" them in suitable physical geometries.[4]

At the same time, the Isotope Economy will systematically *expand* the array of isotopes, beyond those known today, deep into the range of superheavy (transuranic) new elements and "exotic" isotopes of existing elements. Each of those species constitutes a singular condition of the universe: Each possesses a bundle of unique characteristics and anomalies, relative to the others, enriching the spectrum of degrees of freedom in the development of the mankind and the universe.

Second, the mode of economic utilization of isotopes themselves will change radically, extending far beyond their presently predominant role as sources of ionizing radiation, as tracers, and as tools of specialized scientific research, to focus on much larger-scale applications of the *exquisitely fine "tuning" of subatomic processes,* both in respect to the inorganic domain, and in respect to the specific role of isotopes in the domain of living processes. Of immediate significance, in the first phases of the Isotope Economy, are the differences in mass, and above all, in the magnetic properties of the nuclei of isotopes, which interact with each other and the electron structures in their environment, by processes referred to today as "hyperfine interactions" and "nuclear magnetic resonance." This development can be usefully compared to the introduction of the principle of "well-tempering" into vocal polyphony in music, whereby small shifts in intonation

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4. The fact that the radioactive characteristics of atomic nuclei, including the so-called "radioactive decay constants," depend upon the physical environment within which the nuclei are situated, and can be drastically modified by changes in that environment, has been demonstrated in a number of striking experiments (see Notes 18 and 19 below). There should be nothing surprising about this in principle. For, the essence of quantum physics lies in the realization, that "particles" exist only as global processes, interacting everywhere in the universe, and never as strictly localized entities.

Nevertheless, the reductionist view of particles as "little hard balls" and of nuclear processes as fundamentally decoupled from their environment (for example, in atoms and molecules) continues to persist in the minds of even many professional physicists. See also my remarks here in the subsection on "Changing the Constants of Radioactivity."

cause new "cross voices" to emerge between and among the voices, resulting in a vastly increased power in the communication of ideas.[5]

By exploiting to the fullest extent, the implications of the ambiguity that arose in chemistry with the discovery of different isotopes of one and the same element, mankind opens up a "higher cardinality" of potentialities, incomparably greater than the mere numerical increase in the exploitable atomic species, mentioned above, would suggest. If, for example, we are synthesizing an organic molecule having 4 carbon atoms in nonsymmetrical positions, then by choosing for each carbon either of the two stable isotopes of carbon, C-12 or C-13, we obtain 16 different molecules, having the same chemical structure, but different "fine-tuned" magnetic and other properties. If we include the long-lived isotope C-14, the number grows to 81. If, in addition, there are 5 hydrogen atoms in the molecule, then by choosing between ordinary hydrogen and the stable isotope deuterium, up to 2,592 different molecules result!

"Isotopically engineered materials," synthesized from pure isotopes or selected combinations of them and possessing novel "collective" physical properties, will begin to supplant the more primitive types of materials employed today in human activity. Some of these are already under development today.[6] In addition to their special thermal, magnetic, electrical, and mechanical characteristics, these materials will play an essential role in the realization of new forms of nuclear energy and in generation and application of coherent, ultrashort-wavelength radiation, such as the gamma-ray laser.

At the same time, mankind stands on the threshold of revolutionary developments in biology and medicine, connected with understanding *how the fundamental distinction between living and nonliving processes,* demonstrated most forcefully by Louis Pasteur and Vernadsky, expresses itself on the subatomic level. While we cannot today predict the exact forms this revolution will take, we already know that it will have much to do with the specific role of isotopes in living processes, and will lead to a qualitative and quantitative transformation in the uses of isotopes, not only in biology and medicine, but also in agriculture and the management of the biosphere as a whole. It is, for example, quite conceivable, that by altering and controlling the isotopic composition of plant, animal, and human nutrition in certain ways, mankind could obtain a variety of beneficial effects; and that in the not-too-distant future, very large amounts of isotopically enriched substances will be required for that purpose.

Third, the Isotope Economy will employ artificial transmutation on a large scale, to generate various species of atoms as raw materials for industrial production. This means, to begin with, utilizing nuclear fission reactors, coupled with reprocessing of all fission products, more and more as *atom-generators and transmutation machines,* rather than simply sources of heat and electricity. By their very nature, fission reactions of heavy nuclei produce a wide spectrum of lighter isotopes, as well as a flux of neutrons which can induce further transmutations in surrounding material. A next step will be to add the potentialities of nuclear fusion, to create a combined "fission-fusion economy" mimicking the astrophysical generation of elements in certain respects.

The large neutron fluxes generated by fusion (deuterium-tritium) reactions, permit much faster rates of "breeding" of fuels for fission reactors, and of transmutation generally. Production of neutrons through accelerator-driven spallation,[7] provides a third method for large-scale atom-generation, probably starting with facilities for the transmutation of high-level nuclear "waste."

In the foreseeable future, more sophisticated methods will begin to emerge, based on the coherent control of nuclear processes by precisely tuned electromagnetic radiation and related means. Man will progressively develop the capacity to synthesize macroscopic amounts of atoms of any desired species, increasingly at will; and to do this on such a scale as to substantially supplement, and in some case even surpass, the quantities and qualities of raw materials available from "natural sources." Parallel with the artificial generation of elements, applications of high-temperature plasmas to the processing of ores, waste, and other materials—the so-called "fusion torch"—will vastly increase the range of economically exploitable natural resources, and permit a virtually 100 percent recycling of used materials in the economy.

Fourth, the Isotope Economy is intrinsically "astrophysical" in nature and in cultural orientation. Its maintenance and development will depend upon extensive, ongoing astrophysical investigations, that cannot be carried out from only the Earth and near-Earth region, but require an expansion of human activity throughout the inner region of the Solar System. To master subatomic processes for the Isotope Economy on the Earth, we must learn how those processes operate on the galactic scales of space-time; and we must come to know, much better than present-day earthly specula-

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5. See, for example, the web page of the Schiller Institute on the singing of Bach's choral "Jesu meine Freude," including excerpts from Lyndon LaRouche's Washington, D.C. presentation on Nov. 9, 2004: http://www.schillerinstitute.org/music/jesu_meine_text.html, as well as the presentation by LaRouche to a youth cadre school at the Presidents' Day Conference, Feb. 18, 2003, on "Classical Art: The Art of Communicating Ideas," http://www.schillerinstitute.org/conf-iclc/2003/pres_day/lar_to cadre.html.

6. See, for example, "Isotope Engineering," by V.G. Plekhanov, in the English edition of *Uspekhi Fizicheskikh Nauk*, Sept. 2000, Vol. 170, No. 11; also see Notes 9 and 10 below.

7. Spallation is a process in which the "shock" created by the impact of a very high-energy particle on a nucleus, causes its disintegration into a large number of fragments, including many neutrons. Spallation reactions occur all the time as the result of cosmic rays impinging on the Earth's upper atmosphere. It is now possible to "artificially" generate neutrons by spallation on a large scale, using modern particle accelerator technology producing high-current proton beams with energies of 500 MeV or more.

Such beams, when directed at a target made of lead (for example), produce 20 to 30 neutrons for every lead atom. As neutron radiation constitutes the most efficient means for the transmutation of atoms, development of these and other large-scale neutron sources is crucial to the Isotope Economy. Neutrons also have a huge range of applications in material science, medicine, and basic physics. See, for example, "Accelerator Radioisotopes Save Lives: The Isotope Production Facility at Los Alamos," by Eugene J. Peterson, http://library.lanl.gov/cgi-bin/getfile?LA-UR-06-0034.pdf.

See also, "Spallation Reactions for Nuclear Waste Transmutation and Production of Radioactive Nuclear Beams" by J. Benlliure, *Eur. Phys. J.*, A 25, S01, 757-762 (2005), http://www.edpsciences.org/articles/epja/pdf/2005/11/10050 2005_Article_506148.pdf; and the website of the U.S. Spallation Neutron Source, https://www.sns.gov/.

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Lawrence Berkeley technicians checking a new edition of the Table of the Isotopes in 1966. An updated version, "The Trilinear Chart of the Nuclides," was published in 2005 by the Radiochemistry Society.

tions permit, the pre-history of our own Solar System and the origin of the elements we find in it today. These requirements translate into the need to build up large networks of space-based astronomical observatories in solar orbits, able to carry out interferometric and related measurements of our galactic and extragalactic environment on a length-scale comparable to the orbit of Mars; plus a greatly expanded program of exploration of the Solar System itself.

All of this cannot be accomplished without establishing a large-scale logistical/production infrastructure in space, with emphasis on the Moon and Mars, capable of sustaining a large scientific-technical labor force living and working for long periods away from Earth, on a relatively self-sufficient basis. Conversely, it is precisely the "quantum jump" in overall productivity, inherent in the technological developments of the Isotope Economy, which make feasible routine travel throughout the inner Solar System and the establishment of permanent manned colonies on Mars. Fusion propulsion systems, for example, can cut the journey times between near-Earth orbit and Mars down from many months, as are required with present chemical propulsion systems, to a couple of weeks or less.

The Isotope Economy In the Process of Becoming

To readers not familiar with recent developments in nuclear-related technology, our characterization of the Isotope Economy might seem to be a very distant prospect, even smacking of "science fiction." In reality, the Isotope Economy is already in the *process of becoming,* and many of its features already exist, in more or less developed form, in laboratories and advanced production facilities around the world.

Isotope separation. The technology of isotope separation, greatly hindered in its progress by efforts to monopolize its military applications, has undergone revolutionary developments over the last 20 years. Initial breakthroughs in laser- and plasma-based methods (AVLIS, SILEX, plasma centrifuge, ion cyclotron resonance, etc.), promise enormous advantages relative to conventional methods.[8] At the same time, conventional methods (centrifugation, diffusion processes, electromagnetic separation, gaseous and thermal diffusion) have been further refined and their range of industrial applications extended to an ever larger number of isotopes. Also, the end of the Cold War freed up for civilian use large capacities for isotope separation, formerly employed in the military sectors of the United States and the former Soviet Union. This, in turn, has greatly expanded the range of isotopes generally available, and reduced their cost, spurring the search for new applications in all fields.

Qualitative transformation in the uses of isotopes. The demand and production of isotopes are presently growing at an exponential rate, led particularly by the medical uses of radioisotopes. At present, in the United States alone, more than 10 million diagnostic procedures are carried out each year using radioisotopes. At the same time, *a qualitative jump* is occurring in the *range* of applications of pure and enriched isotopes in the economy, as exemplified by the greatly expanded role of stable isotopes, and the beginning emergence of a new industrial sector producing "isotopically engineered materials" for the fabrication of semiconductor devices and specialized mechanical components such as cutting tools in metalworking machines. But this is just the beginning of a vast development, comparable in relative economic importance to the explosive development of the chemical industry in the hundred years beginning in the middle of the 19th Century.

Isotopically tuned materials. In this process, the preeminent role of radioactivity in most present-day uses of isotopes, is gradually being supplemented by other characteristics, connected with the exquisitely fine "tuning" of nuclear interactions and with the collective properties of materials, crafted from specifically chosen combinations of isotopes. The differentiation between isotopes of one and the same element is thus becoming more and more important in applications that have nothing directly to do with radioactivity or even, appar-

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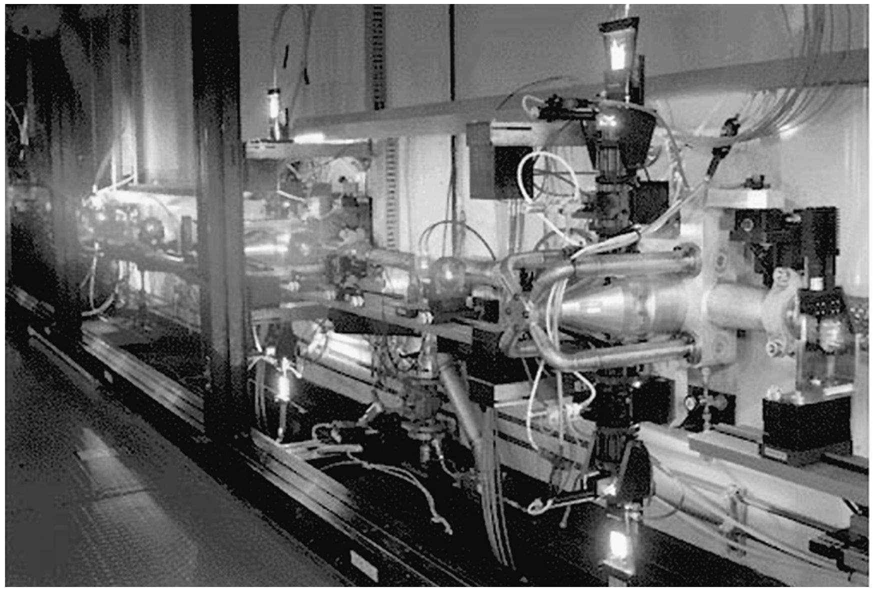
8. *Isotope Separation in Plasma by Ion-Cyclotron Resonance Method,* by A.E.Dubinov, I.Yu.Kornilova, and V.D.Selemir (Russian Federal Nuclear Center), www1.jinr.ru/Archive/Pepan/v-32-4/v-32-4-3.pdf.
On laser isotope separation, see, for example, the article by Steven Hargrove of Lawrence Livermore Laboratory: http://www.llnl.gov/str/Hargrove.html.

ently, with so-called "nuclear properties" of the isotope.

When embedded in crystal lattices or other molecular structures, the nuclei of different isotopes, having differing masses, oscillate at different frequencies. For this reason, among others, materials made using only a single, carefully separated isotope of a given element have a different and more coherent internal "tuning," than materials made with a mixture of isotopes; they display significantly different behavior. At present, for example, laboratories worldwide are researching the possibility of overcoming existing limitations on the power-densities, and therefore the computing power, of semiconductor chips, by utilizing a pure isotope of silicon. "Isotopically pure" structures of silicon, as well as of carbon and a number of other elements, have been found to possess a significantly higher thermal conductivity than the corresponding "natural" materials.[9] A higher thermal conductivity accelerates the potential rate of heat-removal from semiconductor chips, permitting them to operate at a higher power without overheating. A similar effect has been demonstrated in "isotopically pure" diamonds, opening up the possibility of increasing the productivity of various machining operations.[10] It has been established that diamonds made of pure carbon-13, are significantly harder than diamonds composed of the naturally occurring mixture of isotopes.



