left obviously show the escape of a helium ion (He^{++}); for this decreases the mass of the nucleus by four, and decreases its positive charge by two units. The lines that run horizontally to the right show the escape of an electron; for this does not change appreciably the mass of the nucleus, but increases its positive charge by one unit. The extent to which the atom is shaded also indicates its stability, which is the inverse of its rate of disintegration. This rate varies enormously: some kinds of atoms having a half-life of billions of years and others of a small fraction of a second, by the half-life being meant that period in which half of the atoms present at the beginning become disintegrated. The five degrees of shading indicate respectively (1) complete stability (no evidence of disintegration); (2) half-lives of more than one year; (3) between a year and a day; (4) between a day and a minute; and (5) less than a minute.

The direct evidence for the series of disintegrations is the nature and velocities of the particles emitted, the velocities being definite and characteristic for each process. But the conclusions are confirmed at several stages by the study of the residual elements. Thus radium was actually separated in a pure state from uranium minerals by the Curies and its atomic weight proved to be that predicted; radon, the immediate product of the disintegration of radium, was shown to be a gas as its position in the periodic system requires, and to be produced in a volume corresponding to the number of helium-ions emitted; and the final product has been isolated from uranium minerals and shown to be a form of lead with an atomic weight of 206, differing from that (207.2) of ordinary lead, which is doubtless a mixture of isotopes.

These radioactive phenomena exhibited by the higher elements thus confirm the conclusions drawn from the studies of the isotopes and of the artificial decomposition of the lower elements that atom-nuclei are built ultimately out of protons and electrons, but with the intermediate formation of helium nuclei, which themselves consist of four protons and two electrons.

This very inadequate survey of our knowledge of the phenomena of isotopes and of the artificial disruption and radioactive disintegration of nuclei in their bearing upon the structure of atoms must now be brought to a close. All that can be hoped is that it has served to give those of you who may be laymen in the field of modern physics some conception of the marvelous development of that science during the present century.

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THE RELATION OF SCIENCE TO INDUSTRY[1]

A WELL-KNOWN public speaker of fifty years ago once remarked ruefully after disastrous consequences had followed misplaced humor, as they often do, "I rose by my gravity and fell by my levity."

I use this incident as an introduction to my speech on "Science and Industry" for the sake of calling attention to the fact that what is absurd or ridiculous to-day was perfectly good science, or at least perfectly good philosophy, not more than 350 years ago—that the very existence of a "law of gravity" was discovered as late as 1650 A. D., and that "levity" and "levitation" have through all recorded history up to Newton been just as acceptable scientific ideas as gravity and gravitation—so recently have we begun to understand just a little bit about the nature of the world in which we live.

Nor do I need to go back 300 years to make my point as to the newness of our knowledge. It is within the memory of every man of sixty in this audience that in the great Empire State of New York the question could be seriously debated, and in the most intelligent of her communities, too, as to whether Archbishop Usher's chronology computed by adding Adam's 930 years to Enoch's 365 years to Methuselah's 969 years, etc., gave the correct date of the creation. Recent election returns from Arkansas indicate that the same debate is at this very moment going on there.

But what has this to do with "Science and Industry"? Everything! For mankind's fundamental beliefs about the nature of the world and his place in it are in the last analysis the great moving forces behind all his activities. Hence the enormous *practical* importance of correct understandings. It is his beliefs about the nature of his world that determine whether man in Africa spends his time and his energies in beating tomtoms to drive away the evil spirits, or in Phoenicia in building a great "burning fiery furnace" to Moloch into which to throw his children as sacrifices to his God, or in Attica in making war on his fellow Greeks because the Delphic Oracle, or the flight of birds, or the appearance of an animal's entrails bids him to do so, or in medieval Europe in preparing for the millennium to the neglect of all his normal activities and duties as he did to the extent of bringing on a world disaster in the year 1000, or whether he spent his energies in burning heretics in Flanders

[1] Address at the 160th annual banquet of the Chamber of Commerce of the State of New York, Waldorf-Astoria, New York City, November 15, 1928.

or drowning witches in Salem, or in making perpetual motion machines in Philadelphia or magnetic belts in Los Angeles, or soothing syrups in New England.

