New Frontiers of Science

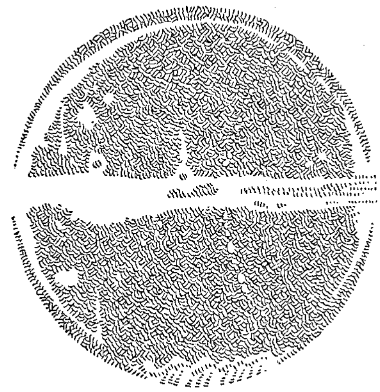
By Rogers D. Rusk

The discovery of heavy water, artificial radioactivity, and transmutation adds to the wonders of scientific advance and portends new methods of treating disease

In spite of frequent suggestions that science slow down and allow man's more backward activities to catch up, there never has been a time in which the progress of science was so rapid and the results so unexpected and surprising as in the past two or three years. The most momentous discoveries of science are usually made with the least noise, and especially some of the most important developments of recent years have come without blare of trumpets or benefit of drums. Such periods of quiet but rapid development as the present one often mark the beginnings of epochs which are too frequently not well recognized until long after they have passed.

As we now look back thirty-five or forty years we see only too clearly that such an epoch was begun in the last decade of the nineteenth century. The sudden spurt of scientific discovery at that time marked the beginning of the modern age of physical science in which we now live. Of course the foundation for the telephone and telegraph, the dynamo-electric power plant and a host of other of the commonplaces of today had long been laid during the course of the century. And yet in the nineties a new world suddenly burst forth, with things to come that were to outdo the prophetic visions and even the fairy tales of the past. In that decade came the epochal discoveries of the electron, radioactivity, X-rays, and the beginnings of wireless communication. The first of these was followed by the development of the electrical theory of matter with its attendant revolution in our view of the whole physical universe while the last three brought developments too well known to need special emphasis.

There came also, five years after the close of the century, the first public announcement of the theory of relativity.

