TABLE I. *Some* (He^3, n) *reactions. Energy release in thousandths of a mass unit.*

TARGET	PRODUCT	Q	TARGET	PRODUCT	Q
H^2	Li^{4*}	−4.1	Al^{27}	P^{29}	6.1
Li^6	B^{8*}	−2.4	Si^{28}	S^{30}	0.3
Li^7	B^{9*}	9.7	Si^{29}	S^{31}	5.5
B^{10}	N^{12}	0.8	P^{31}	Cl^{33}	5.1
C^{12}	O^{14}	−1.5	S^{32}	A^{34}	0.6
N^{14}	F^{16}	−1.9	S^{33}	A^{35}	4.6
O^{16}	Ne^{18}	−3.3	Cl^{35}	K^{37}	5.4
Ne^{20}	Mg^{22}	0.7	A^{36}	Ca^{38}	0.1
Mg^{24}	Si^{26}	1.2			

* These nuclei are probably unstable against disintegration into heavy particles. The masses have been estimated by H. A. Bethe, Phys. Rev. **55**, 434 (1939).

nuclei in the understanding of the beta-decay process,[3] and for the accurate estimate of the Coulomb energy difference between isobars. The available reactions leading to members of this series (the second column of Table IV in reference 4) are severely limited by the proton energies available. The use of He^3, however, would seem to offer the possibility of extending the work far beyond the present limit.

Of probably even greater interest is the feasibility of making members of the series of even nuclei having two more protons than neutrons (listed in the first column of Table IV of reference 4). No nucleus of this type has as yet been reported, although the sequence of these nuclei, along with the two isobaric series having, respectively, equal numbers of protons and neutrons, and two more neutrons than protons, is of the greatest importance in the study of the finer details of the like and unlike particle interactions.

Of the possible reactions (He^3, n), (He^3, H^1) (He^3, He^4), (He^3, H^2) and (He^3, γ), the first three types may with considerable probability be expected to occur. Of these the most useful for the production of nuclei at present not known is (He^3, n). It has been rather well established from the reactions (He^4, n), (H^2, n), (H^1, n), (γ, n) and (n, $2n$) that when sufficient energy is available for the emission of a neutron from the compound nucleus, the probability of this process will be large. It is difficult therefore to think of a reason why reactions of the type (He^3, n) should not be highly probable. In Table I are listed some of the more interesting of such reactions together with the anticipated[4] release of energy. Many of these product nuclei cannot be formed by any other process.

It may be pointed out, too, that the reaction $H^2(He^3, H^1)He^4$ is expected to yield protons of extraordinary energy since the "Q" for this reaction is 19.73 mMU.

It is of course unfortunate that the light isotope of helium exists with only a small abundance, but presumably the methods of isotope concentration now in use will help to increase the obtainable beam intensities.

WALTER H. BARKAS

Institute for Advanced Study,
Princeton, New Jersey,
December 1, 1939.

[1] L. W. Alvarez and R. Cornog, Phys. Rev. **56**, 379 (1939); **56**, 613 (1939).
[2] White, Delsasso, Fox and Creutz, Phys. Rev. **56**, 512 (1939).
[3] E. P. Wigner, Phys. Rev. **56**, 519 (1939).
[4] W. H. Barkas, Phys. Rev. **55**, 691 (1939).

The Use of Radioactive Elements as Tracers in Physiology

In a Letter to the Editor of *The Physical Review*[1] Dr. A. Barnett has raised a question as to whether the radiation from a radioactive tracer may exert a disturbing influence upon the physiological process which is being studied. In particular he refers to the measurement of permeability of the red blood cell, by means of radiosodium. Fortunately there exist some data on the effects of radiation on permeability, and an estimate of the magnitude of the effect can be made. It hardly need be remarked that it is unnecessary to consider the *local* effect of a particular radioactive atom upon a cell which happens to be close to it, first because the range of the beta-ray (or gamma-ray) is much greater than the size of the cell; second because if the atom emits radiation before entering the cell it is thereafter "dead" as far as detection is concerned. The effect upon permeability will therefore be the result of the generalized dose of ionization which is delivered to the material throughout its volume, and this may be spoken of in terms of r units. A large number of experiments upon induced changes in permeability by exposure to gamma-rays and x-rays have been summarized in a review article by Heilbrunn and Mazia.[2] Although the results vary considerably, it is to be noticed that in general no clear-cut effect occurs for doses less than a few hundred r units. What concentration of radiosodium will give a dose of, say, 500 r in 10 hours? If it is assumed that the beta-rays alone are absorbed in the material, the answer is about 10^6 disintegrations per cc per second, or the equivalent of about 10^{-2} milligram of radium per cc, in terms of gamma-ray strength. It is ordinarily not necessary to use tracers in such high concentration as this. However, in exceptional cases a correction may have to be applied for the effect of volume irradiation of the material.

As to the ability of biological material to discriminate between the radioactive and nonradioactive isotopes of a given element, a remark may be made. In the case of hydrogen it is quite clear that the isotopes behave differently, chemically, and this is best illustrated by the fact that they can be separated by chemical means in the laboratory. Obviously this is the extreme case, in that the isotopes differ in weight by a factor two, or even three, if radiohydrogen is included. For the heavier elements the isotopic difference in chemical behavior is agreed to be negligible, as far as any simple reaction is concerned, but biochemists might not allow us to generalize this to include the complicated and delicately balanced systems of reactions which occur in living material. One way in which we may hope to find a rather conclusive answer to this question is as follows. So far as the author is aware, no appreciable difference has been noted in the behavior of biological material toward the various *stable* isotopes of any element, with the possible exception of hydrogen. If such a difference does exist, a variation in the isotopic ratio in an element should be found in going from one compound of biological origin to another. An accurate test of this point is possible by means of the mass spectrograph. It follows, of course, that the difference, biochemically, between radioactive and nonradioactive isotopes will

certainly not be greater than the difference between the stable isotopes of a given element. Finally, it may be pointed out that the use of radioactive isomers as tracers would be free even from the above question, since they differ neither in weight nor in charge. It is almost certain that the number of known isomers will grow, and they may find a unique application in certain tracer problems.