The invention of the airplane and the radio are looked upon by every one as wonderful and preeminently useful achievements, and so they are—perhaps one tenth as useful as some of the discoveries in pure science about which I wish to speak to-night, and hence worthy of at most one or two minutes of a thirty minute speech on the relations of science to industry.

As I listened in Pasadena to the presidential candidates presenting in their own easily recognizable voices from the platform in Madison Square Garden to the people of the United States their claims and the issues of the election, or at least its shibboleths, I found myself aglow with enthusiasm for the future of representative government. The few thousand citizens of Athens gathered about the Acropolis to hear the problems of the city discussed and then to cast their ballots. The 120 million citizens of the United States all had in this recent election precisely the same opportunity and in my judgment they used it judiciously. These public discussions addressed to the *ears* of the nation constitute, I think, a stupendous advance. No such step forward in public education has been taken in my judgment since the invention of printing.

But this new achievement of the race, this new capacity for education was after all only an inevitable incident in the forward sweep of pure science, which means simply knowledge, knowledge of the nature and capacities of the physical world, of the ethereal world (to which the radio belongs), of the biological world and the intellectual world; for this knowledge, as man acquires it, necessarily carries applied science in its wake.

Look for a moment at the historic background out of which these modern marvels, as you call them, the airplane and the radio, have sprung. Neither of them would have been at all possible without 200 years of work in pure science before any bread and butter applications were dreamed of—work beginning in the sixteenth century with Copernicus and Kepler and Galileo, whose discoveries for the first time began to cause mankind to glimpse a nature, or a God, whichever term you prefer, not of caprice and whim as had been all the Gods of the ancient world, but instead a God who rules through law, a nature which can be counted upon and hence is worth knowing and worth carefully studying. This discovery which began to be made about 1600 A. D. I call the supreme discovery of all the ages, for before any application was ever dreamed of, it began to change the whole philosophical and religious outlook of the race, it began to effect a spiritual and an intellectual, not a material revolution —the material revolution came later. This new knowledge was what began at that time to banish the monastic ideal which had led thousands, perhaps millions of men, to withdraw themselves from useful lives. It was this new knowledge that began to inspire man to know his universe so as to be able to live in it more rationally.

As a result of that inspiration there followed 200 years of the pure science involved in the development of the mathematics and of the celestial mechanics necessary merely to understand the movements of the heavenly bodies—useless knowledge to the unthinking, but all constituting an indispensable foundation for the development of the terrestrial mechanics and the industrial civilization which actually followed in the nineteenth century; for the very laws of force and motion essential to the design of all power machines of every sort were completely unknown to the ancient world, completely unknown up to Galileo's time.

Do you practical men fully realize that the airplane was only made possible by the development of the internal combustion engine, and that this in its turn was only made possible by the development of the laws governing all heat engines, the laws of thermodynamics, through the use for the hundred preceding years of the steam engine, and that this was only made possible by the preceding 200 years of work in celestial mechanics, that this was only made possible by the discovery by Galileo and by Newton of the laws of force and motion which have to be utilized in every one of the subsequent developments. That states the relationship of pure science to industry. The one is the child of the other. You may apply any blood test you wish and you will at once establish the relationship. *Pure science begat modern industry.*

In the case of the radio art, the commercial values of which now mount up to the billions of dollars, the parentage is still easier to trace. For if one's vision does not enable him to look back 300 years, even the shortest-sighted of men can scarcely fail to see back as much as eighteen years. For the whole structure of the radio art has been built since 1910 definitely and unquestionably upon researches carried on in the pure science laboratories for 20 years before anyone dreamed that there were immediate commercial applications of these electronic discharges in high vacuum.