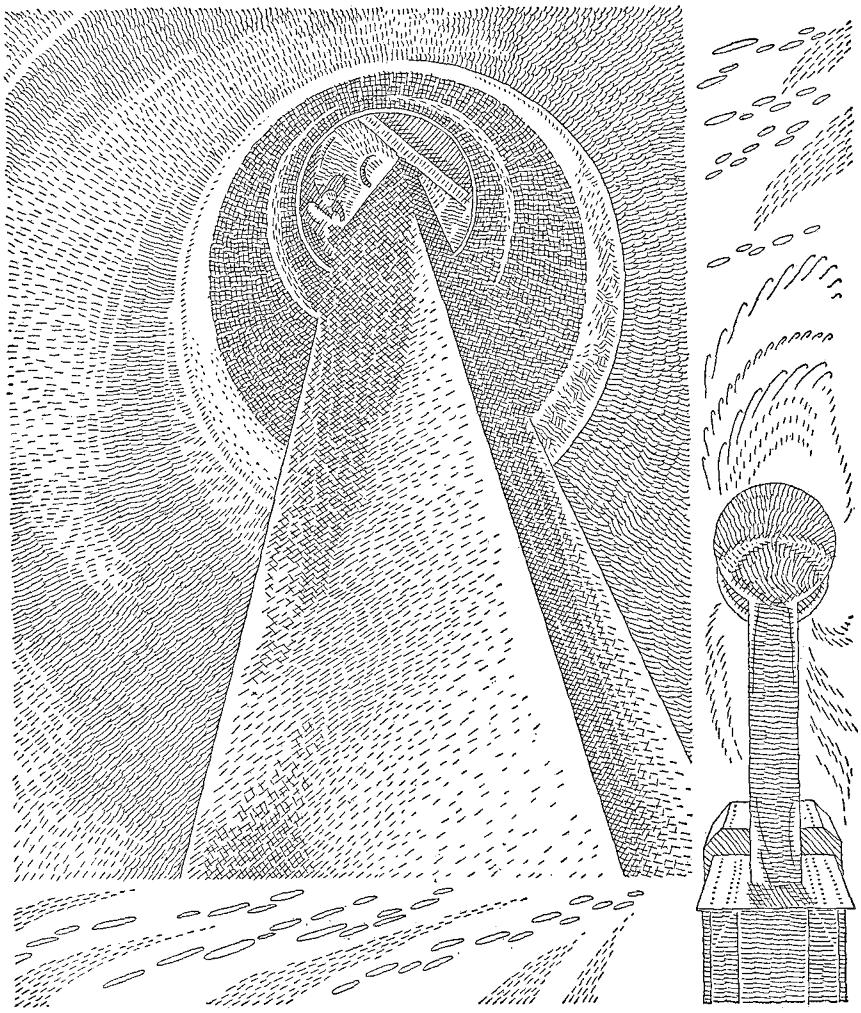


In the three or four decades that have followed, these new fields have opened up fanlike in a multitude of directions, expanding and overlapping in so magical and astonishing a manner as to almost completely bewilder the non-initiate. Indeed the world has become so saturated with surprise at the oft-mentioned marvels of science that the emotion of surprise has almost ceased to function at anything short of murder or catastrophe and not always then. It is for this reason especially that the scientific events of the last two or three years may readily fail in the public mind to achieve the instant importance and emphasis which they actually deserve. For not only has the promise of the immediate future been suddenly expanded, but so also has it taken new and unexpected directions the complete measure of which may not yet be taken but the implications of which are the concern and interest of us all.

First among the epochal scientific milestones of today must be mentioned the discovery and isolation of *heavy water* with its promise of a brand new chemistry. Then there is the new and surprising *artificial radioactivity* which may be produced in a variety of familiar substances. Two new building blocks of the universe have been discovered in the *positive electron,* backward twin brother of the well-known negative electron, and the *neutron,* so-called because of its lack of either positive or negative electrical charge. In addition to these, *transmutation* has become an accepted fact and other discoveries more revolutionary still in their implications are as yet less fully confirmed.

The chemistry of the past has largely been what might be called water-chemistry. Water, the great and universal solvent from daily bath and necessary component of food to the most exacting uses of the chemistry laboratory, is as necessary as the air we breathe. We live on land surrounded by water with a cloud layer of water vapor above us and layer of ground water in the earth not far beneath our feet. The human body itself is something like 90 per cent water and many of the common solids we eat such as sugar contain a large percentage of water of crystallization. Now comes *heavy water*—a new kind of water that looks like the old but has many entirely different properties. At first thought, it might seem to be a device to enable non-athletic millionaires to swim more readily, but upon second thought, at a recent quotation of four dollars a drop, the cost of enough for a swimming pool would approximate the national debt. Furthermore swimming in heavy water might have serious consequences and ordinary salt water which is certainly invigorating is almost as heavy.

During all the past centuries people have been drinking water without ever suspecting that there was anything in it more than ordinary water. Now it



appears that about one in every five thousand molecules of ordinary rain-water is not water (that is to say about one thimble-full in five gallons though some estimates are much less) but deuterium oxide, more commonly known as *heavy water,* and that when this new substance is isolated in sufficient concentration it is found to have strange and unexpected properties.

At Princeton University it has been found that certain micro-organisms are killed by heavy water while others are not. Tadpoles and some small fish died in from one to forty-eight hours when immersed in 92 per cent heavy water. At the University of California tobacco seeds were found to fail to germinate and a quite respectable white mouse became so badly intoxicated that his condition is best described as "plain drunk." An unfortunate feature of the latter experiment was the fact that the mouse became so thirsty and imbibed so lavishly of the costly liquid that the experiment had to be discontinued in the interest of economy.

One is led to speculate whether heavy water might possibly be the beverage prophesied by Professor Haldane as an intoxicant to take the place of alcohol which would leave no after effects and be non-injurious, but the evidence though limited points otherwise. So far no one has had a tumbler full of 100 per cent heavy water to drink, and any statement that a person would be aged fifty years by drinking a few drops is merely journalistic extravagance. Indeed some scientists have already imbibed small amounts with no immediate ill results and Professor Hevesy has found that at the end of nine days half the amount drunk still remained in the body, but the effect of larger amounts is problematical. In spite of such rumors and the real possibilities of ill effects, offers have been received from those who are willing to drink a sizable potion and who may perhaps secretly hope to be rejuvenated instead of aged.

While the nations of the world are exhibiting political discord to a marked degree the story of the scientific discoveries of the past two years strikingly shows that never before in history have the nations of the world cooperated more energetically and efficiently in scientific affairs. Against one problem of universal interest, the problem of cancer, they have presented a solidly united front and although cancer is a fundamentally biological rather than physical problem, nevertheless physics and chemistry have contributed much and may indeed contribute the ultimate solution. Just now experiments are being performed to find the effect of the new heavy water on cancer tissue and these will be watched with keen interest. Likewise artificial radioactivity, to be mentioned later, holds promise of future benefit.

