exactly identical. Some years ago it was pointed out on theoretical grounds that there should be small differences in chemical behavior, and in 1935 Urey and Greiff made calculations for a whole series of isotopic chemical exchange reactions, a number of which have been used in attempts to separate the isotopes of the lighter elements. Among the two-phase gas-liquid chemical reactions which Urey and his co-workers have succeeded in obtaining some fractionation of the isotopes are: (1) The reaction of ammonia gas with ammonium ion in solution; (2) the reaction of ammonia gas with solvated ammonia in water and in alcohol; (3) the reaction of sulfur dioxide gas with bisulfite ion in solution; (4) the reaction of carbon dioxide with bicarbonate ion in solution. In all these cases the heavier isotope prefers to form the ion and is therefore concentrated in the solution. In this respect the heavier isotope is slightly different chemically from the lighter isotope. The fractionation factors α, which in these cases are the same as the equilibrium constants, give a measure of the chemical differences and are as follows:

(1) $N^{15}H_3 + N^{14}H_4^+ \rightleftharpoons N^{14}H_3 + N^{15}H_4^+$ $\alpha = 1.021$
(2) $N^{15}H_3 + N^{14}H_{3(aq)} \rightleftharpoons N^{14}H_3 + N^{15}H_{3(aq)}$ $\alpha = 1.006$
(3) $S^{34}O_2 + HS^{32}O_3^- \rightleftharpoons S^{32}O_2 + HS^{34}O_3^-$ $\alpha = 1.015$
(4) $C^{13}O_2 + HC^{12}O_3^- \rightleftharpoons C^{12}O_2 + HC^{13}O_3^-$ $\alpha = 1.014$

These differences are of the order of 1 to 2 per cent. compared to 300 per cent. to 1000 per cent. for the electrolytic separation of hydrogen and deuterium. However, with sufficient repetition of these equilibrium stages in a counter-current system, appreciable separation of the isotopes can be achieved. By use of reaction (1) Dr. Thode, Dr. Urey and their co-workers at Columbia University have recently announced that they have increased the concentration of N^{15} from 0.3 per cent. to 73 per cent., a remarkable accomplishment and an important one particularly for biological studies.

Lewis and Macdonald, of the University of California, using a counter-current flow of lithium in a mercury amalgam and lithium chloride in an ethyl alcohol solution, increased the concentration of Li^6 from 8 per cent. to about 16 per cent. The Li^6 was preferentially held in the amalgam and in this respect is slightly different chemically from Li^7. A number of investigators, including the present author, have studied the electrolysis of lithium from salt solutions into flowing mercury electrodes. Differences in the rate of discharge of the isotopes ranging from 2 per cent. to 7 per cent. have been observed. These differences are very much smaller than for electrolytic separations of hydrogen and deuterium, but are indeed real.

The present author in collaboration with Dr. Urey has also succeeded in obtaining a small fraction of the lithium and potassium isotopes by chemical exchange with zeolites. Zeolites are complex alkali alumino-silicates commonly used in water softening. The alkali ion is replaceable by other positive ions, and one isotope of lithium, for example, replaces sodium better than the other:

$$Li^+ + Na\ Zeolite \rightleftharpoons Li\ Zeolite + Na^+$$

The differences are again small, but by use of a 100-foot column, appreciable changes in the isotope ratio were produced. Further studies on these zeolite reactions and other similar reactions are being carried out at the University of Minnesota in attempts to obtain a larger separation of the biologically important and significant potassium isotopes.

It is indeed fortunate that the isotopes of an element all undergo the same *kind* of chemical reaction, otherwise their use in "exchange reactions" and "tracer" reactions would be impaired. By determining the extent to which a light isotope exchanges with a heavy isotope in contact with a molecule, one is in a position to say something about the binding or reactivity of the exchanging atoms. Groups containing the heavy isotope may be followed from one molecule to another in order to determine structure or reaction mechanisms. By synthesizing fats containing heavy hydrogen or carbon, or amino-acids and proteins containing heavy nitrogen or sulfur, or drugs or other chemicals, we may tag or label the molecule and trace it through biological processes. All we have to do is put it in the molecule such that it will not easily leave and exchange for the lighter isotopes. By analysis of different parts of the animal for the heavy isotope, we can determine where the substances fed or injected have gone. This is an example of a tracer reaction in biological chemistry, a very important new tool in the study of nutrition, biology and medicine.

We may conclude, therefore, that while the isotopic compounds of the lighter elements have a sufficient difference in chemical characteristics to afford a separation by chemical means (difficult as it may be), the differences are not sufficient to interfere with their valuable use in tracer and exchange reactions.