H. R. CRANE

University of Michigan,
Ann Arbor, Michigan,
November 27, 1939.

[1] A. Barnett, Phys. Rev. **56**, 963 (1939).
[2] L. V. Heilbrunn and Daniel Mazia, *Biological Effects of Radiation*, edited by B. J. Duggar (New York, 1936).

Vitrification of Water

The main reason for the general failure of attempts to obtain water in the vitreous (amorphous) state by a rapid cooling from the liquid state, seems to be the high rate of formation of crystallization nuclei and the high velocity of growth of the ice crystals. With the idea that a sufficiently rapid cooling would finally prevent the formation of ice, we tried various procedures which consisted essentially in immersing suddenly in liquid air preparations in which droplets of water were either sprayed with an atomizer on thin glass or mica sheets or deposited on glass plates by the condensation of steam. An examination of these droplets between crossed Nicols revealed a crystalline structure. The cooling velocity had evidently not been high enough.

We finally succeeded in obtaining amorphous solid water by flattening small quantities of liquid water between two metal plates, cooled in liquid air, one of which was thrown toward the other at a high speed. A cylindrical stream of water 1 mm in diameter was made to flow vertically from a pipette. A brass disk 12 mm in diameter and 2 mm thick, mounted on a rod perpendicular to the plane of the disk, and cooled in liquid air immediately before being used, was fastened about 2 mm behind the stream, the direction of the latter being parallel to the plane of the disk. Another brass disk of the same size, mounted on a rod 12 cm long, and cooled in liquid air, was thrown against the first disk by the propelling action of the spring of a toy pistol. The pistol had previously been fastened in a steady position and adjusted so that the disk that it was to throw was parallel to the other disk and about 13 mm away from it. The disk thrown by the pistol was, then, at a distance of 1 cm from the stream.

The water flattened between the two disks takes the shape of a film a few microns thick. Pieces of this film, which sometimes have an area of 10 mm^2, were transported on a cooled glass slide into a specially built desiccated chamber placed on the stage of a polarizing microscope. These pieces are dark between crossed Nicols and stay dark for about 30 seconds. Then, with the rise in temperature, one can observe a gradual reestablishment of light and, finally, when the temperature approaches the melting point of ice, the preparation is full of crystals large enough to be well observed under the microscope. Water has evidently undergone vitrification and devitrification.

This experiment, of course, does not allow one to conclude anything as to the possible formation of crystalline nuclei smaller than the wave-length of the light used to detect them.

B. J. LUYET

Department of Biology,
Saint Louis University,
Saint Louis, Missouri,
November 16, 1939.

Radioactive Isotopes in Biology

In a recent note[1] it has been suggested that the general body of biological work with artificially radioactive indicators, which is currently appearing in journals, is subject to the criticism that apparently no one has made any measurements of the effects of these radioactive isotopes on biological materials. As regards the general systemic effects of radioactive isotopes, Hamilton and Alles[2] have data to show that at the concentrations with which they worked, there was no effect on electrocardiographic tracings, respiratory rate, pulse, and blood pressure. Greenberg and Glazko[3] also found no difference between active and inactive salts when used on isolated hearts, *in vitro*. Work from this laboratory[4] has shown that in the case of the unicellular alga *Nitella*, high activities (1–50 millicuries/liter) of radioactive Na will produce a decrease in the rate of uptake of sodium by the cell. This rate of penetration is inversely proportional to the logarithm of the millicurie dose, and is almost certainly due to the radiation from the artificial isotope $_{11}Na^{24}$ and not due to some differential penetration of inactive Na rather than active Na. That this is so is shown by the fact that the above results could be quantitatively duplicated with x-rays as a radiant source. Radioactive $_{19}K^{42}$ could also be shown to produce the effect as stated above.

When doses of below 1 millicurie per liter of radioactive Na were used, there was no longer any change in the rate of penetration with dosage, and it was concluded that below this value there was no effect. In most of the published experiments so far done the dosage has been below this limit, although it is true that there are papers describing work in which undoubtedly the radiation was producing an effect. In the case of the experiments of Cohn and Cohn[5] who used radioactive Na, the writer is acquainted with the dosage used and it is certainly below the activity to produce any so far known biological effect. In regard to the criticism in the previous note[1] it appears there are several points on membrane structure and permeability in which more recent work has shown him to be in error. Limited space does not permit of their discussion. In concluding it seems desirable to emphasize that the radiations emitted from the various radioactive isotopes important in biology vary so markedly in their character that a different limit of biological effect will have to be made for each one.

LORIN J. MULLINS

Department of Zoology,
University of California,
Berkeley, California,
November 17, 1939.

[1] A. Barnett, Phys. Rev. **56**, 963 (1939).
[2] J. G. Hamilton and G. Alles, Am. J. Physiol. **125**, 2 (1939).
[3] A. J. Glazko and D. M. Greenberg, Am. J. Physiol. **125**, 2 (1939).
[4] L. J. Mullins, J. Cell. Comp. Physiol. **14**, 3 (1939).
[5] W. E. Cohn, and E. T. Cohn, Proc. Soc. Exp. Biol. Med. **41**, 445–49 (1939).