Why is heavy water heavier than ordinary water? The question is not so complicated and difficult to answer, in fact it is relatively simple and from its promise of importance may be worth a moment of thought by even the most unscientific. The discovery of heavy water is one of the greatest romances of modern science. Ordinary water is composed of two common gases, oxygen and hydrogen. In each molecule of water are two hydrogen atoms associated with an oxygen atom sixteen times heavier than each hydrogen atom. It was the discovery of the hitherto unknown double-weight hydrogen atom, and the fact that this double-weight hydrogen atom might be substituted for the single-weight hydrogen atom in various compounds including water that led to the discovery of heavy water. Every high-school boy recognizes H_2O, the symbols of the chemist which stand for water, but every high-school boy must now learn a new symbol, D_2O, which stands for deuterium oxide or heavy water. (Indeed the possibility of still other and even rarer forms of heavy water involving a heavier oxygen atom or a triple-weight hydrogen atom must not be overlooked.)

The story of the discovery of the heavy hydrogen or deuterium atom is the story of a small decimal fraction. Some discoveries seem to burst forth from a clear sky while others result from a long chain of painstaking exact measurements. It was a common remark in the early nineties that the major discoveries of science had all been made and that there remained only the problem of refining past measurements and extending them to a further and further decimal. The rocket-like burst of discovery that followed that period threatened to go to the other extreme and almost obscure the decimal fraction and its potent values. One recalls, however, that it was a very small numerical discrepancy in the orbit of the planet Uranus which led to the prediction by Adams and Leverrier of the planet Neptune and its subsequent discovery. Likewise it was a small decimal fraction representing an extremely small variation in the density of air that led to the discovery of the rare gas argon by the late Lord Rayleigh and subsequently the gas neon which no one at that time could have possibly foreseen would lend itself so thoroughly to the neon sign and the unæsthetic glare of our city streets.

Doctor Harold Clayton Urey of Columbia University, born in Indiana and a product of the University of Montana (with his co-workers Doctors Brickwedde and Murphy) announced the discovery and isolation of heavy hydrogen and heavy water in 1932, and was forthwith awarded the Nobel prize in Chemistry at the close of 1934. A series of important events led up to these discoveries in which again a small decimal fraction was involved.

Aston in England had shown some years ago by a series of brilliant experiments that not all atoms possessing the same name are exactly alike, that the families of chlorine and mercury for instance like the families of Smith and Jones may vary within themselves. To use Aston's own words he found that "some of the most respectable atoms with which he had long been familiar had been leading double (and sometimes triple or more) lives," that there were often several groups of the atoms bearing a single name that all behaved pretty much alike but whose weights differed. This was somewhat upsetting to the chemists who had long been talking with great authority of atomic weight. It now appeared that an atomic weight did not represent the weight of an atom but merely an average of all those atoms possessing the same name.

This apparent upset, however, was simply the beginning of newer and better things. At first hydrogen itself, the lightest of all atoms, was not suspected of this duplicity until a very precise measurement by Aston showed a constant and inexplicable discrepancy when compared with the measurements of the chemists. It was suggested that the discrepancy of only one part in five thousand might possibly be due to an unknown and double-weight atom of hydrogen. From the vantage point of an after-view we can now see clearly that again it was the case of a small decimal fraction which may remake the world.

As yet there was no proof but merely an assumption that a double-weight hydrogen atom might exist and might exactly make up the discrepancy. In this country, Doctor Urey of Columbia lost no time in setting forth on the quest of this new and unknown particle. As Einstein has said in another connection, "it was very much like shooting birds in the dark in a strange country where there were very few birds." However, in an amazingly short time Doctor Urey with the assistance of Doctors Brickwedde and Murphy triumphed. Heavy hydrogen was produced and combined with oxygen to form heavy water.