LLNL

The Atomic Vapor Laser Isotope Separation (AVLIS) technology was developed in the 1970s, and a full-scale pilot plant was built at Lawrence Livermore National Laboratory, which successfully demonstrated uranium enrichment and other potential isotope uses in the 1990s. But the AVLIS was shut down in a stunning example of "shareholder values." The U.S. Energy Policy Act of 1992 "privatized" uranium enrichment, transferring the technology to a private company, USEC, which decided in 1999 to halt the AVLIS project because the investment returns were projected to pose too much risk to shareholders. The pilot plant was dismantled. Here, a dye laser in the AVLIS project.

Hyperfine interactions and magnetic isotope effects. These applications, just mentioned, however, make use of effects of differences of *mass* between isotopes, while not yet taking into account what is really a much more essential differentiating characteristic: their *magnetic properties,* which are crucial to the phenomenon of *nuclear magnetic resonance.* As I shall point out in the following section, a new field of chemistry and biology has opened up in recent years, in connection with the experimental demonstration that so-called "hyperfine interactions," involving nuclei, play a fundamental role in all living cells.

Isotope-dependent nuclear magnetic effects will become ever more important, also, in determining the behavior of man-made nonliving materials, including most probably new types of "room-temperature superconductors."

Fission reactors as atom factories. Meanwhile, the economic importance of the isotopes generated by nuclear fission reactors and accelerators, in many ways *already* exceeds that of the electrical power produced by those same reactors! In the foreseeable future, fission reactors, instead of being seen chiefly as electric power sources, generating isotopes as a by-product, will operate more and more as *atom-producers, generating electricity as a by-product.* Fission reactions have the peculiarity, that starting from a single heavy isotope (U-235, Pu-239, or Th-232), they generate an extensive spectrum of different isotopes, encompassing nearly all the elements of the Periodic Table. It is already possible today, by "tuning" the neutron spectrum and fuel composition in a reactor, to influence the distribution of fission products to a significant extent.

Nuclear waste as a valuable "ore" for the extraction of precious metals. Already today, in addition to large amounts of useful radioisotopes and recyclable fission fuels, nuclear fission reactors have generated large amounts of industrially important precious metals, such as palladium, rhodium, and ruthenium. The extraction of these metals from so-called "nuclear waste," for economic use as catalysts, in special alloys, and in corrosion-resistant materials, has already been proven feasible.[11] The

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9. See two papers by E.E. Haller, Lawrence Berkeley National Laboratory and University of California, Berkeley on "Isotopically Controlled Semiconductors" at http://www.osti.gov/bridge/servlets/purl/799566-6qpAuC/native/799566.pdf and http://www.osti.gov/energycitations/servlets/purl/861238-fD0wMA/861238.pdf.

10. See "South Africa Leads World Race for Carbon-isotope Laser-separation Plant," in Creamer Media's *Engineering News Online*, http://www.engineeringnews.co.za/eng/features/laser/?show=19347, and "Isotopically Enriched Designer-Diamond Anvil," at http://www.phy.uab.edu/research/DOE/IsotopicallyEnriched.htm.

11. "Potential Applications of Fission Platinoids in Industry," by Zdenek Kolarik, *Platinum Metals Rev.*, 2005, Vol. 49, No. 2, http://www.platinummetalsreview.com/pdf/79-90-pmr-apr05.pdf. Also, "Electrochemical Separation of Rare Metal Fission Products from High-level Liquid Waste of Spent Nuclear Fuel," by Masaki Ozawa and Tetsuo Ikegami, Japan Nuclear Cycle Development Institute, Ooarai Engineering Center, Japan, http://www.nea.fr/html/pt/docs/iem/jeju02/session2/SessionII-14.pdf.

iter.org

The International Thermonuclear Experimental Reactor (ITER), now under construction in Cadarache, France, will be the next step toward a prototype power station, producing 500 megawatts of fusion power.

amounts of these metals, synthesized every year as reaction products in the world's presently operating nuclear power reactors, if they were to be extracted from the spent fuel during reprocessing, would already amount to significant percentages of the total yearly amounts extracted from the Earth by mining. Noting that the relative concentrations of many rare metals contained in the spent fuel of nuclear breeder reactors, is tens of thousands to millions of times higher than their average content in the Earth's crust, Japanese researchers recently declared such spent fuel to be one of the most valuable "ores" known today.

Complete reprocessing. The full exploitation of fission's potential as an atom-producer, will begin with the "closing" of the nuclear fuel cycle, by the complete chemical reprocessing of spent fuel, separation of useful isotopes, recycling of fissionable materials, and transmutation of undesired species through irradiation with accelerator-generated neutrons, or in specially designed "nuclear waste-burning" reactors. All of this has been worked out in detail by nuclear laboratories around the world, and the essential technological base already exists.[12]

Large-scale transmutation by particle accelerators. The technology of high-current particle accelerators has advanced to the point, that the transmutation of macroscopic amounts of isotopes by irradiation with neutrons from an accelerator-driven neutron source is already a technological possibility. Numerous laboratories around the world are presently working on designs for Accelerator Driven Transmutation Systems (ADS), as a means to deal with the problem of long-lived radioactive isotopes from "nuclear waste." A single ADS system with a beam power of 20 megawatts, could transmute the long-lived isotopes from 10 standard nuclear power plants into short-lived and stable isotopes, producing 800 megawatts of thermal power at the same time.[13] Similar technology could be used for other transmutation applications, as well as for driving "subcritical" nuclear reactors of various types.

The advent of nuclear fusion. The next step toward a full-scale Isotope Economy will be to combine the potentials of fusion—which in many respects are complementary to those of fission—with fission processes and accelerator-based transmutation, while at the same time phasing in new methods of controlled transmutation, now under experimental development (see below). Over the last 10 years, nuclear fusion technology has progressed steadily, on multiple fronts. In 1997, the experimental fusion reactor JET (Joint European Torus) in Culham, England, produced more than 16 megawatts of power through fusion reactions, sustained over several seconds, at temperatures of 100 million degrees C. The International Thermonuclear Experimental Reactor (ITER), now under construction in Cadarache, France, will produce 500 megawatts of fusion power, in pulses of over six minutes, with the next step being a prototype power station. Parallel with the standard tokamak design, there has been significant progress across the board in fusion experiments, including fast liner, plasma focus, "inertial confinement" by lasers, ion beams, and others.

The "brute force" approach to fusion: Not the best, but approaching success. Contrary to often-repeated myths, the possibility of generating large amounts of power by fusion reactions has long since been demonstrated—namely, in the explosion of the first hydrogen bomb, over a half century ago. The hydrogen bomb, however, requires a smaller, fission chain-reaction detonator (a small atomic bomb) in order to bring a mixture of hydrogen isotopes to the necessary high densities and temperatures, for large quantities of fusion reactions to occur. The essential difficulty of tapping fusion as a power source for civilian purposes, lies in the challenge of generating large amounts of fusion reactions in an efficient, controlled way, without using an atomic bomb as a trigger. Over the last 30 years, progress in controlled nuclear fusion has been greatly retarded by lack of political will, orientation toward a merely engineering or "applied science" approach, rather than going for fundamental discoveries; restriction of pursuit of experimental hypotheses to a few chosen directions; the stifling atmosphere of bureaucratically managed "Big Science," etc. Nevertheless, the accumulation of hard, "brute force" applied physics and engineering work, has

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12. See, for example "Processing of Used Nuclear Fuel for Recycle," World Nuclear Association, Oct. 2006, http://www.world-nuclear.org/info/printable_information_papers/inf69print.htm.

13. See for example: "Introduction to ADS for Waste Incineration and Energy Production," by H. Condé, Dept. of Neutron Research, Uppsala University, http://www.nupecc.org/iai2001/pdf/ADS.pdf; and "Progress Report on Nuclear Transmutation," by Hiroyuki Oigawa, http://j-parc.jp/documents/pdf/iac/ADS.pdf

brought a first-generation fusion power reactor into technological reach.

As mentioned, work is beginning on the construction of a giant fusion test reactor, the ITER, in Cadarache.[14] The core of the ITER reactor is a toroidal chamber, filled at the start with extremely thin gas, which an electrical discharge, induced by huge transformer coils surrounding the chamber, transforms into the initial plasma. The plasma is subsequently heated by microwaves and neutral particle beams to a temperature the equivalent of more than 100 million degrees C, and additional deuterium-tritium fuel mixture is injected. The reactor employs a combination of currents generated inside the plasma, and magnetic fields imposed from the outside, creating a kind of "magnetic bottle" holding the plasma suspended in the chamber's central region, and keeping it insulated from the chamber's walls by a high vacuum. When in operation, this reactor is projected to be able to generate a sustained gross power output of 500 megawatts from fusion reactions between nuclei of the hydrogen isotopes deuterium and tritium, during periods of approximately six and a half minutes at a time. (The device will be able to produce a pulse about once every thirty minutes.)

Because of this pulsed mode of operation and the high power consumption of its magnetic and plasma heating systems, ITER cannot be regarded as a full prototype of a future fusion power plant; nevertheless, it is expected to finally establish the practical feasibility of such a power plant, while at the same time bringing a large number of technologies, required for a future power reactor, to a relatively high degree of perfection.

The fusion-fission hybrid. The distribution of atomic species found in the Solar System today, bears strong evidence to the effect, that the isotopes we find around us today were generated by a combination of fission and fusion processes. So also, the coming Isotope Economy will base itself on a synergy of these complementary nuclear processes. The first, near-term embodiments of this principle are known as the "fusion hybrid" or "fusion-fission hybrid" reactors.

The hybrid technology takes advantage of the fact that "fission reactions are neutron-poor, but energy-rich, while fusion reactions are neutron-rich, but energetically poor." Although each fission reaction of uranium releases about three neutrons on average, in fission reactors the bulk of those neutrons is immediately consumed again, partly to maintain the fission chain-reaction process, and partly by absorption in the complex mixture of isotopes present in a fission reactor core, plus losses to the outside. For this reason, nuclear fission reactors operate with a relatively strict neutron balance. In a fusion reactor, however, neutrons produced from the fusion of deuterium and tritium are not needed to maintain the process, nor does the fusion plasma contain large amounts of neutron-absorbing substances; hence, these neutrons are available to do useful work elsewhere. On the other hand, D-T fusion releases 10 times less energy per reaction, than the fission of a U-235 nucleus.

Accordingly, the principle of the "hybrids," is *to use fusion reactions to produce neutrons, and fission reactions to produce power.* The synergy works as follows: We utilize the neutron flux generated by a fusion plasma (1) to breed nuclear fuel for fission reactors, from U-238 or thorium; (2) to transmute radioactive products from fission reactors; or (3) to drive a fission reactor operating in a subcritical mode.[15] These applications do not require that the fusion reactor itself produce an excess of power. The overall power benefit comes from the fission side of the equation, so to speak: in the "burning" of fission fuel, produced by the hybrid, in separate fission reactors; in the fission reactions occurring in an adjacent "subcritical" blanket; or, in the case of transmutation of waste, from the release of energy stored in the radioactive fission products.

Dropping the requirement of "energy breakeven" greatly reduces the demands on the fusion reactor, putting them within the reach of the type of design and parameters that were already demonstrated by the European JET reactor in Culham, and will be greatly improved in the ITER reactor being constructed in France. These reactors, while still operating far below the breakeven levels for power generation, have already achieved parameters that are sufficient, in principle, for the construction of hybrid systems for the production (breeding) of nuclear fission fuels, for large-scale transmutation of nuclear waste, and for power production using neutrons, generated in fusion reactions, to drive a "subcritical" nuclear fission reactor.

The fusion torch and plasma mass separation. The level of technological mastery of energy-dense plasmas, achieved in the course of fusion reactor development so far, also makes it possible to, in principle, realize "first approximations" of the so-called *fusion torch (or high-temperature plasma torch)* concept invented by the American fusion scientists Bernard Eastlund and William Gough.[16] Utilizing magnetically confined plasmas fusion torches, either alone or in combination with the so-called plasma centrifuge, we will ultimately be able to process and separate any material—low-grade ores, waste, sea water, or anything else—into its component atomic species, obtaining pure isotopes from an arbitrary feedstock. In the limit, this technology will permit a nearly 100 percent

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14. The official website of the ITER project is http://www.iter.org.

15. The term "subcritical" refers to a nuclear fission reactor, whose configuration and parameters fall below the threshold required for a self-sustaining fission chain reaction process. A subcritical reactor can nevertheless be used as a power source, if an additional source of neutrons is provided—from a particle accelerator or a fusion reactor, for example—to keep the fission processes going. One advantage of a "subcritical" fission reactor, is that the danger of a "runaway" chain reaction is eliminated: the chain reactions stop immediately when the external source of neutrons is turned off.

See, for example, "Accelerator-driven Sub-critical Reactor System (ADS) for Nuclear Energy Generation," by S.S. Kapoor, http://www.iisc.ernet.in/pramana/v59/p941/fulltext.pdf, and "Tokamak Fusion Neutron Source Requirements for Nuclear Applications," by W.M. Stacey, Georgia Institute of Technology, Atlanta, Ga., http://www-pub.iaea.org/MTCD/Meetings/FEC2006/ft_p5-5.pdf.

16. For an overview on the fusion torch and background on fusion technology see the accompanying article, this issue, "Fusion Torch Can Create New Raw Materials." A detailed description of a tokamak-based fusion torch design can be found via the patents page of the Eastlund Scientific Enterprises Corporation, http://www.eastlundscience.com/index.html.

See, for example, the patent "Method and Apparatus for Ionizing All the Elements in a Complex Substance. . . ." available under http://www.freepatentsonline.com/5681434.html.

Lawrence Berkeley Laboratory

The main tunnel at Yucca Mountain, the U.S. nuclear "waste" storage facility in Nevada. Although it is the subject of great hysteria, the products generated by nuclear fission include large amounts of precious metals, making it a valuable "ore." The fusion torch technology will make it possible to deal with such radioactive materials.

effective recycling of materials, and expand the exploitable range of natural resources by many orders of magnitude.

Thanks to the fact that plasmas can have almost unlimited power densities, and at the same time be readily manipulated by applied currents, magnetic fields, and microwaves, plasmas have become an ever more important working medium for the processing of materials. Today's industrial applications include plasma steel-making, plasma chemistry, plasma surface treatments, plasma ion deposition, and many others. But in the future, the most important large-scale use of energy-dense plasmas, apart from fusion power generation, will almost certainly be the "fusion torch."

The original inventors, Eastlund and Gough, realized that fusion plasmas, with their high temperatures and power densities, constitute a kind of "universal solvent": Any known material, injected into such a plasma, is instantly dissociated into electrons and ions of the component atoms. Once that dissociation has taken place, the different component species of ions, making up the resulting mixed plasma, can be separated by a variety of methods, either in the original region, or by drawing the mixed plasma off into a separation chamber.