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SPAWNING OF OSTREA VIRGINICA AT LOW TEMPERATURES[1]

SINCE the end of the last century it has been generally accepted among aquatic biologists that under natural conditions the eastern oyster (*O. virginica*) may spawn only when the water temperature reaches

[1] Published with the permission of the U. S. Bureau of Fisheries.

20.0° C. or higher (Townsend, Stafford, Churchill, Prytherch and others).[2, 3, 4, 5] These field observations were confirmed in the laboratory by Galtsoff,[6, 7] who stated that the results of his extensive experiments with *O. virginica* showed that no spawning occurred below 20.0° C. However, the writer's observations of the last two summers on the spawning of oysters in Long Island Sound indicate that spawning may take place at temperatures several degrees lower than the so-called critical temperature of 20.0° C. In 1937 the initial and general spawning of the oyster population of the Sound, living in water from 1 to 25 feet, took place on and about July 3. The date of spawning was ascertained by Mr. James Engle and the writer by the age of oyster larvae found in the water, by the time of the beginning of oyster setting and, chiefly, by gross and histological studies of oyster gonads. The last method provided infallible proof that the gonads of oysters were partly discharged. The bottom water temperature several days prior to and during spawning time ranged from 17.5 to 18.5° C.

In 1938 the first spawning of oysters occurred on June 28, far ahead of the expected time. At one of our stations located in 30 feet of water, half of the oysters examined were found with partly discharged gonads, although the highest bottom temperature recorded at that station prior to and at the beginning of spawning was only 16.4° C. The highest temperature recorded at any of our 15 sampling stations, distributed over a distance of 30 miles of the oyster-producing section of the Sound, was 18.3° C. The average bottom water temperature of all 15 stations was 17.0° C. To avoid any errors in recording, the water temperature measurements were taken simultaneously with four deep-sea reversing thermometers, their correctness verified by the U. S. Bureau of Standards. The temperature was read by two investigators. At the invitation of the writer, Dr. P. S. Galtsoff, of the U. S. Bureau of Fisheries, was present on the investigation trip on June 30 and confirmed the fact that oysters spawned at temperatures lower than 20.0° C.

The observations of the last two summers refute the method advanced by Prytherch[8] for predicting one month in advance the time of spawning. His method is based upon the assumption that the spawning of oysters can not occur at a temperature lower than 20.0° C. Evidently, some other factors, undetermined at present, are involved in inducing the spawning of oysters at low temperatures. Until these factors and their role in stimulating the shedding of sex cells can be ascertained, no infallible method for predicting the time of spawning of oysters living under natural conditions can be advanced.

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[4] E. P. Churchill, Rept. U. S. Fish. Comm. for 1919, 1–51, 1921.
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[6] P. S. Galtsoff, *Collecting Net*, 4: 10, 277–278, 1931.
[7] P. S. Galtsoff, *Proc. Nat. Acad. Sci.*, 16–9, 555–559, 1930.
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HANDEDNESS OF TWINS

That the members of an occasional pair of identical twins differ in unimanual handedness is a well-established fact. The reasons for such reversals, however, have long been a matter of controversy. Newman and his school believe such reversals occur in those pairs in which division of the embryo occurred relatively later in embryonic development than in those pairs in which no reversals are manifest. The supposition is that in the former instance certain irreversible developments have taken place prior to separation of the embryos, thus one resulting embryo would be similar to the right and the other to the left side of what would have been a single individual had no separation taken place. According to this system of reasoning, identical twins showing less similarity in general appearance should show more reversals in handedness and other bilateral traits. The above theory has met with considerable criticism by various students of twins, in that no significant correlation has ever been shown to exist between the general similarity in features and appearance and the degree of reversal in handedness.

For several years the writer has noted that in both identical and fraternal twins showing reversals in unimanual handedness, an apparently high percentage of such pairs have one or more left-handers among their immediate relatives. An opportunity to obtain a considerable amount of pertinent data was afforded the writer by an invitation to attend a recent[1] twin party at Waterville, Maine. The party was sponsored by Mr. Welton P. Farrow to celebrate the visit of his identical twin brother, whom he had not seen for nineteen years.

Close to two hundred pairs of twins attended the party. The finest cooperation was given to the writer and his assistants, and data were obtained on the unimanual handedness of 109 pairs of twins and their immediate families. These data, plus data previously obtained, were sufficient to permit a statistical analysis.

[1] Held on August 16, 1938.