Never in the history of science has a discovery been so seized upon and its extension and development so hastened by laboratories co-operating everywhere the world over and by scientists who at once saw the far-reaching possibilities of the new discovery. Fortunately at the same time a simple method of producing heavy water was also discovered. Wherever electricity has been flowing through water solutions for a long period of time, *there* is heavy water in paying quantities. In every old storage battery in the country (and the older the better) ordinary water has been driven off in the fumes and an increased per cent of heavy water remains. All over the country electrolytic plants based on this principle have sprung up like mushrooms and are rapidly getting under way. In spite of the relatively small amount of heavy water in ordinary water the enormous volume of water on the earth makes the supply of heavy water well nigh inexhaustible, and already the price has fallen from a prohibitory pricelessness to a not unreasonable sum for small amounts. This is only the beginning.

It has not been so very long ago since chemistry was a youthful and immature science, and the chemical nature of only a few substances was known. Indeed some of the simplest chemical compounds were believed to be unique elements not further divisible. It was only in 1783 that Lavoisier showed that water was not a fundamental element itself, but was made up of two other substances, hydrogen and oxygen. Today there are something like three hundred and fifty thousand chemical compounds whose nature and composition are well known. Of these approximately 90 per cent contain either hydrogen or water or both. If heavy hydrogen or water is substituted for the ordinary hydrogen or water in these compounds many variations in their properties may be expected. It is not impossible that substances now poisonous may become foods or medicine, or vice versa, that substances now stiff may become flexible or that some now transparent may become opaque. Predictions are hazardous and the changes produced may be of degree only. What is less remote and of even greater interest is the possibility of directly tracing food and drugs in their effects on the body. Substituting heavy hydrogen for ordinary hydrogen in a compound is like tying a red tag to it. Wherever it goes it will display its tag to the watchful scientist, and the secrets of many a vital process may be revealed.

The possibilities of industrial use of heavy water seem more hazy at the present moment than the biological applications but it may take a generation or more to survey the major possibilities. Certainly the whole field of chemistry must now be gone over using heavy water instead of ordinary water, with results which at present can scarcely be guessed. Some of the wildest promises will most probably not come true while others unthought of may suddenly appear.

Following closely upon the metaphorical heels of heavy water has come the discovery of *artificial radioactivity* closely linked up with the discovery of the neutron and that dream of the alchemists of old—the transmutation of matter. The word artificial, however, is most unfortunate as there are many people who will immediately conclude that it is not the real thing, whereas it most certainly is the real thing. What is actually meant is that the radioactivity is artificially induced in substances which are not ordinarily radioactive. Up until the discovery of radioactivity by Becquerel and the Curies in the nineties, if the world was convinced of anything at all it was convinced of the utter impossibility of any such thing as radioactivity. Then, very suddenly, the impossible was discovered. Now, quite miraculously to relate, the artificial process has been discovered a generation later by the very daughter (and her husband) of Mme. Curie herself.

Before radioactivity was discovered it had been customary to speak of atoms with great deference as the ultimate particles of matter. Atoms were changeless and unchanging, the only permanencies in a world of life and death, growth and decay. The atoms of a candle might be dissipated in its smoke but after it was burned there were just as many atoms as before. Some were scattered about the room, some were breathed into the lungs, some were deposited on the wall paper, others were mingled with those of the air, nevertheless, they were all there. True it was that the grouping of atoms to form molecules might change or break down altogether, but the atoms remained unchanged. They could not even be cut in two. They were ultimate. It is related of the famous Lord Kelvin that in conversation with a student one day the student inadvertently ventured the profane speculation that atoms might be divisible, whereupon the great Kelvin rebuked him with the query, "Don't you know that the very word comes from the Greek, meaning indivisible?" "That," came the quick reply of the student, "is the disadvantage of knowing Greek."

Today the old permanencies of the Victorian world have one by one vanished and with them has vanished the solid, material, shatter-proof atom. Some of the most striking experiments of the past two years have had to do with the shattering of atoms. In fact shooting atoms to bits has become the sport of all scientists who are so fortunate as to possess the means of producing the appropriate kind of projectiles for such target practice, and new results from such activities are coming in from day to day. It all harks back to the original discovery of radioactivity and the fact that what the alchemists of old had searched for fruitlessly had been going on all the time under their noses. The atoms of a number of different substances, all *heavier* than lead, had been spontaneously giving off penetrating rays for ages and at the same time the residue had formed itself into new and lighter atoms. Sooner or later all such atoms turned into lead and apparently there the transmutation stopped.