The most familiar method of isotope separation is by centrifugal action, as exemplified by the classical gas centrifuges used today for enrichment of uranium isotopes, on the basis of their slightly different masses. Plasmas can in principle sustain rotation at orders-of-magnitude higher speeds than can mechanical devices. Experimental plasma centrifuges for isotope separation are already in operation today. In practice, future plasma mass separation devices may employ combinations of electric, magnetic, and electromagnetic fields, as well as induced waves and high-speed rotational motion in the plasma itself, to accomplish the desired results. Also, a variety of different devices may be operated in a cascade, as is already done today.

Most likely, in large-scale practice, dissociation and element separation/isotope separation operations will not be carried out directly in a fusion reaction plasma, but either in plasma diverted from a fusion reactor into auxiliary chambers, or in a freshly created plasma, powered by an outside source.

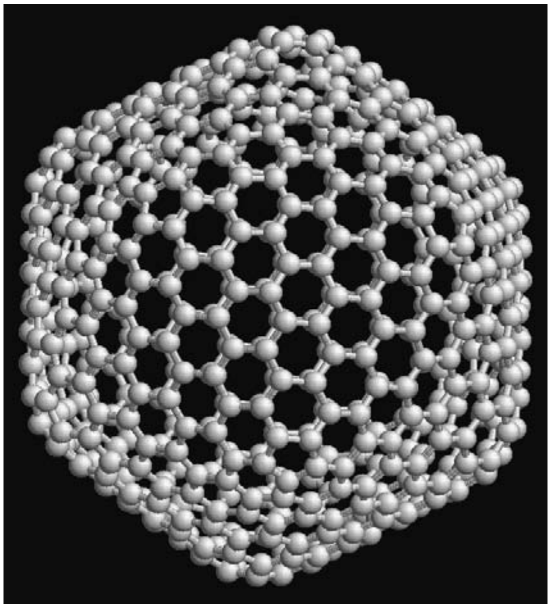
First applications of the "fusion torch" principle are presently being studied in the United States as a possible method of dealing with the huge accumulation of radioactive materials, left over from 50 years of nuclear weapons production at Hanford and other locations. The first torch plasmas will be externally powered.

Laser-controlled nuclear transmutation. The last five years' breakthroughs in the construction of powerful ultra-short-pulse lasers (femtosecond lasers) and of lasers operating in the X-ray range, now make it possible to trigger nuclear transmutation processes directly with lasers. So-called "tabletop femtosecond lasers," compact devices which are now available commercially and are becoming standard equipment at major physics departments and laboratories, use novel methods of "pulse compression" and amplification to produce extremely short light pulses—of the order of 10^{-13} to 10^{-15} seconds in length. Some of these lasers can now reach power densities of up to 10^{19} watts per square centimeter, sufficient to trigger nuclear reactions, on a routine basis, through the action of gamma-rays generated in a material irradiated by the laser.

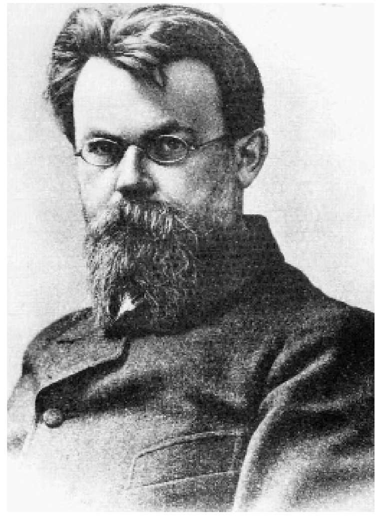
Also, the electromagnetic fields generated by these lasers can be used to accelerate charged particles to energies sufficient to trigger nuclear reactions. Thereby, small laboratories can today carry out experimental work which in the past required gigantic cyclotrons and other particle-accelerator machines.

The "tabletop lasers" are replicating, with much simpler means, results obtained earlier by giant lasers such as the VULCAN laser at Rutherford Appleton Laboratory in England and the Petawatt Laser at Lawrence Livermore Laboratory in California. In 1999, for example, Livermore induced the fission of nuclei of U-238 by laser pulses. Soon, a laboratory at the Friedrich Schiller University in Jena did the same thing with a tabletop laser. Other experiments on VULCAN demonstrated the use of laser pulses to transmute long-lived radioactive isotopes, such as iodine-129 (half-life 15 million years), into short-lived isotopes (in this case, I-128 with a half-life of only 25 minutes).[17] Such methods, once perfected, may provide an effective means to "deactivate" radioactive waste produced in nuclear fission power plants, transforming it into stable, non-radioactive elements. Laboratories around the world are today striving to develop laser sources of ever shorter wavelengths, moving ever further in the direction of "harder" X-rays. Every decrease in the wavelength expands the range and efficiency of nuclear processes that can be generated directly (photonuclear reac-

17. "Laser-driven Photo-transmutation of Long-lived Nuclear Waste: Application to Iodine-129," by K.W.D Ledingham, http://www.clf.rl.ac.uk/Reports/2002-2003/pdf/10.pdf.



The stability of many nuclei can change, depending on the electronic environment of the nucleus. Decreases in radioactive half-lives have been obtained by embedding beryllium-7 atoms in a "buckyball" complex of atoms, such as this one.



Vladimir I. Vernadsky, the Ukrainian-Russian biogeochemist, recognized a century ago that the discovery of new dynamic principles, transcending the chemistry of the periodic system and closely bound up with the origins of our Solar System, would unleash a revolution in all aspects of man's relationship to nature.

tions). The realization of gamma-ray lasers, not yet within immediate reach, would revolutionize the experimental methods of nuclear physics.

Changing the "constants" of radioactivity. The teaching and practice of nuclear physics continue to be encumbered by prejudices and misconceptions that were introduced very early into the field. Among the most crippling is the preconceived idea, that the processes "inside" the atomic nucleus constitute a categorically separate world, governed by mysterious entities called "strong forces," and basically not interacting with their surroundings except through violent, "high-energy" events, considered to be essentially statistical in character. The popular term "atom smasher," used for high-energy particle accelerators in the early days, reflects a simplistic, Rambo-like quality of conception which persists, despite massive evidence of the exquisitely fine tuning of nuclear processes. The prejudice remains, even among professionals today, that such processes as radioactive decay of nuclei are practically beyond human control, except by subjecting the nuclei to gigantic forces, or bombarding them with particles from high-energy accelerators or nuclear reactors. The rate of radioactive decay of a nucleus, is still wrongly regarded as a kind of natural constant, rather than a function of the physical geometry within which that nucleus is embedded.

This dogmatic attitude among professionals led to the silly misconception, adopted as a "fact" of public policy for decades, that the long-lived isotopes contained in "nuclear waste," could only be dealt with by storing them underground for tens or hundreds of thousands of years!

This notion continues to dominate public discussions today, even though the professional world has long since acknowledged the option of large-scale transmutation through particle accelerators or in fusion devices, as mentioned above. These methods will work, but they represent a primitive, "brute force" method, to be replaced by much more intelligent approaches, as soon as they become available.

In the meantime, overwhelming experimental evidence has accumulated for the existence of finely tuned, "low-energy" nuclear processes, very different from those upon which nuclear technology has been based until now, and whose future mastery defines a revolutionary pathway for development of the Isotope Economy.

It is now well established, for example, that the stability or lifetimes of nuclei can change by many orders of magnitude, depending on the electronic environment of the nucleus. Thus, for example, the isotope dysprosium-163 is stable in normal atomic form, but when ionized (stripped of its electrons) the Dy-163 nucleus becomes unstable. The rhenium isotope Re-187 has a half-life of over 40 billion years in atomic form, but when ionized, the half-life is reduced more than a billion times, to less than 33 years.[18] The complete ionization of a free atom is a very energy-intensive process. Smaller, but still easily measurable decreases in radioactive half-lives, have been obtained by much "softer" means: by embedding beryllium-7 atoms in so-called fullerines ("buckyball" complexes of atoms), and just recently again, by embedding sodium-22 in palladium metal, afterward cooled to a temperature of 12°K.[19]

The effects in these experiments were only on the order of 1 percent, but (1) they refute the dogma that nuclear processes are "oblivious" to their environment, except under "high-energy" conditions; (2) they broadly cohere with the results of many "cold fusion" experiments, which are more difficult to interpret, but show a multitude of transmutation effects—sometimes very spectacular ones—that demonstrably do not come from usual "high-energy" sorts of nuclear reactions.

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18. See M. Jung et al. "First Observation of Bound-state $\beta-$ Decay," *Physical Review Letters,* Vol. 69, No. 15, pp. 2164-2167, 1992 (on Dy-163); F. Bosch, et al., "Observation of Bound-state $\beta-$ Decay of Fully Ionized ^{187}Re, *Physical Review Letters,* Vol. 77, No. 26, pp. 5190-5193, 1996; and P. Kienle, "Beta-decay Experiments and Astrophysical Implications," in N. Prantzos and S. Harissopulus, *Proceedings: Nuclei in the Cosmos,* pp. 181-186, 1999.
19. See for example "Radioactivity Speeds Up," Physics Web 21, September 2004, http://physicsweb.org/article/news/8/9/12/1.

The Role of Isotopes In Living Processes

The truly revolutionary aspect of the Isotope Economy, lies in the areas of intersection of the three great experimental domains in our universe: the domain of ostensibly nonliving processes, the domain of living processes, and the domain of those processes that depend upon human creative reason. The unequivocal proofs of the absolute distinction between the principles governing these three domains, were provided by Vladimir Vernadsky for the first and second domains, and Lyndon LaRouche for the second and third.[20] All three domains are anti-entropic in character.

The most paradoxical, and fruitful feature of this strict division, arises from the circumstance that the principles underlying the three stated domains, insofar as they are truly universal, are *implicitly ever-present* and coextensive with the universe as a whole! In other words, we do not have three separate universes, one for each domain, but only *one, multiply connected universe,* in which every existing thing (singularity) participates simultaneously, but in different ways, in each of the three distinct principles (or sets of principles) of action. The meaning of this becomes clear, when we examine the special case of isotopes and nuclear reactions.

The existence of an intimate connection between nuclear reactions, isotopes, and living processes, is deeply rooted in the prehistory of our planet. To the best of our knowledge, the great bulk of atomic species, from which the tissues of living organisms on this planet are composed, were generated during earlier phases of the evolution of our Solar System, prior to the formation of the Earth, and constitute in that sense a "fossil" of that earlier development. Also, to the best of our knowledge—although there are somewhat divergent viewpoints on this question—the Solar System originated in a single, proto-stellar entity which was our Sun at an earlier stage in its development.

A Unitary Origin of the Solar System

Before turning to living processes per se, let us look at the most coherent of the available hypotheses on what the earlier evolution of the Solar System may have looked like.

According to the "polarized fusion" hypothesis put forward by LaRouche, the array of atomic species found in the Solar System today was essentially generated in situ, as part of the same unitary process that led to formation of the system of planets: The proto-Sun was a rapidly spinning object, "spinning off" a disk of plasma and going on to "process" it, by a combination of intense radiation and powerful magnetohydrodynamic inductions, driven by the proto-Sun's rapid rotation and intense magnetic field. This action by the Sun created the conditions for "polarized fusion" to take place in the disk—a fusion process in which, it is proposed, an extremely strong magnetic polarization of the nuclei, and perhaps other "catalytic" effects of the electromagnetic geometry set up in the disk, caused the fusion process to be orders of magnitude more efficient than ordinary "thermal" fusion.

Thereby, the proto-Sun was able to generate the entire range of elements and isotopes, which we find on the Earth and elsewhere in the Solar System today. (This would include the atomic species heavier than iron in the periodic system, which could not have been generated, in the observed amounts, by the sorts of fusion reactions thought to occur in our present-day Sun.) The magnetohydrodynamically structured plasma disk, with its newly generated stock of elements, subsequently resolved into an harmonically ordered array of rings, corresponding to the locations of the planetary orbits as we find them today. Finally, the planets themselves condensed out of the rings.

Unfortunately, most astrophysicists today reject the notion of a unitary origin of the System, its elements, and the harmonic ordering of its planets. Instead they believe that the heavier elements found today in the Solar System, pre-date the birth of our present Sun and were generated by nuclear reactions during one or more gigantic explosions of stars—the "supernovas." Which star or stars these were, nobody can say, because no astronomical traces of such an early explosion have been observed in the vicinity of our Solar System. But there is another possibility; namely, that the supernova events that astronomers actually observe from time to time in our galaxy, and which the astrophysicists interpret as bomb-like explosions, are actually processes of the type LaRouche has proposed; and that the heavy-element-generating supernova the astrophysicists postulate, is in reality just an exuberant phase in the early life of own proto-Sun!

However these issues may be resolved in the future, the implications are these:

First, from the standpoint of the prehistory of our Solar System, the existence of life on our Earth is inseparably connected with the existence of the nuclear reactions that produced the atomic species from which living tissue is composed. In that sense, the material preconditions for our biosphere and its organic evolution, were created by a preceding phase of non-organic, but anti-entropic evolution of the Solar System—the "nucleosphere."

Second, life on Earth continues to be *nuclear-powered:* Our entire biosphere lives from the Sun, whose radiative power is generated by fusion reactions. But the biosphere is coupled to our star not only in terms of the gross flow of radiant power, but also through more subtle magnetic interactions, which cause what the Russian researcher A.L. Chizhevsky called "the biosphere echo of solar activity," reflected in the behavior of microorganisms and other living processes, as well as in the weather and climate.[21]

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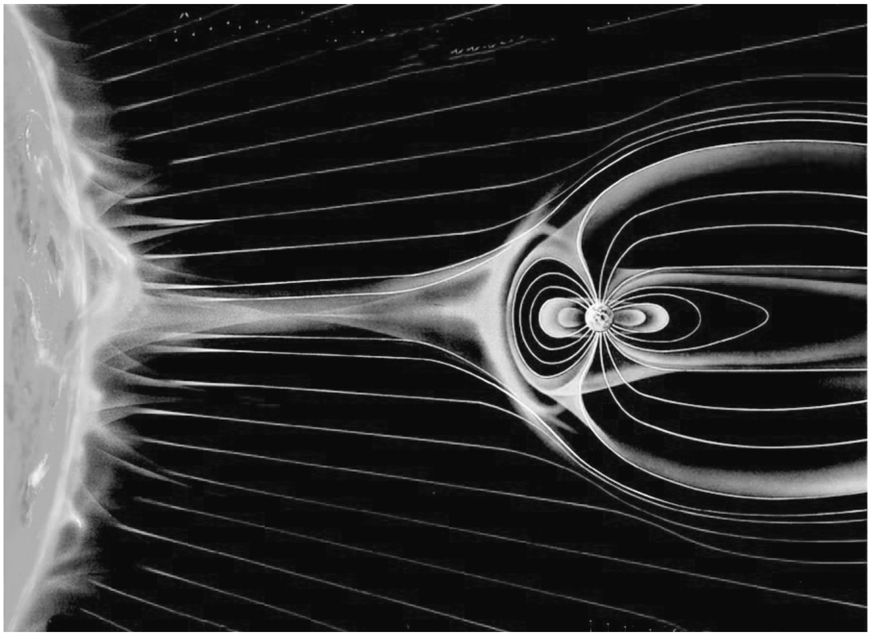
20. See the author's comparison of the work of Vernadsky and LaRouche on these points, in "Vernadsky and the Future of Biophysics," in *EIR*, Feb. 18, 2005. Also, see "On the Fundamental Material-Energetic Distinction Between Living and Nonliving Natural Bodies of the Biosphere," by Vladimir Ivanovich Vernadsky, *21st Century*, Winter 2000-2001, http://www.21stcenturysciencetech.com/articles/vernadsky.html; and Lyndon LaRouche, "On the Noetic Principle: Vernadsky and Dirichlet's Principle," *EIR*, June 3, 2005, http://www.larouchepub.com/lar/2005/3222vernad_dirichlet.html.

