Journal of the Minnesota Academy of Science

Volume 19 | Number 1 Article 14

4-1951

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Charles L. Critchfield
University of Minnesota

and miscible with fluorocarbons. The compound boils at 277°C. It is quite resistant to hydrolysis and is nonflammable.

It can be seen that the introduction of substantial amounts of fluorine into typical organic structures results in compounds possessing many unique and interesting properties. The number of such compounds is enormous, multiplying by many times the number of possible organic compounds. Since these fluorinated compounds have received only general attention during the past ten years, it is obvious that there remains much to be learned in this new and exciting field of chemistry. Likewise, the technologies of many industries will be affected since their progress depends on the availability of materials with superior properties.

MODERN PHYSICS

CHARLES L. CRITCHFIELD
University of Minnesota

ABSTRACT

Modern physics is usually defined as a field different from ordinary, or classical, physics. Classical physics provides the rules and formulas by which objects of everyday experience behave or operate. By such rules, radios and television sets are built, farm machinery is designed, heat is converted into mechanical energy, cameras are made, and innumerable things of ordinary experience are achieved. The development of labor-saving machines and of gadgets for our entertainment has brought with it the development of instruments by which additional knowledge of the world can be obtained. By instruments the human being can see much farther away, detect much tinier objects, and measure much greater velocities than his unaided, animal senses permit. Since intuitive concepts are based upon unaided perception and may be inadequate alone, it is not too surprising that intensive inquiry into these unfamiliar worlds, far removed from ordinary life, reveals some new laws of physics. It is this part of the subject that we shall call modern physics as distinct from classical physics.

There are four main lines of development, starting essentially with the twentieth century, that may be classified as modern physics in the sense defined above. These are set out briefly below in numbered paragraphs.

1. One branch of modern physics is the result of extending our observations, and analyses, to distances vastly greater, and to objects much larger, than those of everyday life. This is the world of planets and stars and galaxies. The instruments involved are principally the large telescopes, of course, and its adjuncts in cameras, clocks, spectroscopes and so on. Precise, as well as distant, observa-

tions have revealed that space is curved in all its three dimensions plus the fourth dimension, known as time. Through Einstein's general theory of relativity the curvature of space is determined mathematically by the presence of matter, and conversely, the path of a free material object through space is determined mathematically by the curvature of the space.

2. The second new world we consider is the inverse of the first, that is, the result of extending observations and experiments to distances and objects that are exceedingly minute in comparison with ordinary experience, even though the latter is aided by microscopes. This is the realm of atomic particles: electrons, protons, neutrons, mesons, atoms, molecules, and so on. The instruments are various specializations of vacuum tubes, X-ray, atom smashers, cyclotrons, etc., and specialized developments for detection of ionic electricity. After many years of experimenting and theorizing it was found that particles of atomic size, and smaller, could not be considered in the same way as particles of more usual size. For example, we are accustomed to describing the state of motion of a train, or a bullet, in a given direction and at a given time, by giving the position occupied at that time and stating the velocity with which it was going at that time. When a similar description is attempted for a particle of atomic size, it is found that one can only give the position at a given time and say nothing at all about the velocity, or he can specify the velocity and be able to say nothing about its position at that time, or say something more indefinite about both, within certain limits. This means that a simultaneous, exact determination of position and velocity, in a given direction, is impossible and that the state of motion in that direction is described by one number rather than the two to which we are accustomed. The number of possible states of motion is, therefore, much smaller for atomic particles than we had supposed, and this fact explains away the difficulties that classical physics found with the theory of specific heats. The branch of physics that deals with the motion of very small particles is known as the 'quantum mechanics.'

3. As a third extension of human senses we consider the realm of very high velocities. It has been known for a long time that light signals travel at a definite, and very high speed, viz., 186,000 miles per second. Intuition would tell us that the measured speed must depend upon the velocity of the measuring instruments. Fifty years ago, however, it was discovered that the speed of a light signal in space was the same for two observers whether they moved together or with different velocities. This result led to Einstein's special theory of relativity which essentially states that all uniformly moving systems are equivalent, that is, the laws of nature in general, and the velocity of light in particular, are the same for each regardless of their difference in velocity. One consequence of this theory is that no measured (signal) velocity may exceed that of light. The

observed rate of a clock depends upon the relative velocity of the observer. A related consequence is that the measured mass of a particle increases as the measured velocity increases and, more generally, that mass and energy are equivalent. These consequences have been amply verified, but they are foreign to our customary thinking and constitute, therefore, a branch of modern physics.

4. Finally, we come to the outstanding, incomplete branch of modern physics in which the nature of atomic and nuclear particles is being investigated. In this branch the physicist is dealing not only with much smaller objects and much higher velocities than ordinary, but he is inquiring into what happens at very small distances when two fast nuclear particles collide. Intuitively one expects some kind of force to be manifested by deflections and recoils. In addition, however, it is observed in such collisions that new, minute particles are created and fly off in addition to, or sometimes instead of, the original pair. These new particles, called pi mesons, are heavier than electrons and lighter than protons (276 electron masses for charged mesons, 264 m_e for uncharged) and may have positive, negative or no electrical charge. These mesons disintegrate spontaneously into other particles, one of which is a new particle called the mu meson (210 m_e), which in turn disintegrates into three stable particles. It is not the purpose here to summarize the interrelations of the now numerous "elementary" particles but rather to indicate that by using modern instruments to delve into the world of very small collision distances, new and astonishing phenomena are being discovered. Eventually, it is hoped to form a general theory of the relationship between such collisions and the creation of particles and, perhaps, such a theory will account for the spontaneous distintegration of elementary particles.

An inviolate requirement on any branch of modern physics is this: that when its rules are applied to objects of our everyday experience, the rules become the everyday rules. Thus, when we apply the general theory of relativity to the falling of an apple, we obtain the same result, with any reasonable accuracy, as by Newton's law of gravitation. If we apply quantum mechanics to a bowling ball, we find that we do not need to know both position and speed precisely and that the limits within which the theory will permit us to know them are well out of range of being tested. And, of course, the curious concept of relative velocity in special relativity reduces to the ordinary one when velocities are very small compared with that of light. If, and when, a theory of collisions of small particles emerges, and if there is a limit pertaining to ordinary experience, that limit too must be found in the present framework of classical physics.