It is precisely the same story everywhere in all branches of human progress. I suspect it would be difficult to find one single exception. Here is the latest illustration that came to my attention less than a week ago, in fact just as I was getting aboard the train, in a letter from the Air Reduction Sales Company. It reads as follows: "We take pleasure in handing you herewith a complete set of luminescent tubes, each containing in the pure state one of the ele-

ments of the air, namely, nitrogen, oxygen, argon, hydrogen, neon, helium, krypton and xenon. It seems to us worthy of note that at the beginning of this century these gaseous elements as such had practically no commercial value or significance. To-day the estimated value of the plants and equipment that have been created either to manufacture or to use and handle these gases in industry amounts to three hundred million dollars."

The writer of this letter might have added that the chain of discovery which led up to this result started in the most "useless" of all sciences, astronomy; for helium, as its name implies and as everybody knows, was first discovered in the sun with the aid of the spectroscope, and thirty years later it was its discovery in minute amounts in our atmosphere, also with the aid of the spectroscope, that set us looking for the other inert gases of which the letter speaks and which have recently found such enormous application in neon tubes and the like.

But why continue this recital, for no intelligent man to-day needs to be convinced that our material prosperity rests wholly upon the development of our science. It is as to the broader values, intellectual and spiritual, that even intelligent men sometimes express doubt. Let me then start with the foundations that I have already laid and try to show to what these beginnings are leading, whither we are going, not materially, but as feeling, thinking and willing beings.

Was Pasteur only a scientific enthusiast when he wrote "In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring discussions of politics seem to be our guide—empty appearances! What really leads us forward is a few scientific discoveries and their application."

Or was H. G. Wells, himself not a scientist at all, merely talking nonsense when he wrote quite recently (and note that he is not talking about a material thing either):

> When the intellectual history of this time comes to be written, nothing, I think, will stand out more strikingly than the empty gulf in quality between the superb and richly fruitful scientific investigations that are going on, and the general thought of other educated sections of the community. I do not mean that scientific men are, as a whole, a class of supermen, dealing and thinking about everything in a way altogether better than the common run of humanity, but in their field they think and work with an intensity, integrity, breadth, a boldness, patience, thoroughness, fruitfulness, excepting only a few artists, which puts their work out of all comparison with any other human activity. In these particular directions the human mind has achieved a new and higher quality of attitude and gesture, a veracity, a self-detachment, and self-abrogating vigor of criticism that tends to spread out and must ultimately spread to every other human affair.

These may be extravagant statements, most of us scientists are sure they are, but I should like to attempt to picture a little of what I think was in the back of the minds of their authors when they made those statements. I shall do it by drawing an analogy between the life of mankind as a whole and the life of man as an individual. But first let me answer the question as to what we know about the duration of the life of mankind. A hundred years ago we knew practically nothing about it, as my opening remarks on Archbishop Usher's chronology showed. But since then we have made some scientific discoveries—discoveries that are not usually listed as of industrial importance at all, but which in my opinion outweigh by far, in practical value to the race, either the invention of the airplane or of the radio, and that simply because they change fundamentally our ideas about the nature of the outside world, and hence change also the nature of our acting in relation to it.

We have learned within the past half dozen years through studies in radio activity that this world of ours has in all probability been a going concern, in something like its present geological aspects as to crustal constituents, temperatures, etc., for more than a billion years, and hence that the human race can probably count on occupying it for a very long time to come, say another billion years; and further, that mankind has been doing business on it in something like his present shape for something like 20,000 years, or possibly 50,000, but in any case a time that is negligibly small in comparison with the time that is behind and the time that is presumably ahead of him—in other words, we have learned that mankind, speaking of him as an individual human being, is now just an infant a few months old at the most, an infant that up to about one minute ago, for the 300 years since Galileo is but a minute in the geological time-scale, has been lying in his crib spending his waking hours playing with his fingers, wiggling his toes, shaking his rattle, in a word, in simply becoming conscious of his own sensations and his functions, waking up, as he did amazingly in Greece, to his own mental and emotional insides. Just one minute ago he began for the first time to peer out through the slats in his crib, to wonder and to begin to try to find out what kind of an external world it is that lies around him, what kind of a world it is in which he has got to live for the next billion years. The answers to that question, even though never completely given, are henceforth his one supreme concern. In this minute of experience that he has already had he has