21. See for example "The works of A.L. Chizhevsky on Solar-Terrestrial Links. Heliobiology on the Eve of the XXI Century: Results, Problems, and Prospects," B.M. Vladimirsky, *Biophysics,* Vol. 43, No. 4, pp. 532-536 (1998)



K. Endo/NASA/National Geophysical Data Center

Artist's illustration of solar winds impacting the Earth's magnetosphere.The atomic species found in the Solar System today were generated in the same unitary process that led to the formation of the system of planets: A process of polarized fusion taking place in the disk allowed the proto-Sun to generate the entire range of elements and isotopes found today. Note that the Earth-Sun distance is not to scale.

Having thus established, without any doubt, the *astrophysical* relationship between nuclear processes and life on the Earth, let us now look for the relationship on the *microphysical* level.

Following the discovery of isotopes, much experimental work was done in the effort to find a special role of particular isotopes in living processes. Early work indicated that living processes enriched isotopes to a certain extent—i.e., the ratios between the concentrations of isotopes of a given element in living tissue, differ from those in the environment around them in a *characteristic* way. Although this is today a well-established fact, widely exploited in investigations of geology, geochemistry, ecology, botany, paleontology, and so forth, the shifts in the isotope ratios involved are nearly always on the level of parts per thousand. This is comparable in magnitude to the isotope shifts caused by nonliving processes, and orders of magnitude less than the effect of concentration of the chemical elements themselves, to which we owe the biological origin of many concentrated mineral deposits.

There have also been some indications, that microorganisms may be able to carry out certain transmutations; however, the evidence remains equivocal, and no very good hypothesis has been proposed, for what fundamental role such transmutations, to the extent they occur, might play in the organization of living processes.

Leaving aside strongly radioactive isotopes, whose isotope-specific effects on living organisms appear entirely explicable on the basis of the radiation itself, living organisms seem rather insensitive to even gross changes in the isotope concentrations in the environment and in the material they ingest. Indeed, it is on this apparent indifference that the technique of isotope tracing of metabolic pathways and many medical diagnostic methods are based. The clear, but not surprising exception is deuterium, twice as heavy as ordinary hydrogen, whose chemical properties are already sensibly different from those of hydrogen. Ingestion of heavy water (D_2O) in large quantities leads to lethal metabolic disturbances in animals; nevertheless, bacteria can be raised on heavy water to the point that nearly all the hydrogen in them is replaced by deuterium, without seeming to cause harm.

The Role of Nuclear Magnetism

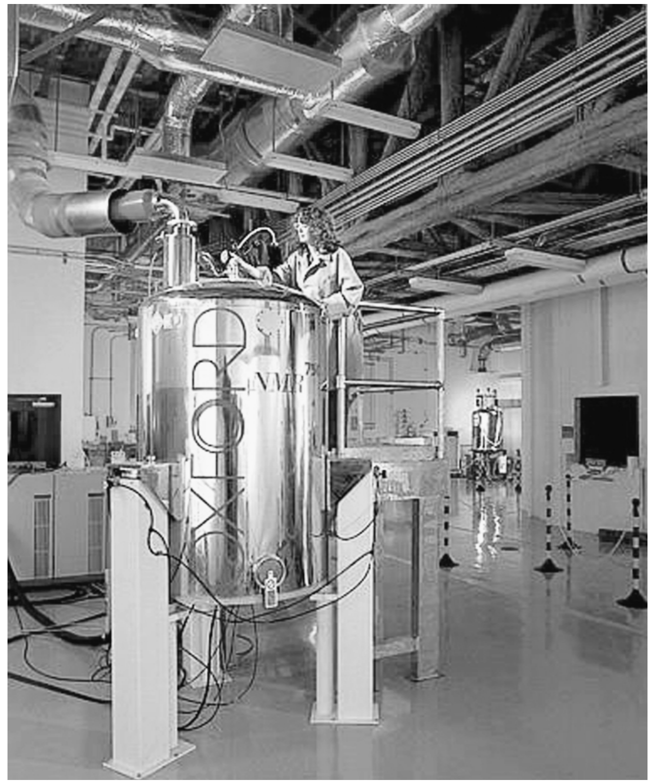
Does this mean that isotopes play no direct role, as such, in the organization of the living processes? On the contrary! But the best clue we have so far, comes from a very different direction than a mere statistical effect of isotope concentrations. The key lies in the *magnetic* characteristics of atomic nuclei, which differ radically among different isotopes of one and the same element. These characteristics are exploited on a routine basis in nuclear magnetic resonance (NMR) imaging, used in every modern hospital, and NMR spectroscopy, but their full significance is only beginning to be grasped.

The signals used in NMR, for example, are emitted by atomic nuclei interacting with the combination of a magnetic field produced by the coils surrounding the patient or specimen and a microwave pulse used to "excite" nuclear oscillations. Here, the differences among isotopes become decisive. For nuclei of isotopes whose atomic number and mass number are both even, the magnetic moments that determine the strength of interaction with the magnetic fields, are indistinguishable from zero. These nuclei contribute nothing to the signal. The nuclei with odd atomic number or odd mass number, on the other hand, have noticeable magnetic moments, whose values depend somehow on the internal configuration of the nuclei. They give distinct signals that permit NMR machines to "tune in" to specific isotopes in living tissue. Those signals express not only the presence of the corresponding isotopes, but also certain characteristics of the physical geometry around them, mediated through magnetic interactions among the various nuclei and the electron structures within which they are embedded.

The interaction between nuclei and the surrounding electronic structures—known as the "hyperfine interaction"—also reflects itself in extremely slight, but very precisely defined shifts in the optical spectra of atoms and molecules, and in other types of spectra. The hyperfine structure is closely related to the quantum-physical invariant called "spin," which is believed to underlie the magnetic properties of nuclei and other particles, and is closely interwoven with the so-called fine structure constant and other basic constants of physics. Unfortunately, of all the topics in quantum physics, the phenomenon of "spin" suffered the relatively greatest amount of mystification at the hands of Wolfgang Pauli and others.

Now, it is hard to imagine that such a well-organized, finely tuned process would have no *functional* significance in living processes. In fact, the extraordinary sensitivity of living processes to constant and varying magnetic fields is well known and forms an entire field of research, called "magnetobiology" or "biomagnetism." The biosphere is constantly subject to the magnetic field of the Earth, which in turn is coupled to that of the Sun and with the solar activity.

But despite many attempts, the fundamental biological significance of this sensitivity and the nature of the interactions involved, have not been clarified. Part of the reason, is the seemingly "infinitesimal" magnitude of the *"nuclear component"* of the magnetic fields in living and nonliving material. The magnetic interactions among molecules, which have been intensively studied and are known to play a decisive role in the biochemistry and biophysics of living processes—especially as concerns the role of so-called free radicals[22] derive nearly entirely from their *electronic* structures. These—at least so it was assumed—are relatively independent of the isotope-related nuclear magnetism. The magnetic moments of nuclei are 1,000 or more times weaker than those associated with the electrons and their orbital configurations. To obtain a sufficient signal from the nuclei, NMR machines employ magnetic fields that are typically 20,000-30,000 times stronger than the natural magnetic field on the Earth.



The magnetic characteristics of atomic nuclei play a key role in living processes. These are exploited routinely in nuclear magnetic resonance (NMR) spectroscopy. Here, an NMR spectrometer at the William R. Wiley Environmental Sciences Laboratory in Washington state.

The Strength of Weak Effects

But as science over the centuries has demonstrated again and again, it is often the weakest effects, the ones that tend to be ignored, that actually control the largest ones. In recent years, thanks particularly to the work of physical chemists in Russia, decisive evidence has been brought to light, for an essential role of isotope-specific "hyperfine" interactions in all living processes.

In the course of 2005, a research group led by the famous chemist Prof. Anatoly Buchachenko at the N.N. Semenov Institute for Chemical Physics of the Russian Academy of Sciences, demonstrated "magnetic isotope effects" in the biological synthesis of ATP, commonly known as the key "energy-carrying" substance in *almost all living cells.*

The decisive process in ATP synthesis, known as phosphorylation, depends on the activity of several enzymes that contain magnesium ions in specific locations. Now, it turns out that the rate of functioning of those enzymes changes dramatically, when one magnesium isotope is replaced by another. In a paper published in the Aug. 2, 2005 issue of the U.S. *Proceedings of the National Academy of Sciences,* Buchachenko et al. report the results of their investigations with the following words:

> In one of their brilliant papers, Weber and Senior pointed out that, despite great progress in our knowledge on the structure and our understanding of the molecular dynamics and functioning of ATP-synthesizing enzymes, the chemical mechanism of phosphorylation remains enigmatic: "Our understanding of ATP synthesis remains rudimentary in molecular terms.". . . The key reaction for the formation of the energy-carrying chemical bond P-O-P remains obscure. . . . Within the area of enzymatic reaction chemistry, all ideas are limited to speculations. . . . [But] an insight into the chemical mechanism follows from a recently discovered and remarkable phenomenon: a dependence of the phosphorylating activity of enzymes on Mg [magnesium] isotopy. This unusual effect was found for creatine kinese and ATP synthase. The rate of ATP production by enzymes in which the Mg 2+ ion has magnetic nucleus ^{25}Mg (nuclear spin 5/2, magnetic moment, -0.855 Bohr magneton) was shown to be *two to three times higher*

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22. The term "free radical" signifies, in the language of present-day conceptions of physical chemistry, roughly the following: The electrons, participating in the electronic configurations of atoms and molecules, display the strong tendency to form (essentially) magnetically coupled pairs with oppositely oriented spins. When, in a given atom or molecule, this pairing is incomplete and the outerward-most electron configuration contains a lone, unpaired electron, then the given entity is called a "free radical." Generally speaking, such free radicals are chemically highly reactive, and possess strong paramagnetic properties, giving them a special role in chemical, and above all, biochemical processes. But the last word has not been said on this topic, by far.

> than that induced by the same enzymes carrying spinless, nonmagnetic nuclei ^{24}Mg and ^{26}Mg. The discovery of this attention-catching effect convincingly demonstrates that enzymatic phosphorylation is an ion-radical, electron-spin-selective process in which the Mg ion Mg 2+ manifests itself as a reagent.

The paper goes on to report the comparable effect for still another crucial magnesium-containing enzyme involved in phosphorylation, phosphoglycerate kinase (PGK). Here the phosphorylation rates are 2.6 times higher with the magnetic isotope Mg-25, than with the nonmagnetic isotopes. Further analysis shows also that this is not a mere kinetic acceleration effect, but that the reaction process follows *different pathways* according to which isotope is present.

The technical details are not important for our present purposes. The point to be made here, is that a vast new field of biology and chemistry has been opened up, in which the magnetic characteristics of specific isotopes play a decisive role. Although the recent demonstration of isotope-specificity in the synthesis of ATP, obtained in materials of uniquely biological origin, constitutes a particularly striking case, these results cohere with the research in so-called "spin-selective chemistry," that has been developing over the last 20 years. The following quotes give a certain sense of this direction, while highlighting the need to overcome the mystification of quantum physics, which I mentioned above:

> Spin chemistry as a new field of chemical science is based on the fundamental principle: *chemical reactions are spin selective; they are allowed only for such spin states of products whose total electron spin is identical to that of the reagents and are forbidden if they require a change in spin.* Only magnetic interactions are able to change the spin of reactive intermediates. . . . Being *electron spin-selective,* the chemical interactions between the spin-carrying chemical species (radicals for instance) are also inevitably nuclear spin selective. If both electron and nuclear spin subsystems are coupled by the Fermi, or hyperfine magnetic interaction (HFI), then the nuclear subsystem can affect the behavior of the electron spin subsystem through HFI and, hence, modify the chemical reactivity. The *nuclear spin selectivity* differentiates the reaction rates for radicals (or, in general, for any other spin-bearing chemical species) with magnetic or nonmagnetic isotopic nuclei. This new phenomenon is the *magnetic isotope effect (MIE)* in contrast to the well-known classical isotope effect (CIE) which is a consequence of the nuclear mass selectivity of chemical reactions. Both isotope effects sort the isotope nuclei among the reaction products: *CIE selects the nuclei according to their masses, while MIE selects the nuclei according to their spins and magnetic moments.* (A. Buchachenko, "Comparative Analysis of Magnetic and Classical Isotope Effects," *Chem. Rev.,* 1995, 95.)

> The value for magnetic interactions of a field of 100,000 gauss with a nuclear spin is only ca. 1×10^{-5} Kcal/mole . . . or less [i.e., 500,000 times weaker than intermolecular bonds and more than 30 million times weaker than ordinary covalent bonds—JT]. In spite of the tiny value of these magnetic forces, we shall show that they can control the reactivity of radical pairs in a spectacular manner, if the supramolecular conditions are correct. (Nicolas Turro, *Chemical Communications,* 2002.)

Another, more speculative direction of thinking deserves mention:

> The availability of chemical elements on Earth has spawned a nearly unlimited variety of structures and organisms by variations of the chemical composition. It appears that by finding some biological role for essentially all chemical elements (including "microelements") Nature optimizes the resources of chemical diversification available to it. A similar possibility can likely arise for the isotopic diversity of elements. It seems improbable that Nature could "overlook" an additional level of informational diversification available through the isotopic degree of freedom. . . .
>
> Sternberg, DeNiro, and Savage (1986) and Galimov (1982) presented much-ignored findings about the isotopic composition of biochemical and genetic pathways. For example, during photosynthesis, the carbon obtained from CO_2 consists of ^{12}C and ^{13}C, but depending on the species of the plant, only one of these isotopes is preferentially fractionated. In the production of energy in the form of ATP, the carbon isotopes are selectively placed so that they will be propagated throughout the series of reactions in that same position. The conservation of isotopic structure persists in spite of the fact that the catalysis of enzymes changes the carbon skeletal structure of the intermediate molecules. . . .
>
> Elementary combinatorial analysis leads to an enormously large number of possible isotopic permutations of chemically fixed structures. For example, a segment of a DNA molecule with 1 million carbon atoms has about 10,000 randomly distributed ^{13}C atoms. The number of isotopically distinguished distributions (the number of possible placements of 10,000 atoms among 1,000,000 sites) is about 10^{24000}, far greater than the number of atoms in the Universe. . . . (J. Pui and Alexander Berezin, "Mind, Matter and Diversity of Stable Isotopes," *Journal of Scientific Exploration,* Vol. 15, 2001.)