No human being was able to start the process, or to stop it until it stopped of its own accord. It had been going on ever since the beginning of things, and the residue left in certain minerals provides one of the most important means of estimating the age of the earth—something more than a thousand million years. No alchemist of old ever desired to create lead out of something else, but here it was going on all the time unbeknown. Kings had already used too much lead to debase their coinage whenever the exchequer ran low. What the alchemist wanted was to turn lead into gold. Gold, however, is lighter than lead and the process of disintegration stops too soon.

Within recent months, however, entirely new discoveries have been made; first, that many common substances, *lighter* than lead, are feebly radioactive; and second, it has been found possible to artificially instil more violent radioactivity into substances otherwise thought of as quiet, sober, and sedate. The discovery had scarcely been made by the Curie-Joliots when new and more intense methods of doing the same thing were developed in this country and abroad. For example a bit of silver or even a silver dollar may be made temporarily radioactive and might thus be used in the treatment of disease. Ordinary sodium, well known component of table salt, may likewise be made radioactive and the medical profession has at once seen the possibility of more direct internal application.

The immediate value of this discovery would amount to millions of dollars except for one fly in the ointment. The induced radioactivity wears itself out in a comparatively short time. Were it not so, a single radioactive source could induce the effect in an unlimited amount of common material and this could at once be distributed over the country for the ready and cheap treatment of disease. At the moment the scientists are divided. Some think it is merely a matter of time until a cheap source is available. Others point out the possibility that the total amount of induced radioactivity may never be more than that of the source. This pessimism is in turn partially dispelled by the medics who see new methods of treatment available. It may be possible to inject the artificially radioactive substance directly into the region to be treated and left there, thus getting direct effect on cancer or other tissue without so much affecting healthy tissue and without worrying about overdosage or loss of valuable radioactive material. This has been done with difficulty in the past and every once in a while some luckless patient has swallowed a tube of radioactive material and has had to be pumped out in order to recover the valuable treasure.

How is artificial radioactivity produced? Apparently it is the result of giving the nucleus or "heart" of an atom a tremendous shock. Up until very recently it has not been possible to do this. It has been a case of "nigger dodge the ball" or else the ball dodged the nigger, or else the blow was quite ineffective. It has been necessary to bring up the heavy siege guns just as the German Army did before Liége. These atomic heavy siege guns had to be invented and they are of different kinds. At Massachusetts Institute of Technology a giant voltage generator has been developed powerful enough to shoot a projectile (a positive particle) with a "kick" of several million volts. A huge metal sphere with an observer sitting securely inside of it has electricity piled upon it from an endless belt until a crashing lightning flash bursts from the sphere. Such huge voltages are difficult to control.

At the University of California a positive particle is whirled in a more modest electric field, being speeded up at each whirl until it likewise represents an energy of some millions of volts. The first of these might be called the artificial thunderbolt method, to distinguish it from the attempt of some German scientists to harness real thunderbolts in which one of the party lost his life. The second of these might be called the electrical sling-shot method, and last of all comes the atomic explosion method. At Columbia University and elsewhere the natural energy of the alpha particle from a radioactive source is utilized. The alpha particle is a projectile of tremendous energy. It travels with a speed thirty thousand times that of an army rifle bullet. When these particles strike beryllium (a rare metal) it has been found within recent months that an entirely new particle is dislodged.

Scientists had just about run out of names for new particles, but this new particle is neutral electrically. It carries neither a positive nor negative charge, and so it was unanimously agreed to conveniently call it the *neutron*. Perhaps less is known about the newly discovered neutron than about any other known particle. It may be possible to dislodge it from any kind of atom, but beryllium is a particularly rich source. Most of our methods of investigation of minute particles beyond the power of the microscope are electrical methods, but the neutron does not respond to any of these. It presents a new puzzle, a new mystery in the world of matter. It appears to be smaller than any known particle and yet its weight is thought to be close to that of a hydrogen atom. It is smaller with respect to a speck of dust than a speck of dust is smaller than the earth. A stream of neutrons can be fired through a five-inch sheet of lead, and only a very few will be lost. Indeed it would be impossible to capture and keep them. Even though locked in the stoutest steel vault hermetically sealed, they would rapidly escape. Because of their lack of electrical charge they could be packed so closely together that a cubic inch would weigh more than a million tons. No similar particle has ever been discovered and the presence of these may help to explain why some of the dense stars have been found to weigh thousands of times more, volume for volume, than our own earth.