tumbled down in his crib, bumped his head against the slats, and seen stars—real ones and unreal ones, and he hasn't yet learned to distinguish with certainty between those that actually exist and those that only seem to exist because his eye-balls have been subjected to the pressure that comes from a blow, and so he is reaching out his hands part of the time trying to grasp illusions, and yet slowly, painfully learning, bit by bit, that there is an external world, physical and biological, that can be known, that can be counted upon, when it has once become known, to act consistently, not capriciously, that there is a *law* of gravity and that it isn't necessary to be covered with bruises all the time because he forgets that it exists, that there is a principle of conservation of energy, and that all constructive and worth while effort everywhere must henceforth take it into account and be consonant with it, that it is not worth while to spend much time hereafter with sentimentalists who wish that that law did not exist and sometimes try to legislate it out of existence, that again there are facts of heredity that it is utterly futile to inveigh against, that our whole duty is rather to bend every energy to know what they are and then to find how to best live in conformity with them, that in a single sentence there is the possibility ahead of mankind of learning, in the next billion years of its existence, to live at least a million times more wisely than we now live. This is what Pasteur meant when he said, "What really leads us forward is a few scientific discoveries and their applications." This is what Wells meant when he contrasted the result of the objective method of learning used in the pursuit of science with what he calls "the general thought of other educated sections of the community." The one guesses and acts upon its hunches or its prejudices, the other tries at least to know, and succeeds in knowing part of the time.

We need science in education, and much more of it than we now have, not primarily to train technicians for the industries which demand them, though that may be important, but much more to give everybody a little glimpse of the scientific mode of approach to life's problems, to give every one some familiarity with at least one field in which the distinction between correct and incorrect or right and wrong is not always blurred and uncertain, to let him see that it is not true that "one opinion is as good as another," to let every one understand that up to Galileo's time it was reputable science to talk about gravity and levity, but that after Galileo's time the use of levity became limited to the ridiculous, that "the town that voted the earth was flat, flat as my hat, flatter than that," had a perfect right to exist before 1400 A.D., but not after that date, that we are learning slowly through the accumulated experience and experimenting of the centuries, especially since 1600 A.D., more about the eternal laws that do govern in the world in which we live. And for my own part I do not believe for a moment that these eternal laws are limited to the physical world either. Less than sixty years ago, to take one single illustration, there existed a relatively large political party in the United States called the Greenback Party which jumped at conclusions and which conducted campaigns to induce our government to go over to a fiat money basis. I do not suppose such a party could exist to-day unless it be in states that pass anti-evolution laws, for there are some laws that *have become established,* even in the field of finance.

This brings me to a brief discussion of the current opposition to the advance of science—an opposition participated in even by some intelligent people, on the ground that mankind can not be trusted with too much knowledge, by others on the ground that beauty and art and high emotion are incompatible with science. Now, fear of knowledge is as old as the Garden of Eden and as recent as Dr. Faust, and there is no new answer to be made to it. The old answer is merely to point to what the increase in knowledge has done to the lot of mankind in the past, and I think that answer is sufficient, for it has certainly enfranchised the slave, and given every man, even the poorest, such opportunities as not even the prince of old enjoyed. Who would go back to the stone age because stone age man had no explosives? Of course every new capacity for beauty and joy brings with it the possibility of misuse and hence a new capacity for sorrow. But it is our knowledge alone that makes us men instead of lizards, and thank God, we can not go back whether we would or no. Our supreme, our God-like task, is to create greater beauty and fuller joy with every increased power rather than to turn our weeping eyes toward the past and fling ourselves madly, unreasoningly athwart the path of progress. Beauty in the amoeba's house disappeared when man cleaned up the miasmic swamp, but it was only because the amoeba had not the capacity to adapt itself to modern sanitation.

No, the only real question in a nation like ours is not whether science is good for us materially, intellectually, esthetically, artistically. Of course it is, for science is simply knowledge and all knowledge helps. The only real question is how the forward march of pure science, and of applied science which necessarily follows upon the heels, can best be maintained and stimulated, for, as Pasteur said, "It is this alone that really leads us forward."