Pui and Berezin go on to speculate, that permutations of the isotopic distributions in the tissues of the brain, may play an essential role in mental processes.

I should emphasize, that the above-cited work on the "magnetic isotope effect" represents only one, rather promising direction of research. Relative to the question we posed at the beginning of this section, the cited work still has the weakness, that it focusses only on the chemical-combinatorial "machinery" of these new isotope effects, and not on their relationship to the principles of living processes per se.

We can clearly see from these studies, however, that it is the special *physical-geometrical* environment, created in living tissue, that provides the context within which "infinitesimally small" isotopic shifts—which in the nonliving domain under normal circumstances would have only marginal, apparently merely statistical effects—can play a determining role in the course of macroscopic events. The unique character of living processes would thus reside, not in some specific mechanism or structure, but in the *power to generate and maintain such higher physical geometries,* which Vernadsky identified in his work, but which is more adequately addressed by LaRouche's elaboration of the Riemann-Dirichlet Principle.

The Multiple-Connectness Of the Isotope Economy with Astrophysics, Space Colonization, and the History of the Solar System

Man's physical existence, which depends upon his constant action upon the universe, calls forth another aspect of the relationship between the nonliving, living, and Noöspheric domains, which takes a new form in the Isotope Economy.

Up to now, mankind's requirements for raw materials have been met nearly entirely on the basis of extracting those materials from surface or subsurface deposits of minerals, created in the course of hundreds of millions or even billions of years of the Earth's geological history. The origin of many, if not most of those deposits is connected with activity of living organisms (mostly microorganisms) which concentrated specific chemical elements from their environment, and deposited them in fossil formations, sediments, or biologically transformed rocks.

In almost all cases, man's present rate of extraction of raw materials vastly—sometimes by billions of times—exceeds the rate at which mineral deposits of comparable quality are spontaneously replenished or created anew in nature.

Clearly, this process cannot continue indefinitely. True, in absolute terms man is still very, very far from exhausting the Earth's immense store of mineral deposits. But the implicit limits of the present, purely extractive mode reflect themselves today in marginally increasing physical costs in extraction and processing, required to obtain any given quality of material. We are thus obliged to go into increasingly remote areas of the Earth's surface, to meet greater costs in transport and other infrastructure; to dig or drill much deeper into the ground or sea bottom; to resort to lower-quality deposits having larger processing costs, as the higher-quality deposits become exhausted, and so forth.

These circumstances, together with the highly uneven geographical distribution of most raw materials, have already led to serious bottlenecks on a regional level and to a rise of geopolitical tensions through the maneuvering of nations such as China to secure their access to raw materials supplies, at the same time as speculative financial interests move to grab control over those same supplies, on the eve of an anticipated major crisis of the world financial system.

In the face of this situation, Lyndon LaRouche has proposed a "Vernadsky Strategy" with a 50-year time-frame. The Vernadsky Strategy provides for large-scale physical investments and other measures to guarantee adequate raw materials supplies at stable prices to all the world's nations, as a key component of an overall policy for reorganization of the world financial and economic system. LaRouche's strategy starts from the realization, that the task of securing long-term raw materials supplies to the world economy over the coming 50 years, can only be solved from the standpoint of Vernadsky's "Noösphere": Man must now progress from the stage of simply extracting mineral resources in a more or less disorganized way, to consciously managing and developing the entire process of generation and utilization of those resources on a planetary scale. This includes not only the "natural" processes of replenishment of resources within the biosphere, but also—increasingly!—the deliberate "de novo" creation of resources by man, through such processes as the large-scale transmutation of elements. At the same time, we need revolutionary advances in the technology of extraction and processing of raw materials and recycling of waste material, offsetting the tendency for marginal increase in the cost of raw materials, while at the same time radically improving the range and quality of the final products.

Until the emergence of nuclear energy, man's existence had been based exclusively upon a store of 83-odd stable chemical elements preexisting in the biosphere, and whose existence dates back nearly entirely to the genesis of the Solar System itself (the exception is certain quantities of elements created after the formation of the Earth by the radioactive disintegration of other elements).

In the course of the biosphere's evolution, the circulation of chemical elements on the Earth—the geochemical migration of atoms, as Vernadsky called it—has become more and more dominated by the action of living processes. In virtue of their ability to concentrate elements existing in their environment, living organisms, among them especially microorganisms, actually created many of the mineral deposits that man mines today as sources of raw materials.

In addition, even "inorganic" processes of ore-formation and evolution, which did not involve the *direct* action of living organisms, were *indirectly* influenced by the *biogenic migration of elements in the biosphere.*[23] This migration of elements is by no means limited to the immediate vicinity of the Earth's surface; the "sphere of influence" of the biosphere

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23. In his 1938 paper "On the Fundamental Material-Energetic Distinction Between Living and Nonliving Natural Bodies of The Biosphere" (translation published in the Winter 2000-2001 edition of *21st Century*), Vladimir Vernadsky elucidated the significance of the biogenic migration of elements in the following terms:

"Between the living and inert matter of the biosphere, there is a single, continuous material and energetic connection, which is continuously maintained during the processes of respiration, feeding, and reproduction of living matter, and is necessary for its survival: the biogenic migration of atoms of the chemical elements, from the inert bodies of the biosphere into the living natural bodies and back again. This appears in the form of motion—the departure and arrival of specific chemical compounds and elements to and from living organisms in connection with the processes of feeding, respiration, excretion, and reproduction, characteristic of living matter. These processes define the biogeochemical energy of living matter. . . ."


NASA

Artist's illustration of NASA's Mars rover, with its robotic arm ready to explore a rock. Very few of the conclusions of astrophysicists, Tennenbaum writes, "have been established with any real degree of certainty; nor could they be, so long as human activity remains bound to the immediate vicinity of the Earth."

extends via the constant vertical circulation of water (and the gases and ions dissolved in it) all the way down to the upper and lower mantle of the Earth.

Man's development of large-scale mining, transport, and industrial activities, has fundamentally changed the patterns of "migration" of mineral elements in the biosphere, leading finally to the point where man begins to create new resources by the transmutation of elements. This latest stage, Vernadsky associated with the emergence of the Noösphere.

As long as we merely used the pre-existing stores of elements on the Earth, Man was not directly concerned with the historical process of their creation, although the geologist and prospector are very much concerned with the history of their subsequent migrations on the Earth. Now, this changes dramatically.

Man's Economy Becomes Astrophysical

For the first time, human activity is transcending the limits of mere redistribution and combination of elements, to deal with their processes of generation. Indeed the business of large-scale synthesis, by nuclear reactions, of old and new atomic species, characteristic of the emerging Isotope Economy, brings man's economic activity into immediate, intimate relationship with the astrophysical domain, and the processes of formation of stars and planets. Discovering the principles behind those processes, and applying them to the task of further development of the biosphere and its extension into ever larger regions of the Solar System, self-defines man as a *universal being,* and not merely an inhabitant of the planet Earth; a being acting in accordance with a higher directionality, embedded in the Cosmos as a whole.

Conversely, the constant stream of new scientific discoveries in subatomic physics and related areas, required for the realization and maintenance of an Isotope Economy on Earth, cannot be supplied without the extension of *large-scale human activity beyond the orbital vicinity of the Earth,* to Mars and eventually beyond.

There are many, interconnected scientific and physical-economic reasons for this. As even the notion of a "neutron star," for example, suggests, subatomic processes are essentially *astrophysical* in character. Mankind's increasing mastery of such processes demands extensive cross-spectral investigations of faraway anomalous objects in our galaxy and in other galaxies, which cannot be made from the Earth or even from the Earth-plus-Moon system, on account of the insufficient parallax, disturbances coming from the Sun, and other causes. We must be able to carry out interferometry and related measurements on a length scale comparable to the Mars orbit—measurements eventually involving hundreds of laser-interlinked measuring stations "parked" in suitable solar orbits.[24] To set up and maintain these stations, and to constantly update them with new instruments in keeping with the advance of science and technology, requires constant human intervention and, accordingly, a vast logistical base to support the needed labor force and its activity in these distant orbital regions.

Some, even among professionals, might disagree with our assertion, that the progress of nuclear physics and astrophysics really necessitates such a—seemingly extravagant—program of space colonization. The "authoritative" tone of standard astronomical and astrophysical treatises, concerning such matters as the early universe, the structure of our galaxy and the mechanism of star-formation, the nuclear processes going on in the Sun, stars, and so forth, often gives the misleading impression, that the basic facts in these fields had already been established, and only details remain to be investigated. The truth, however, is that very few of those conclusions have been established with any real degree of certainty; *nor could they be,* so long as human activity remains bound to the immediate vicinity of the Earth.

This is the case even on the level of such "elementary" kinds of astronomical data, as the distances and true motions of relatively "nearby" objects in our galaxy. A shocking demonstration of this occurred late last year, when an international group of astronomers determined, by direct triangulation, that previous estimates of the distance separating our Solar System from the closest spiral arm in the galaxy—the Perseus Arm—were in

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24. For the current applications of large-scale interferometry in astronomy, see for example, "Space Very Long Baseline Interferometry" at http://www.hia-iha.nrc-cnrc.gc.ca/projects/vlbi_e.html. Also, the article "Very Long Baseline Interferometry" in Wikipedia.

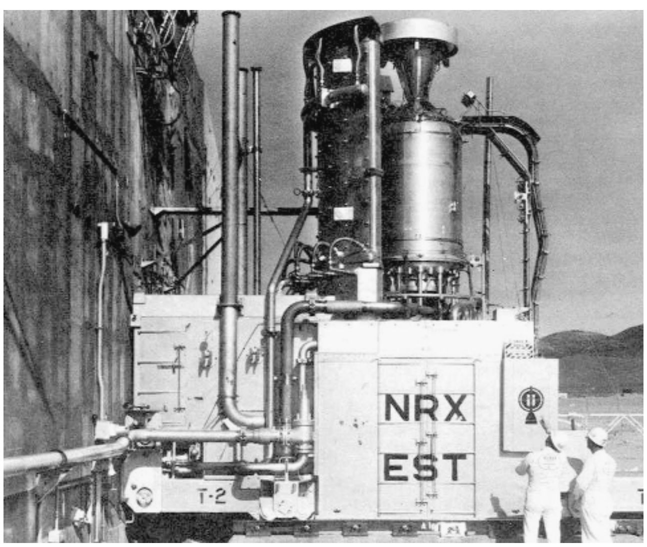
error by 200 percent![25] That occurred, despite the impression of super-precision of modern astronomical measurements, generated with the help of sophisticated instrumentation on the Earth and orbital observatories.

Evidently, the maps of our galaxy, reproduced as "fact" in countless treatises and textbooks, will have to be redrawn. Perhaps we know as little about the real form, history, and inner workings of our galaxy today, as Europe knew about the continent of America prior to Columbus's voyages! It is true that Eratosthenes, many centuries earlier, was able to determine the diameter of the Earth to an astonishing degree of precision, from the evidence of a small portion of its surface; just as Johannes Kepler, a century after Columbus, could discover the basic principle of the planetary motions in our the Solar System, without leaving the Earth. The significance of those triumphs of human reason, however, is not that we can learn everything about the universe merely sitting in our armchair on the Earth, but rather, that, thanks to the accumulated accomplishments of human reason, we have learned enough, working *from* the Earth, to now move out beyond the Earth. Accordingly, Eratosthenes' breakthrough was immediately followed by the first documented attempt to circumnavigate the Earth.

The point here is, that our present knowledge of nuclear physics, while highly imperfect, nevertheless suffices for the construction of first generations of nuclear fission- and fusion-powered space vehicles, and other technologies, and that will permit us to carry out the kinds of activities in the Solar System needed to assure a flow of future breakthroughs in nuclear physics.

Naturally, the mere spatial expansion of man's activities constitutes only a *necessary* condition for continued scientific breakthroughs. To get the breakthroughs, we need not only observations, but improved ways of *thinking* about them.

25. See a short report "Perseus Spiral Arm of the Milky Way much closer than thought"on Physorg.com at http://www.physorg.com/news9124.html; and "The Distance to the Perseus Spiral Arm in the Milky Way," by Y. Xu et al. at http://arxiv.org/pdf/astro-ph/0512223.



NASA

Nuclear rockets and fusion rockets are essential for man's exploration of the universe. Here, a nuclear rocket system ready for engine testing; the reactor and exhaust nozzle are visible above the lettering NRX (NERVA Reactor Experiment). The U.S. nuclear propulsion program, known as NERVA (Nuclear Engine for Rocket Vehicle Application), was developed in the 1960s as an essential component of the space program, but the nuclear program was killed in 1972 as part of the attack on science, and nuclear science in particular. Now NASA is again funding nuclear propulsion systems in its "Project Prometheus."

Back to Dynamics: The Revival of Nuclear Physics

In most of the discussion so far, I have restricted myself to developments that can be projected on the basis of the current knowledge and technological capabilities. These developments suffice to "insert" the world into the "orbit" of the Isotope Economy, but not for much more. Very soon, the need to carry out a long-overdue, sweeping revision of present physical theories will become acute. The medium- and long-term success of the Isotope Economy, depends upon doing the same thing for nuclear physics and physical science in general, as Johannes Kepler did for astronomy nearly 500 years ago.

Indeed, the present state of nuclear physics bears an uncanny resemblance to the hodgepodge of conflicting models and calculational procedures, which characterized the astronomy of Kepler's day, and which he swept away with his epoch-making *New Astronomy*. Kepler was well aware of the fact that he was not simply correcting flawed theories, but was combatting a monstrous fraud, perpetrated centuries before by Aristotle and Ptolemy, whose political promotion imposed a "dark age" in European science, from the death of Archimedes until the 15th Century Renaissance.

We should hope that the kind of training obtained by working through Kepler's method of discovery, will permit a new generation of young physicists to accomplish the analogous task with nuclear physics and astrophysics today.[26]

The concluding two sections of this article are intended as a prelude for things to come. I shall start with a very simple paradox, which one of the founders of nuclear physics, Werner Heisenberg, returned to at the end of his life.