The neutron, since its discovery, has in turn been put to use. The Italian scientist Fermi announced the discovery of artificial radioactivity produced by neutron bombardment in March, 1934. The neutron has the property of rendering hard hits on the nucleus of an atom because the neutron carries no apparent electrical field and can get closer to the central nucleus than any known particle. The atoms of some common substances are thus shocked into radioactivity and for some time after being bombarded with Fermi's "siege gun," which produces neutrons as projectiles, the atoms of the substance spontaneously fly to pieces and form other atoms in the process.

Not only does this process represent *artificial radioactivity* but it likewise represents the *transmutation* of the elements as a reality. New atoms are formed from the old, and experiments so far indicate that sometimes *lighter* atoms are formed and sometimes *heavier* atoms are formed. It has even been possible to roughly identify the atoms formed though everybody knows the process is a very inefficient one and gold for the great American dole will scarcely be formed in the laboratory for a long time to come, if ever. In fact by far the most expensive method of getting gold or any other substance at the present moment would be to create it by transmutation. That does not lessen the scientific interest in transmutation. Neither does that minimize the fact that what the alchemists dreamed of and what the nineteenth century scientists laughed at as foolishly impossible has now been actually accomplished with a number of the lighter elements.

Not only have transmutations been accomplished by bombarding with neutrons, but also by bombardment with an array of atomic projectiles. Speeding up the new double-weight hydrogen atom, stripped of its electron, has proved to be a most effective projectile, and last but not least the *cosmic ray* is being utilized to induce artificial transformations.

The name *cosmic ray* has made so fancied an appeal to the learned and unlearned alike that such general interest in a scientific problem has seldom been equalled. Actually the name is a misnomer because nobody knows anything about the cosmic nature of these rays other than they originate outside of the earth, whether this be in the spiral nebulæ, in the Milky Way, or from exploding stars. Indeed the original speculations that such rays may announce the birth of new atoms have no foundation at all in actual measurement. What is more to the point is that these rays *do exist,* shooting through us time after time, although we are wholly unaware; and that the energy possessed by them is greater than that of any other known ray. Though first thought to be rays of light, they are now admitted to be mostly charged particles, at least those we detect are charged particles, and no one knows what the charged particles are due to.

Millikan has sent his cosmic ray instruments to mountain tops, has sunk them deep in lakes and has sent them high up in balloons and airplanes. Automatic instruments have been set on steamships travelling far and wide. Parties organized by Compton went to the far corners of the earth from the Himalayas to Spitzbergen. The enormous mass of data obtained has given no clue as yet to their origin. What we know is that they can penetrate our atmosphere and have enough energy left over to disintegrate atoms.

Of all the sources of atomic projectiles the cosmic ray has far surpassed all others in its apparent power but such high-powered cosmic rays are too infrequent to provide a plentiful source. Until recently the dream of several million volt electrical currents was unrealized and has only been achieved by the recent types of high-voltage generators. The latest estimates of the maximum energies of cosmic rays, however, far exceed this recently realized dream. They exceed, in fact, anything conceivably possible in the laboratory. Millikan has estimated the maximum to be as high as ten billion volts or higher and Compton has set forty billion as the possible upper limit.

There is no known source of such energy in the universe aside perhaps from a flaming, variable star in which matter may perhaps be annihilated and turned directly into energy in a fashion quite unapproachable in the laboratory. It is not to be wondered at that such cosmic rays when striking an ordinary atom may produce atomic bursts in which the fragments of an atom are scattered in all directions, and these have been recently observed. When one starts to say that the atom is "blown to atoms" one is reminded that language has not developed rapidly enough to properly encompass such things.

Aside from the mystery of the origin of cosmic rays and aside from the startling but harmless fact that each and every human being is now and then shot through and through by these million and even billion volt particles—aside from all this, and the many other scientific problems revealed, is the remaining fact that by means of cosmic rays still another elemental particle of matter has been discovered very recently, and for this another American scientist gets first credit. This new particle is the *positive electron* and it might be called the mirror image or twin brother of the now well known negative electron discovered a generation ago by J. J. Thompson in England. The discovery of the negative electron began the modern revolution of physical science, and merged the age-long puzzles of what is matter, and what is electricity, into a single problem.