The answer to that question will depend upon the nature of one's whole social philosophy. If you think

that social progress is best brought about by a paternalistic régime of some kind, by throwing upon a few elected or hereditary officials the whole responsibility for social initiative of all sorts, then you will say, "Let the government do it all; let it establish state universities and state research laboratories and state experimental projects of all kinds as it has done in most European countries and let the whole responsibility for our scientific progress lie in these institutions." But if you believe with the early makers of our nation in the widest possible *distribution* of social responsibility, in the *wide-spread* stimulation of constructive effort, in the nearest possible approach to equality of *opportunity,* not only for rising to wealth and position, but for sharing in community service, if you believe with the President-elect that government should only step in where private enterprise fails, that it should act only as a *stimulant* to *private initiative* and a *check to private greed,* then your industries in the New York Chamber of Commerce, your industries which are themselves the offspring of pure science, will join in the great nation-wide movement to keep alive the spirit of science all over this land of ours through keeping pure science going strong in the universities its logical home, and applied science going strong in the private industrial laboratories where it thrives best. No country ever had such an opportunity as ours, no country ever had such a widespread stimulation of individual initiative, such a large number of citizens who had learned to treat financial power as a public trust, such resources to command, such results to anticipate. With our American ideals American industry can not fail, I think, to realize this opportunity, and to support and keep in the finest possible condition, "the hen that lays her golden egg." That is my conception of the relation of science to industry in the United States.

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WILLIAM NORTH RICE

1845–1928

WILLIAM NORTH RICE died November 13 at the home of his son, Professor Edward L. Rice, in Delaware, Ohio, 8 days before his 83d birthday. Two days before, on Sunday, he had attended church service, taken his usual walk, and was in excellent spirits.

Professor Rice, a thoroughly trained classical scholar, was the youngest member and valedictorian of the class of 1865 at Wesleyan University. In 1867 he received his doctor of philosophy degree from Sheffield Scientific School (Yale). He was immediately appointed professor of geology and natural history in Wesleyan and after a year of study in Germany commenced what proved to be a lifetime of service at his *alma mater.* In 1884 the work which he had been carrying was divided and he continued as professor of geology until 1918, when he retired as professor of geology, emeritus.

Professor Rice was first and always a teacher, and his chief monument will always be the affectionate memory of the students who for fifty years sat under his clear, accurate and inspiring instruction. Nor was his influence in educational matters confined to the classroom. At Wesleyan, perhaps more than in most colleges, the faculty determines the college policies. Between 1870 and 1920 the three outstanding faculty names at Wesleyan were VanVleck, Winchester and Rice: each was a great teacher and each exerted a large influence on the development of the college. No one of the three was more responsible for the educational evolution of Wesleyan than Professor Rice, though he himself would doubtless make an exception of VanVleck. For ten years he was secretary of the faculty and three times served as acting president.

Professor Rice was an ordained minister of the Methodist Church and while he never held a regular pastoral charge was an occasional and effective preacher through life. This double interest in religion and in teaching led him naturally into what is perhaps the most outstanding activity of his life, his study of and writings on the relations of science and religion. In the early seventies he had accepted the evolution theory—the *Origin of Species* was a new book in 1865—and during the following years at Wesleyan both in his college classes and in his Sunday afternoon Bible class he was ever intent on helping the student to meet and accept the new scientific knowledge without loss of religious faith. Wesleyan students in those days who came under his influence were not troubled by evolution or Old Testament criticism. Out of this work came his best known and most important book, *Christian Faith in an Age of Science.* There were fundamentalists even in those days and when it was necessary to meet them outside college walls Professor Rice, who was a brilliant debater, never came off second best. A recent clash with John Roach Straton gave him especial joy, and when Straton began to quote Price's *The New Geology* his comment was, "Now hath the Lord delivered him into my hands." He used to say of himself—"I must be orthodox for have I not for years been Chairman of the Committee of the N. Y. East Conference of the Methodist Church which has to pass on the orthodoxy of candidates for the Methodist ministry!"