The question is simply this: Nearly all of us are raised in the empiricist-reductionist doctrine, that every entity in the universe is built up from some sort of simpler elements or "building blocks" which are parts of them. A typical example of this is the notion that molecules are composed of atoms, atoms from electrons and nuclei, nuclei from protons and neutrons, etc. But what do we really mean, when we say that one entity is a *part* of another? Or that it is "made up of" such parts?

Without needing to go into anything so advanced as nuclear

26. See the article, "Animating Creativity: The Functioning of a Healthy, Human Mind," by the New Astronomy Animations Team, in *EIR* Oct. 13, 2006. Work by the Animations Team can be found on the website of the LaRouche Youth Movement, www.wlym.com, at http://wlym.com/@~animations.

The half-assembled Chicago cyclotron magnet, with inset of its designer, Dr. Robert J. Moon (1986). This cyclotron, the second in the world, was built by the late Dr. Moon and a team of students of Dr. William Harkins at the University of Chicago in 1936.

Dr. Robert J. Moon

physics, we can demonstrate the paradox very beautifully with the case of *water.* In high school, we learn that water is composed of entities called water molecules, and that these are composed of one oxygen and and two hydrogen atoms each according to the formula H_2O. But, there is no simple relationship at all between the *properties* of oxygen and hydrogen, on the one side, and the properties of "water" which is supposed to be composed of them! In fact, the high school chemistry student, letting a bit of oxygen and hydrogen gas combine, will be very hard put to recognize *anything* at all suggesting the properties of those two gases in the droplets of water that are formed as a product of the little explosion in his test tube! At most, the *masses* of the reacting portions of hydrogen and oxygen, or rather their *sum,* appear to have been preserved as the mass of the resulting water. But even this (approximate) invariance is noticeably violated in the world of nuclear reactions: There, the result of the fusion of two nuclei can be very significantly *lighter* than the sum of their masses. (See discussion below.)

These anomalies make it clear, that the *source* of the properties of water (for example) cannot be found in either oxygen or hydrogen, neither separately nor together. Whence, then, did those properties come? Should we not rather assume, that "water" was already *present,* as a potential state of organization, and merely required the two as means to *express* itself? The essence of "water" lies in the *change* that occurred in the reaction.

The source of the difficulty is the tendency, going back to Aristotle, and renewed by Galileo and Paolo Sarpi's counterrevolution against Kepler's Platonic method, to falsely regard objects of the senses as "real," and ideas as "abstract"; whereas in reality, the opposite is true; namely, that it is ideas that are real, and what we call sense objects are merely effects deriving from them.

This elementary error, in turn, lies at the origin of the still-ongoing, vain attempts by physicists, to deduce the properties of atomic nuclei from the assumption, that the nuclei are "made up" of particles interacting pairwise according to this or that mathematical formula. This attempt to emulate Isaac Newton, who in fact totally failed to account for the most elementary harmonic features of the Solar System with his force law,[27] has now occupied nuclear physicists for nearly a century. Yet no one has been able to come up with a solution, and the vain search for one has led the entire theoretical development of nuclear physics into a blind alley.

In former times, many scientists had some awareness of the fraud of reductionism. Back in the early 1970s, for example, in the process leading to the founding of the Fusion Energy Foundation, Lyndon LaRouche became acquainted with the University of Chicago physicist and physical chemist Prof. Robert J. Moon, a veteran of the wartime Manhattan Project who had designed the first cyclotron used in the Project.[28] According to the story I have heard, Moon

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27. In his works, *Mysterium Cosmographicum, Nova Astronomia,* and *Harmonia Mundi,* Johannes Kepler set forth a comprehensive conception of the organization of the solar system as a single, harmonically ordered system in which the orbits and motions of the planets are all coupled to one another. Unfortunately, Kepler's conception was subsequently buried under the influence of Galileo and Newton, and especially the politically motivated promotion of Newtonian mechanics as the supposely *sine qua non* of physical theory. In fact, Newton derived his famous "force law" by a mere algebraic inversion of the empirical laws that govern motion in single elliptical orbit, ignoring the deeper harmonic features of Kepler's system.
    The resulting, abstract reductionist approach of Newton, while apparently suited to the hypothetical case of a single, isolated planet orbiting the Sun, is plunged into hopeless mathematical difficulties—the infamous "Three Body Problem" or "N-body problem"—when confronted with a more complex system. Not only does Newton's approach fail to account for even the most elementary features of the harmonic distribution of the planetary orbits taken together, but it completely misses the reality, that our Solar System has developed, and continues to exist, as a single coherent astrophysical system, organically linked to the Sun. On a deeper level, it is necessary to rethink the assumption, that the so-called "gravitational," "electromagnetic," and "nuclear forces" really exist in nature, as separable entities.
28. See the special issue of *21st Century,* "The Continuing Legacy of Dr. Robert J. Moon," Fall 2004.

then voiced his opinion, that "contemporary nuclear physics is a bunch of garbage." As an *example* of this, Moon claimed that the standard interpretation of the famous "alpha scattering" experiments, upon which Rutherford and later physicists derived their estimates of the size and other fundamental characteristics of the atomic nucleus, were based on fallacious and arbitrary assumptions concerning the nature of the interactions between the nucleus and the alpha particles used to bombard the nucleus.

Similarly, according to Moon, the entirety of research into controlled nuclear fusion had been thrown onto the wrong track by the mistaken assumption, that a so-called "Coulomb force" between nuclei must be overcome, in order to make fusion reactions occur. It is this assumption, which precludes the possibility of "polarized fusion" of the sort LaRouche proposes. In the search for means to "overcome the Coulomb barrier," fusion scientists saw themselves obliged to impart enormous velocities to the nuclei, which in turn meant working with temperatures of millions of degrees celsius. And yet, as many experiments demonstrate, that "barrier" can be made to disappear, if the system is placed in a suitable physical geometry. (Such a possibility is already acknowledged in so-called wave mechanics, but in a sophistical way, as "resonant tunnelling.")

But if the states of atomic nuclei are not determined by elementary forces, and if indeed there is no such thing as an "elementary force," then what determines the states of atomic nuclei? The first step would be to admit that *it is the states of organization themselves, and the intentionality behind them, which are the proximate efficient agents of nuclear processes.* It is exactly with this idea in mind that the late Dr. Moon, inspired by discussions with LaRouche, in 1985 proposed a new, geometrical approach to nuclear physics, without the assumptions about "elementary forces." In proposing his now-famous model of the nucleus in terms of embedded regular solids, Moon emphasized, for example, that "the proton is a singularity that exists within, and depends upon, the geometry of the whole of space." He insisted that *the particles arise from the geometries, rather than the geometries arising from particles deciding to arrange themselves in this or that way.*

But how, for example, could a geometrical entity—let us say, a regular solid—be able to exercise any sort of efficient action in the universe? Consider the following four passages, one from Plato's *Timaeus,*[29] two from posthumous fragments by Bernhard Riemann,[30] and one from the last published writing by Werner Heisenberg in 1976,[31] respectively:

Plato in *Timaeus:*

What we always observe becoming different at different times, such as fire, we should not refer to as a *this,* but in each case as a *thus,* nor refer to water as a *this,* but always a *thus;* and of those things that we suppose we can indicate by pointing and using the expressions "this" and "that," we should never refer to any of them as if they have any permanence. . . . We should not use these expressions, but we should call "such-like" ("thus") that which in each and every thing continually recurs as similar, and thus call "fire" that which is such-like throughout everything, and so on for everything which is subject to a process of becoming.

Riemann:

I. What an Agent strives to realize, must be determined by the concept of the agency; its action can depend on nothing else, than its own nature.

II. This requirement is fulfilled, when the Agent strives to maintain or to establish *itself.*

III. But such an action is unthinkable, if the Agent is a thing, an existent, but is only thinkable, when it is a condition (state) or a relationship. When there is a striving, to maintain something or to create something, then deviations from this "something"—in fact, deviations in varying degrees—must be possible; and this "something" will in fact, insofar as this striving is opposing other tendencies, only be maintained or created as closely as possible. But there is no degree of existence; a differentiation in terms of degree is only thinkable for a state or a relationship. Therefore, when an Agent strives to maintain or create itself, that Agent must be a condition or a relationship.

Second fragment by Riemann:

With each act of thinking, something persisting and substantial enters our soul. I call it *Geistesmasse* [thought-mass]. All thinking, therefore, is generation of new *Geistesmassen.* . . . The *Geistesmassen* are imperishable, everlasting. Only the relative power of these connections changes, through the integration of new *Geistesmassen.* The *Geistesmassen* do not need a material carrier, and do not exercise any constant effect in the world of appearances. They have no relation to any part of matter, and are, therefore, not located in space. But, any new generation, and any new connection between *Geistesmassen,* requires a material substrate. . . . Each *Geistesmasse* strives to generate a similar *Geistesmasse.* It therefore strives to bring about the same form of motion of matter, through which it was generated.

Finally, Heisenberg:

I believe that certain erroneous developments in particle theory—and I am afraid that such developments do exist—are caused by a misconception that it is possible to avoid philosophical arguments altogether. Starting with

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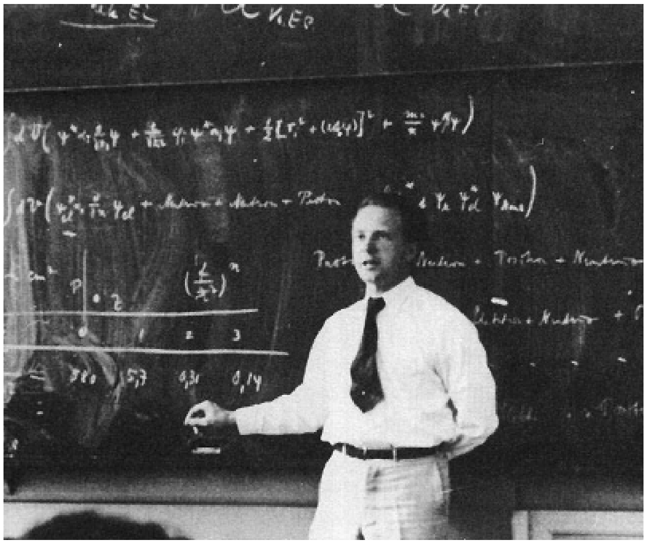
29. The best translation of the *Timaeus* into modern languages, as far as this author knows, is that made by LaRouche's collaborators and published in the February 1980 issue of *The Campaigner,* pp. 35-74.

30. From *Bernhard Riemann's Gesammelte Mathematische Werke,* Sändig Reprint Verlag, in the section "Fragmente philosophischen Inhalts," pp. 509-510 and p. 524. An English version appears in *21st Century,* Winter 1995-1996.

31. "The Nature of Elementary Particles," Werner Heisenberg, *Physics Today,* Vol. 29, No. 3, pp. 32-40 (March 1976), and reproduced in *Heisenberg Gesammelte Werke* (Collected Works), Springer-Verlag 1984, pp. 917-927.



Werner Heisenberg wrote that when the wrong questions are posed in particle physics, the wrong answers naturally emerge. "The particle spectrum can be understood only if the underlying dynamics of matter is known; dynamics is the central problem," he wrote, recommending the study of the philosophy of Plato to solve this problem.

> poor philosophy, they pose the wrong questions. . . .
>
> Before this time [the experiments of Andersen and Blackett demonstrating so-called pair production of electrons and positrons by a quantum of light—JT] it was assumed that there were two fundamental kinds of particles, electrons and protons . . . their number was fixed and they were referred to as "elementary" particles. Matter was seen as being ultimately constructed of electrons and protons. The experiments of Andersen and Blackett provided definite proof that this hypothesis is wrong. Electrons can be created and annihilated; their number is not constant; they are not "elementary" in the original meaning of the word. . . .
>
> There is no difference between elementary particles and compound systems [such as atoms and molecules—JT]. This is probably the most important experimental result of the last fifty years. That development convincingly suggests the following analogy: Let us compare the so-called "elementary" particles with the stationary states of an atom or molecule. We may think of these as various states of one single molecule or as the many different molecules of chemistry. One may therefore speak simply of a "spectrum of matter.". . .
>
> Wrong questions and wrong pictures creep automatically into particle physics and lead to developments that do not fit the real situation in nature. . . . We will have to accept the fact that the experimental data on a very large and very small scale do not necessarily produce pictures, and we must learn to do without them. . . . The philosophy of Plato appears to be the most adequate. The particle spectrum can be understood only if the underlying dynamics of matter is known; dynamics is the central problem.

Radioactivity, Isotopes, And the Ironies of The Periodic System

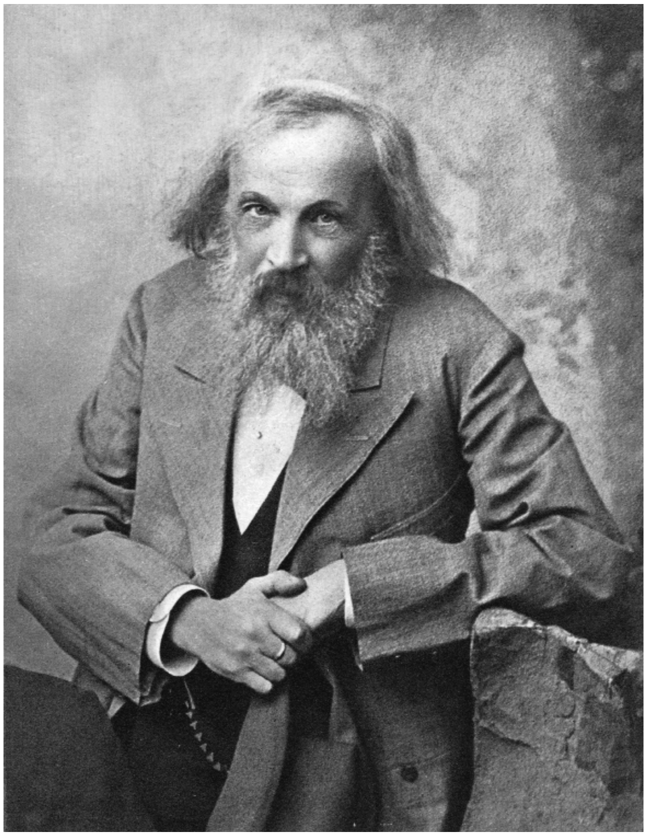
Bearing these paradoxes in mind, the following paragraphs are intended to provide the reader—above all, the non-specialist reader—with some brief background on the discovery and nature of isotopes, and some principles of nuclear physics related to them, as far as they are known today.