From that time on it became more evident that all matter was electrical and in the nearly forty years since that discovery scientists have been pursuing the new idea throughout all the realms of science. Indeed it came as a shock to many people that everything in the universe is composed of electricity and that the food they eat, their own bodies and perhaps even the mechanism of their brains was electrical. But all this time it remained a mystery why the smallest positive particles (protons) always weighed so much more than the smallest negative particles (electrons). For forty years scientists tried to separate the weight and the electrical charge in the nucleus of the atom where the positive particles were massed but the latter always went along with the former. It became such a commonplace idea that most people forgot to think that there might be a positive electron similar in size but opposite in charge to the negative electron.

However, in August, 1932, came the announcement from Pasadena and the school of Robert Andrews Millikan that the positive electron had been discovered. Millikan had long ago won the Nobel prize for making the most exact measurement of the negative electron. Now it was his assistant and co-worker Anderson, who was to announce the discovery of the positive electron or positron and it all came out of the study of cosmic rays which had long been pursued by Millikan and his assistants.

No more clever piece of scientific apparatus has ever been devised than that of C. T. R. Wilson by which the tracks of these high-speed atomic particles can be made as plain to the naked eye as the tracks of lions and tigers are to the big-game hunter. In fact the smaller the particle the bigger game it is to the physicist. A miniature cloud is suddenly condensed and a string of silvery droplets indicates the paths of particles moving so fast that in comparison a rifle bullet would seem to be standing still.

It had long been customary to test these particles by applying a magnetic field and then noting that the paths of electrons became curved in the direction in which a negative charge would be deflected. No particle of the same size had ever been observed to curve in the opposite direction. Then Anderson thought of turning his apparatus over on its side to better study the tracks of particles knocked out of atoms by cosmic rays coming down from overhead. The idea was simple. But the ordinary style of apparatus would not work on its side. A new type of apparatus had to be built and many thousands of tracks of particles were observed, when lo and behold a very few of these curved the wrong way! They could only be positive electrons.

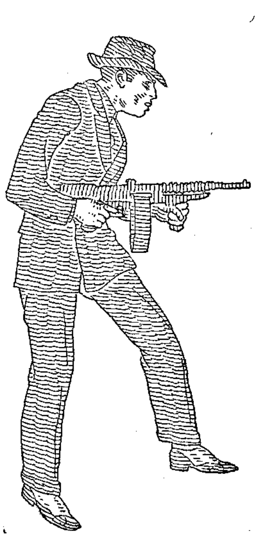
A commentator on the subject has said that whereas these particles were first observed at a rate of three or four per year, by the end of 1934 they could be produced at the rate of 30,000 per second and in spite of the tremendous increase this number is still small compared to the number of negative electrons given off in an ordinary radio tube.

What is left after the positive electron is ejected from an atom? One used to speak of a hydrogen atom as being made up of a proton (positively charged nucleus) and an electron. The nuclei of heavier atoms were thought to contain protons in various groupings. It was common to say that the universe was built of protons and electrons and nothing else. But if a positive particle in the nucleus loses its charge but not its weight, what is left over must be a *neutral something* possessing weight. It is the proton which many scientists think has thus been broken up into a *positive electron* and a *neutron*. Perhaps at last the weight and the charge of the proton have been separated.

The negative electrons in the atoms have long been known and studied, and now at last the stronghold of the nucleus is giving up its secrets. The *neutron* and the *positive electron* must take their place along with the negative electron as the most elemental and fundamental particles in the universe. Instead of saying that the universe is composed of positive and negative charges (protons and electrons), it now seems more appropriate to say that the building blocks of the universe are positive and negative electrons plus neutrons. Who will break up the neutron and show us that it is nothing less than two opposite charges locked together in some new and close embrace? Such a race is more to the clever than to the swift and is at the moment open to all comers.