One should always remember, that atomic and nuclear physics, insofar as they are valid, developed by applying essentially the same method, used by Johannes Kepler in his original discovery of the principle of gravitation in the *astrophysical* domain, to the domain of *microphysics.* That relationship between astrophysics and microphysics is lawful and necessary. It came to the fore once more, in the manner in which nuclear physics developed out of the anomalies of the periodic system of elements. So I will take up the story at that point.

At the time that Dmitri Mendeleyev began his scientific work in 1855, the central axiomatic assumption of chemistry was the notion of a chemical *element.* This notion is associated with the idea, that we cannot differentiate or divide substance indefinitely, without encountering some kind of a limit, boundary, or, as we say, singularity. In the specific practice of chemistry up to the time of Mendeleyev, the exploration of this area took the form mainly of what are called chemical separation methods: distillation, precipitation, electrolysis, centrifugation, and so forth. Generally speaking, we start with any kind of stuff, and we do various things to it, to see if we can induce a separation or differentiation of the original stuff into two or more new substances, each having clearly distinct characteristics.

So in electrolysis, out of water, we produce hydrogen and oxygen, for example. And then we take those new substances which we produced by the separation of the first one, and try to do the same thing with each of those two. We keep doing that, trying to push the process to the point of a limit, a singularity. Through this kind of exploration, chemists in fact did arrive at a limit, as expected, in the form of what were sometimes called "simple bodies" or elements—substances which seemingly could no longer be caused to differentiate further. From ancient times, a number of such elements had been identified: iron, copper, tin, lead, mercury, gold, silver, sulfur, and carbon. About five more elements were added in the Middle Ages, and then, under the influence of Gottfried Leibniz's work in launching the Industrial Revolution, there occurred, from about the 1740s on, an explosive development of physical chemistry. Thus, by the time Mendeleyev graduated from the Main Pedagogical Institute of St. Petersburg, about 64 chemical elements were known.

There are different, opposing types of hypotheses associated with the term "chemical element." Empiricism has insisted, for example, on the supposedly self-evident axiom or idea which is still repeated, unfortunately, in much of our elementary education: namely that the elements represent unbreakable, ulti-



Dmitri Mendeleyev. "The implications of what was set in motion by the discovery of radioactivity and the isotopes, growing out Mendeleyev's 'Keplerian' understanding of the periodic system, go far, far beyond anything the world has seen up to now."

mate "building blocks" of matter, whose supposed quality of reality is borrowed from the baby's earliest years in the playpen. The great French chemist Lavoisier, on the contrary, adopted the more adult view that the chemical elements are *singularities,* in a search not for ultimate building blocks, but for what he called the "principles" of matter.

In 1869, Mendeleyev published his first version of the Periodic Table, demonstrating that the chemical elements constitute a single, harmonically ordered organism—entirely as Kepler had seen the system of planetary orbits. Mendeleyev's discovery of the periodic system was provoked by his work as a teacher. In teaching, he was irritated and provoked by the chaotic mass of data on the individual elements, and asked himself the question: Is what we're doing here really a science? Can I present this as a science? Mendeleyev wrote the following:

> The mere accumulation of facts, even an extremely extensive collection, . . . does not constitute scientific method; it provides neither a direction for further discoveries nor does it even deserve the name of science in the higher sense of that word. The cathedral of science requires not only material, but a design, harmony . . . a design . . . for the harmonic composition of parts and to indicate the pathway, by which the most fruitful new material might be generated.

Mendeleyev arrived at his discovery, after many failed attempts by other chemists, by juxtaposing two distinct types of experimentally defined orderings of the elements:

First, the natural division of the elements into *distinct chemical groups,* each composed of elements having similar or analogous characteristics of the member-elements, relative to the totality of the elements, in terms of the types of chemical compounds and crystals they form, and other physical-chemical properties.

Second, the "ranking" of the elements in a *single sequence,* according to increasing values of their atomic weight, starting from hydrogen and ending with uranium.

Mendeleyev's choice of that second ordering principle, was crucial. He correctly hypothesized, that the "atomic weights," among all the known physical and chemical parameters, reflected an *invariant,* a "something" that is preserved in all chemical transformations. At the same time, Mendeleyev steadfastly rejected all attempts at a simplistic explanation of the sequence of elements, in terms of their being built up, in a linear fashion; for example, from hydrogen as the main "building block." Mendeleyev insisted that each single chemical element represented a true "individual."

Struggling with the ambiguities and inaccuracies of the then-existing empirical data, Mendeleyev finally gave birth to the "natural system of elements," as he called it, and the fundamental discovery, that the chemical properties of an element are essentially a multiple-periodic function of the *ordinal number* of the element in the series of increasing atomic weights. This principle not only permitted nearly the entirety of then-existing knowledge of the chemical elements to be brought together into a coherent whole, but also led Mendeleyev, and later others, to successfully predict the existence and characteristics of "missing" chemical individuals.

The Underlying Dynamic Process

But Mendeleyev himself regarded his discovery merely as a *first step.* In his 1870 article "On the Natural System of Elements," he wrote:

> When we succeed in discovering the exact laws for the periodic dependence of the properties of elements from their atomic weights, and for the atomic interrelations between the elements, then we will come nearer to understanding the true nature of the mutual differences between the elements; then chemistry will be able to leave the hypothetical domain of the static conceptions, which have prevailed until today, behind it; and the possibility will open up, to apply to chemistry the *dynamical approach, which has been so fruitfully employed for the investigation of most physical phenomena* [emphasis added].

The breakthrough in uncovering the *dynamic* process underlying the periodic system, came from three experimental directions. First, by studying the anomalies of the system of elements: its still-unfilled gaps; the question, why the series of

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Marie Curie surmised that radioactivity was connected with a process of "atomic transformation" that underlay the close association of radium and polonium with uranium and certain other substances. Subsequent research confirmed her conjecture: Radium was slowly being turned into lead.

elements seemed to break off at uranium; and finally, the anomalous character of the atomic weights themselves, whose ratios are often close to, but still distinctly different from, simple whole-number ratios (see below). Second, by investigating various forms of *radiation* emitted by atoms. Third, through pursuit of the anomalies of geochemistry, by investigating the distribution of the elements in nature, in minerals for example, where certain elements are found in close association with one another, "as if" they had some "hereditary" relationship to each other.

Following Roentgen's discovery of X-rays, which are generated when accelerated electrons strike the surface of a metal, Becquerel found that salts of uranium *spontaneously* emitted a weak sort of radiation, capable of darkening photographic plates, but apparently without the need for any stimulation from the outside. Marie Curie later coined the term "radioactivity," suggesting that the source of Becquerel's radiation lay in an inherent, dynamic activity of the atoms themselves. Following up this situation with a new method of measurement, Marie Curie investigated all available minerals, finding Becquerel's radiation present *exclusively* in minerals containing uranium and thorium—the last and next-to-last elements in Mendeleyev's system! Certain anomalies led her to suspect, that the main source of the radiation was not uranium and thorium themselves, but traces of some other element or elements, associated with them in the same minerals. Marie and her husband, Pierre, were subsequently able to isolate, from large amounts of the uranium ore by-product pitchblend, two new, highly radioactive elements: first polonium, and then radium, filling the empty spots of ordinal numbers 84 and 88 in Mendeleyev's table.

That was 1898. An avalanche of new experimental discoveries unfolded in the following years. It was found that radium, in addition to emitting a continuous bluish glow, also produced significant amounts of heat, amounting each year to the equivalent of burning 100 times its weight in coal! And yet, the heat and light emission from radium seemed to continue, year after year, with no sensible decrease. Marie Curie hypothesized that this radioactivity was connected with a process of "atomic transformation" that somehow underlay the close association of radium and polonium with uranium and certain other substances, always found together in uranium-containing minerals; and that the radium was very slowly transforming itself into one or other elements.

Subsequent research confirmed her conjecture: Radium was very slowly transforming itself into . . . lead! The rate of transformation was so slow, that after about *1,600 years* only about *one half* of the original amount of radium will have turned into lead, accompanied simultaneously by a gradual release of helium gas. In that process, the radium will have emitted an amount of heat equivalent to nearly a *million times* its weight in coal. It was immediately evident, that the discovery of this new, "atomic" energy would lead to a revolution in human affairs, as soon as means were found for accelerating the spontaneous, apparently very slow process of atomic transformation.

Meanwhile, the bigger picture gradually came into focus, of the existence of several distinct "radioactive decay chains," starting from uranium and thorium, in the course of which many successive atomic transformations occur, simultaneously and at widely differing average rates, and in which the generation and decay of radium and polonium constitute intermediate steps on the way to lead as the "end-point." One of them, for example, has 15 transformations, jumping back and forth upwards and downwards in the periodic system, before finally arriving at lead. Some of the steps occur within seconds, others several minutes or days, still others take years, all the way up to *several billion years* for the initial step leading from uranium.

As Mendeleyev had anticipated, a highly dynamic reality began to come into view, beneath the apparently tranquil surface of the periodic system, with its seemingly fixed relationships: a world of creation, death, and metamorphosis of elements, in which different principles are at work than those expressed in the Periodic Table per se.

Transmutation and the Discovery of Isotopes

So far, radioactivity concerned only the spontaneous transformations occurring in a small handful of elements. But by 1926, scientists had learned to carry out the first "artificial transmutations" of other elements, transforming nitrogen atoms into oxygen atoms by exposing them to radiation from a radioactive source. Evidently, the transmutation of elements—the dream of the alchemists—was a universal potentiality. The view suggested itself, that the distribution of elements, found today on the Earth, is a "fossil" of an evolutionary process, involving possibly many forms of nuclear reactions. The phenomena of atomic energy provided a crucial clue to the long-standing riddle, what the power source of our Sun might be, as well as a possible relationship between nuclear processes going on in the Sun and stars, and the origin of the chemical elements.

But already, earlier during the first decade of the 20th Century, scientists had discovered something else of fundamental importance: There was something very special about the substances produced in radioactive decay processes. Some of those products of atomic transformations resembled naturally occurring elements very closely, and could not be separated from them chemically when mixed together; yet they had very different radioactive characteristics. For example, the substance then called "ionium," arising from the decay of uranium, appeared chemically identical with thorium, but decayed in mere days; whereas the half-life of natural thorium is so long (over 10 billion years), that it could barely be estimated at that time.

In 1910, Frederick Soddy suggested that there might exist subspecies of one and the same element, having different atomic weights, but virtually identical chemical properties. He coined for these the term "isotope," meaning in Greek "the same position," to signify that from a chemical point of view, these subspecies would belong to the same position in Mendeleyev's periodic system. A few years later, researchers could confirm, for example, that the lead accompanying minerals of uranium has a *different atomic weight,* than the lead found in minerals of natural thorium. Thus, "lead is not lead": different radioactive chains end up in different lead isotopes. These discoveries laid bare an extraordinary ambiguity in the concept of an element, which had been the entire basis of chemistry!

By the late 1920s, with Aston's development of the mass spectrograph, and thereby of the ability to measure atomic weights with vastly greater precision, it had become clear that the existence of distinct isotopes was a ubiquitous property of the chemical elements; and that practically all elements found in nature, whether radioactive or not, consisted of mixtures of isotopes in various ratios. It became evident, that the number of isotopes is many times larger than the number of elements, even as regards the stable isotopes. Iron, for example, has four known stable isotopes; calcium has six, and tin, has the record highest number, with ten, all occurring with significant abundance on the Earth. It lies in the nature of the nuclear transformation processes, that different isotopes of one and the same element will generally have *different* origins, different *pre-histories* in the evolution of the universe.

Today, some 3,000 different isotopes are known, most of which were created by man. That corresponds to an average of about 30 isotopes for each element! Most of these are short-lived in their "free" state, but they nevertheless represent realizable modes of existence of matter in our world.

All of this means adding a new *dimensionality* to Mendeleyev's periodic system. The discovery of isotopes called for a complete reworking of chemistry. How, then, should we now conceptualize the ordering of a newly emerging "periodic system of isotopes"? The answer, as far as science has gone with it until today, is inseparably connected with the *anomalies of the atomic weights.*

Mendeleyev had based his periodic system on the *ranking* or *ordinal number* of the elements in order of their increasing atomic weight, using the comparison between this ranking and the periodicity of chemical and crystallographic characteristics, to correct for the inaccuracies of measurement of the atomic weights and to determine the positions of "missing" elements in the series. The challenge remained, to better understand the significance of the values of the atomic weights themselves, which manifested both regularities, as well as curious irregularities.

On the one hand, those values, regardless of the units used to express them, display an unmistakable tendency to form whole-number proportions. At the beginning of the 19th Century, the English chemist William Prout pointed out that the atomic weights of the elements appeared to be integral multiples of the atomic weight of hydrogen, the lightest element; and upon this he based his hypothesis, that the elements are somehow composed from hydrogen as the basic building-block.

Mendeleyev, however, rejected this reductionist conception on principle, and it was refuted experimentally by more precise measurements of the atomic weights. Particularly striking was the case of chlorine, recognized as a chemical element in 1820, and whose atomic weight, relative to that of hydrogen, is about 35.5. In fact, when Mendeleyev made his periodic table, he listed the values of the atomic weights for the first two "octaves" of his system, as they were then known, in a very rough approximation, as follows:

H 1						
Li 7	Be 9.40	B 11	C 12	N 14	O 16	F19
Na 23	Mg 24.3	Al 27.4	Si 28	P 31	S 32	Cl 35.5

What is the cause of the mixture between (very nearly) integral, as well as clearly non-integral values, and of the irregular distribution of the "jumps" in the values between successive elements? Did this mean more "missing" elements, or even new chemical groups? Elements perhaps of a different kind, than Mendeleyev allowed for?

New Anomalies

Here the discovery of the isotopes, and the subsequent measurement of their atomic weights, brought a crucial breakthrough. An extraordinary regularity emerged, that had hitherto been hidden; while at the same time, new anomalies appeared, which remain at the core of modern nuclear physics up to this day.

First, it was recognized, that since the naturally occurring elements are in reality mixtures of isotopes, having themselves different atomic weights, the previous measured value for the elements reflected a kind of average of the atomic weights of the corresponding isotopes, "weighted" according to the relative percentages of the isotopes in the mixture. The reason for the half-integral value for chlorine, for example, lies in the circumstance, that naturally occurring chlorine is composed of a mixture of two isotopes, one with atomic weight very nearly 35, the other with atomic weight about 37, in a ratio of approximately 3 to 1.

ATOMIC WEIGHTS AND ISOTOPIC COMPOSITION FOR SELECTED ELEMENTS

Isotope			Relative Atomic Mass	Isotopic Composition
1	H	1	1.007 825 032 1(4)	99.9885(70)
	D	2	2.014 101 778 0(4)	0.0115(70)
	T	3	3.016 049 2675(11)	
2	He	3	3.016 029 309 7(9)	0.000 137(3)
		4	4.002 603 2497(10)	99.999 863(3)
3	Li	6	6.015 122 3(5)	7.59(4)
		7	7.016 004 0(5)	92.41(4)
4	Be	9	9.012 182 1(4)	100
5	B	10	10.012 937 0(4)	19.9(7)
		11	11.009 305 5(5)	80.1(7)
6	C	12	12.000 000 0(0)	98.93(8)
		13	13.003 354 8378(10)	1.07(8)
		14	14.003 241 988(4)	
7	N	14	14.003 074 005 2(9)	99.632(7)15
			15.000 108 898 4(9)	0.368(7)
8	O	16	15.994 914 6221(15)	99.757(16)
		17	16.999 131 50(22)	0.038(1)
		18	17.999 160 4(9)	0.205(14)
9	F	19	18.998 403 20(7)	100
10	Ne	20	19.992 440 1759(20)	90.48(3)
		21	20.993 846 74(4)	0.27(1)
		22	21.991 385 51(23)	9.25(3)
11	Na	23	22.989 769 67(23)	100
12	Mg	24	23.985 041 90(20)	78.99(4)
		25	24.985 837 02(20)	10.00(1)
		26	25.982 593 04(21)	11.01(3)

This table shows the relative atomic mass and relative abundance of isotopes of the 12 lightest elements.

Source: International Union of Pure and Applied Chemistry, 1997, http://www.iupac.org/reports/1998/7001rosman/iso.pdf

Comparing the atomic weights of the *isotopes* with one another, instead of those of the *elements,* the large divergences from whole-number ratios disappeared and a remarkable new set of relationships came into focus.

The relationships of the isotope values stick out most clearly, when they are referenced not to hydrogen, but to a certain specific isotope of carbon (nowadays denoted C-12). When we set as unit 1/12 the atomic weight of carbon-12, then the numerical values of the atomic weights of the known isotopes turn out, without exception, to be within a tenth of so, at most, from a whole number. In most cases the deviation is even much smaller (See Table).

Thus, each isotope can be unambiguously associated with a certain whole number, nowadays called its "mass number," which very nearly coincides with its atomic weight.

Hydrogen, for example has naturally occurring isotopes, of mass numbers 1, 2; oxygen has three: 16, 17, 18; calcium has six of them: 40, 42, 43, 44, 46, 48; tin has ten: 112, 114, 115, 116, 117, 118, 119, 120, 122, 124, and so on. It was natural to expect, that where gaps existed in the series of mass numbers, as between calcium-44 and calcium-46 for example, an additional calcium isotope with mass number 45 should exist, and probably an *unstable one*—as that would explain its apparent rarity in nature. Indeed, as accelerators, and later, nuclear reactors began to produce large quantities of new isotopes, many of those "holes" in the series of isotopes were filled, and the existing series extended upwards and downwards. There could hardly be a doubt, that the isotopes of one and the same element are naturally ordered in the manner of successive whole numbers.

But then a new set of questions arises: Why are some isotopes stable and others not? Why do the gaps tend to occur most often at *odd-number* locations? What is the reason that some elements have many isotopes, others very few, or even only one? What is the reason for certain patterns in the relative abundances of different elements in Nature, which have no obvious relationship to the periodicities of Mendeleyev's table?

In the meantime, investigations of the X-ray spectra of chemical elements provided a new physical foundation for Mendeleyev's ordering of the elements themselves, independent of the atomic weights: The array of X-ray spectral frequencies of a given chemical element, change stepwise in completely regular and systematic fashion, as we go from one element to its successor in the periodic system (see Figure 1). It became possible to predict the X-ray spectra of yet-unknown elements, and to identify and discover them, even in extremely small concentrations, through their telltale X-ray "signature." But the X-ray spectra of isotopes of a given element, are nearly exactly identical, like their chemical behavior.

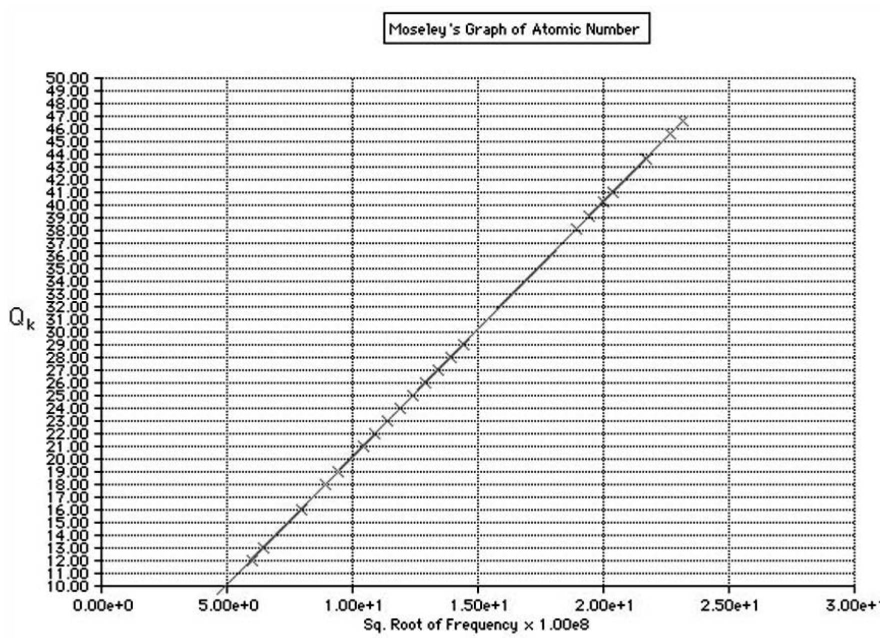
Isotopes and Gaussian Complex Numbers

Thus, atoms in our universe appeared to have a twofold nature:

First, their identity as chemical elements, reflected in their

Figure 1
HIGH FREQUENCY SPECTRA OF THE ELEMENTS

British spectroscopist H.G.J. Moseley published this graph of the spectra of the elements in 1913. He arranged the spectra of the elements on horizontal lines spaced at equal distances, ordering the elements according to atomic weight (with a few exceptions). This revealed the simple proportionality between the atomic number (or ordinal number) of elements in the periodic table (vertical axis), and the square roots of the main frequencies of emission (emission lines) of X-rays by atoms of those elements (horizontal axis), when excited by electrons (cathode rays).



"This is equivalent to assigning to successive elements a series of successive characteristic integers," Moseley wrote. ". . .This proceeding is justified by the fact that it introduces perfect regularity into the X-rays spectra. . . . We can therefore conclude from the evidence of the X-ray spectra alone, without using any theory of atomic structure, that these integers are really characteristic of the elements."

Source: H.G.J. Moseley, M.A., "The High Frequency Spectra of the Elements," *Phil. Mag.* (1913), p. 1024. See http://dbhs.wvusd.k12.ca.us/webdocs/Chem-History/Moseley-article.html.

affinities for other elements, with which they form chemical compounds; in the types of crystals they form, alone or in combination with other elements; in the conditions under which they take solid, liquid, or gaseous forms, and so forth; and in their optical and X-ray spectra.

Second, their "new" identity as isotopes, in the context of all the discoveries we have just summarized, which form the main starting point for the domain called "nuclear physics."

Finally, these two aspects must be intimately connected with each other, in ways that are not yet adequately understood.

Much is left to be done, but we know that the emergence of nuclear physics, in the process we have just sketched, exemplifies the form of progression of

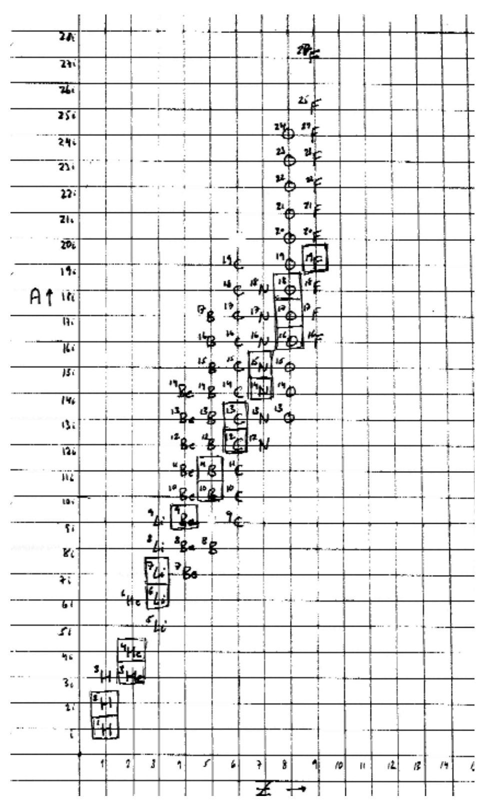


Figure 2
COMPLEX MAPPING OF THE ISOTOPES

The isotopes can be ordered by associating each with a Gaussian complex whole number. The atomic number of the isotope according to Mendeleyev's periodic system is mapped on the horizontal axis (the "real axis"), and the mass number is mapped on the vertical axis, the "imaginary part." This locates the isotopes of an element on lines parallel to the vertical axis, at heights corresponding to the whole number closest to its atomic weight. This lays a preliminary basis for the real work of discovering the physical principles underlying the existence and transformations of the isotopes and the relationship between the chemical and nuclear processes. The tiny discrepancies between the physical values of the atomic weights, and the integers of the mass number are key.

Note that this representation differs from the more common one, which chooses for the vertical coordinate the excess of mass number over atomic number, usually referred to as the neutron number, rather than simply the mass number used here.

human knowledge that Bernhard Riemann described in his famous paper "On the Hypotheses Underlying Geometry": the generation of a higher-order manifold of human practice out of a lower-order one, by the integration of an additional newly discovered physical principle.

How, then, should we now represent the emerging *system of isotopes?* The most straightforward approach, given the fact of the emergence of a new "dimensionality" in Riemann's sense, is that originally employed by Carl Gauss in his treatment of biquadratic residues.[32] To map out the combined effect of two different ordering principles, Gauss extended the ordinary number domain by introducing the so-called *imaginary complex whole numbers.* Gauss's system of complex whole numbers can be represented visually as the system of lattice-points in a plane, where the horizontal, so-called "real axis" represents the mode of displacement corresponding to the ordinary whole numbers, and the vertical so-called "imaginary axis" represents displacement according to the new principle. The relationship between the two principles of displacement, defines a third principle.

Apply this now to the ordering of the isotopes! Think of each isotope as being associated with a complex whole number—i.e., in the geometrical representation, by a specific locus in the lattice—in the following manner. The component of the isotope along the horizontal, "real axis," should be the ordinal number of the corresponding element in Mendeleyev's original periodic system, otherwise known as its atomic number. The "imaginary part," i.e., its component in the vertical direction, should be its mass number. Thus, the isotopes of a given element are located on lines parallel to the vertical axis, at heights corresponding to their atomic weights, or rather to the whole-number closest to them (Figure 2).

To put it more schematically: The isotope of an element of atomic number Z, and having mass number M, corresponds to the Gaussian complex number $Z + iM$.

Merely mapping the isotopes by complex ordinal numbers only lays a preliminary basis for the real work, which is to discover the *physical principles* underlying the existence and transformations of the isotopes, and the relationship between the "chemical" and "nuclear" processes.

A crucial clue lies in the pattern of *tiny discrepancies* between the actual, physical values of the atomic weights, on the one side, and the integer mass numbers used in our mapping, on the other. It is exactly in those tiny discrepancies, that the whole potential of nuclear power resides! They are analogous to the tiny differences between the observed motion of Mars, from that predicted on the assumption of uniform circular motion of the planets, which permitted Kepler to discover the principle of universal gravitation.

What, for example, is the relationship between the atomic weights of two atoms, and that of an atom that might, hypothetically, be formed by some sort of fusion of the two?

One of the simplest cases, would be to combine two atoms of the *hydrogen* isotope of ordinal number $1 + 2i$ (called deuterium), to get an atom of the *helium* isotope $2 + 4i$ (the most common form of helium, helium-4). Here, the complex ordinal numbers add up algebraically. But what about the actual atomic weights?

The atomic weight of deuterium, from actual measurement, is 2.014102 mass units, the double of which is 4.028204. The measured atomic weight of an atom of helium-4, on the other hand, is 4.002603, which is slightly *smaller* than the former value, by 0.025601 mass units, or about 0.6 percent. What might follow from the observation, that a helium-4 atom is 0.6 percent lighter than two deuterium atoms, taken separately? If it were possible for the deuterium atoms to reorganize themselves into a helium atom, the result would involve a *net decrease in mass.*

In fact, the *fusion* of isotopes of hydrogen to form helium is believed to be the main power source of the Sun. The main reactions, that take the form of a chain starting with ordinary hydrogen rather than deuterium, appear to be more complicated than our hypothetical one, but they share the common characteristic: At the end, the atomic weight of the end-product(s) is *less* than that of the reactants. What is the significance of that?

To the best of our present knowledge, Einstein's general answer is correct, namely, that the rate of generation of "missing mass" is proportional to power output of the star. We cannot directly measure the slow loss of mass of the Sun, for example, but we can observe the same sort of proportional relationship quite directly in countless radioactive processes and nuclear reactions. That also holds for nuclear fission, where the sum of masses of the fragments, generated by the fission of a uranium nucleus, is very slightly, but measurably, smaller than the mass of the original nucleus. More precisely, the "missing" mass amounts to 0.087 percent of the mass of the uranium nucleus.

It seems, therefore, to be those tiny discrepancies in terms of atomic weights, that hold the key to the Sun's power to maintain our biosphere, and to our own power to maintain the world population on the basis of nuclear energy in the coming period. And yet, as Kepler confronted the anomaly of slight "errors" in the predicted positions of Mars, relative to the reductionist calculations of Ptolemy, Tycho Brahe, and Copernicus—errors reflecting the existence of a higher principle that he later identified as universal gravitation—so today, a conceptual leap is required, to discover the principles of a new nuclear physics.

I will just note, in conclusion, that the magnetic characteristics of an isotope could be considered as, in a sense, the "imaginary" component of the value of the mass function for the corresponding complex ordinal. By including the additional dimension of nuclear isomers (so-called excited states of nuclei, which have changed magnetic characteristics), we can construct a more comprehensive Riemann surface function for the principles in question.

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32. See Carl Gauss, "The Metaphysics of Complex Numbers," translated from *Gauss Werke*, Vol. 2, pp. 171-178, by Jonathan Tennenbaum in *21st Century*, Spring 1990. Also see "Carl Gauss's Fundamental Theorem of Algebra: His Declaration of Independence" by Bruce Director, *Fidelio*, Summer-Fall 2002, on http://www.schillerinstitute.org/educ/pedagogy/gauss fund bmd0402.html.