All This New Science

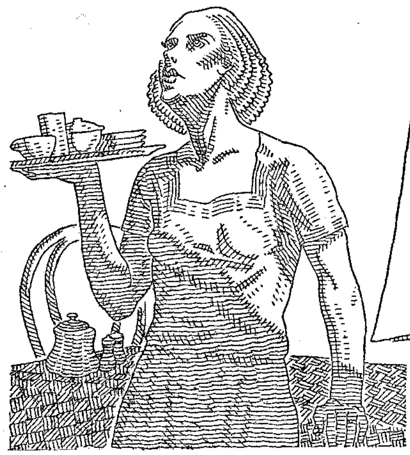
— *Chaucer*

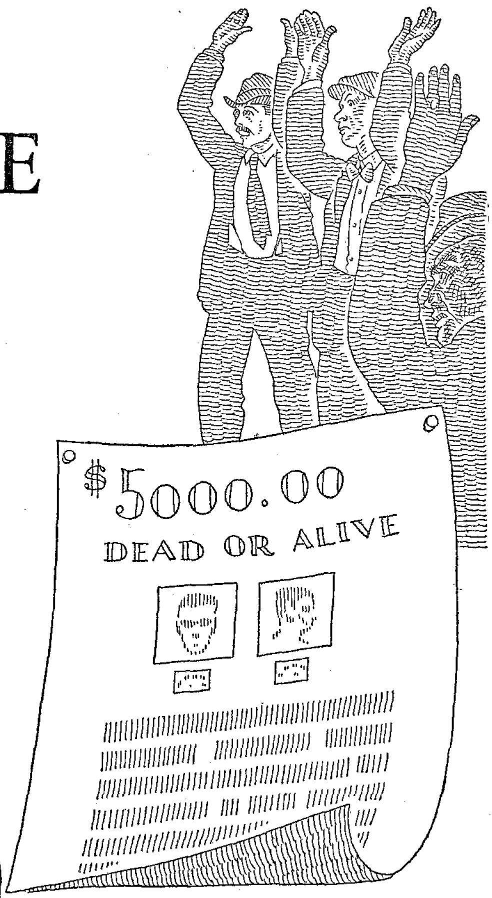


TRIBUTE

A STORY

By Paul Horgan





THE Apache Tavern in Hermosa, New Mexico, was run by a man called Captain, and his wife Billie Jeane. Every time a customer came in for a meal, they were busied anew with the duties they enjoyed, and by taking a sentimental interest in their work and themselves, they cast over their little café a curious atmosphere of comfort and pity. When their coffee urn was hissing, and the swinging door between the cooking range and the eating counter was whapping in the winds of service, and Billie Jeane was catwalking up and down with orders, smiling, her high heels making hard jolts on the floor that shook her frank breasts with each step, then she and her husband were happy because they were busy and because people needed their work for their own good.

Hermosa was a small town, but right opposite the tavern was a county court house, a sandy gaunt building with a wooden cupola, built in 1897, when Hermosa had only one street.

But Highway 380 went by this way now.

There were four paved blocks in the center of town. The machines of city life were here too: a movie house, everybody's radio, cars with radios in them, and the transport planes crossing the same streak of sky this side of the mountains at the same hour every evening, when the evening settled over the immense land there . . . roads taking the eye far down the plains, the blue hover above the river behind town where there were dying willows and white salt hollows, the level horizon diffuse with light except where the mountains began. Slow things lived temperately there still, cows roving, old Mexicans paced by their burros, the fat sheriff who limped majestically and was beloved by his townsmen. But the lives of most people were rolled rapidly like spools leaving thinner threads as they rolled, along the roads in their cars. The roads called them. And the roads were good in all kinds of weather.

The Captain and Billie Jeane were proud of that, they said. It kept business moving, the coffee bubbling and sighing in their urn.

On a day like this, in early November, the café was somnolent in mid-afternoon, but when the door opened, it didn't surprise Billie Jeane unduly, though she glanced at the clock above the pie cabinet, and said to herself, "'t's quarter t'four," and went forward to wait on the man who sat down at the far end of the counter, near the street, where you could look out and see the second story and up of the court house and the baring tree tops in the yard before it. The sights below that were blurred by Billie Jeane's muslin curtains that veiled the lower half of her big front window.

The Captain came to his swinging door and looked across it at the new customer. The Captain wore a white flat cap on his head. He was tall and fat at the waist, with black hair, and pale brown eyes behind black-rimmed glasses. His face wore an almost permanent kind of eagerness, as if he were inhaling a smell that nourished him, a sauce, or hotcakes browning, or gasoline running into the tank of his car. He watched Billie Jeane do her offices at the counter, the glass of water, the butter pat, the tableware, the napkin, and the menu. She smiled and looked out the window and snaked her fingers in her hair fixing her bob. About her plump cheeks rose a starched collar that made her look in silhouette, as the Captain now saw her, like an old court lady in the picture last week. Then she turned and got the order and came down the aisle, saying in a loud voice as if the room were full of clamorous diners,

"Bowl of chili, dry toast, one egg easy," and the Captain retired from his