an electron can be ruled out on the basis of the ionization and degree of multiple scattering of the track. The ionization of the two tracks is roughly equal at the junction point and several times the minimum value for a singly-charged particle. Thus, the tracks indicate about the same velocity for the two particles but show a markedly smaller scattering for the deflected particle, indicating a heavier mass.

Another possible interpretation is that the track was caused by a mesotron or proton that was scattered by a nuclear collision very close to the point where the knock-on collision occurred. The probability of this explanation is reduced considerably by the occurrence along the same track of a second knock-on electron of shorter range with a correspondingly smaller deflection of the heavy particle. Since the value of θ for this second collision is close to 90°, in which range the mass ratio varies rapidly with θ, the uncertainty in the exact direction of the knock-on electron caused by its large scattering makes it impossible to calculate a significant mass ratio. The value of $\csc\phi$ for this collision, however, sets an upper limit of 30 for the mass ratio.

Measurement of Radiocarbon as CO2 in Geiger-Müller Counters[1]

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The gas counting of radioactive carbon dioxide has been studied as a quantitative procedure in the range 2–12 cm Hg pressure. The results presented below demonstrate that this highly efficient counting method may be carried out with routinely available equipment furnishing up to 2,000 or 2,500 v.

Miller and Brown (*1, 2*) have recently reported a satisfactory counting technique at CO_2 pressures from 10 to 50 cm Hg admixed with 2 cm pressure of CS_2 vapor. They report threshold voltages over the range 1,800–4,500 v, depending on counter diameter and CO_2 pressure. This counting gas mixture was used in the experiments reported here. Using a 4-mil tungsten anode, 15.5-mm I.D. Geiger-Müller counter tube and a CS_2 partial pressure of approximately 2 cm, threshold voltages ranged from 1,450 to 2,200 v for the 2–12 cm pressure range. The measured activity was found to be directly proportional to the partial pressure of the radioactive gas sample admitted to the tube. This indicates that the counting efficiency of the tube for beta particles emitted by carbon 14 is very close to 100% in the effective volume over this pressure range.

Pure CO_2 was prepared by heating sodium bicarbonate (E. and A. Tested Purity Reagent) at 350°. Water vapor was condensed in a dry-ice trap. Radioactive CO_2 was prepared by addition of perchloric acid to barium carbonate containing carbon 14. Mallinckrodt carbon disulfide (analytical reagent; boiling range, 46°–47°) was used without further purification.

A scaling circuit and 2,500-v stabilized voltage supply was used with a modified Neher-Harper quenching tube and cathode follower. The latter unit contained two 6AG5 tubes, a 5.6-megohm grid resistor, and a variable cathode resistor usually set to 7,000 ohms. The Geiger-Müller tubes were glass envelopes containing as cathode chemically deposited silver covered with colloidal graphite (*1, 2*). Tungsten wire (4 mil) anodes were used.

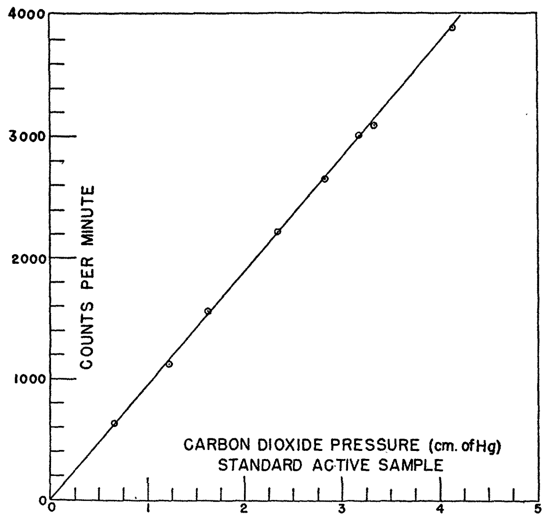

Fig. 1

A "cold finger" attached to the lower portion of the counter tube permitted quantitative condensation of CO_2 and CS_2 at liquid nitrogen temperatures. CO_2 pressures were measured with less than 0.3% error using a constant-volume mercury manometer and "cold finger" having a combined volume of about 18 ml. The resolving time was measured using two external radium sources and was found to be 4.1×10^{-5} min. Corrections using this resolving time were applied to the data.

In Fig. 1 the corrected counts per minute are plotted as a function of the partial pressure of a reference radioactive CO_2 sample using a counter tube having a 15.5-mm I.D. and 15-cm length of cathode surface. The pressures correspond to a temperature of 27.0°. The partial pressure of carbon disulfide in these fillings was 1.85 cm Hg (equivalent to one "doser" volume of vapor in the filling line when the liquid is maintained at 0.0°). In the case of the point closest to the origin, inactive CO_2 was added until the total pressure of CO_2 was 5.8 cm. The average deviation of the experimental points from the straight line drawn in Fig. 1 is 1.1% The range of CO_2 pressures plotted extends to 4 cm Hg. Further measurements made after adding inactive CO_2 up to pressures of about 10 cm Hg checked the line

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drawn in the figure within 1–2%. Several measurements were made in which the CS_2 pressures were 0.9 and 3.5 cm. These results were in agreement with the line drawn in Fig. 1 within 1–2%.

The threshold voltage for partial pressures of 1.0 and 1.85 cm Hg, respectively, of CO_2 and CS_2 is about 1,400 v. An average increase in threshold voltage of about 80 v/cm increase in CO_2 pressure was observed. The following conclusions concerning plateau lengths are based on about 20 fillings over the range 1–7 cm CO_2 pressure: Below 2 cm the plateau length is less than 100 v; over the range 2–3 cm it increases from about 100 to 200 v; and above 3 cm it is usually greater than 200 v. The plateau slope is, on the average, less than 2%/100-v interval and is frequently observed to be less than 1%.

When filled with CO_2 at 10 cm pressure at 27°, the CO_2 content of the 15.5-mm tube is equivalent to a 43-mg sample of barium carbonate. The background count inside a 5-cm thick lead brick housing is about 40 cpm. The effective counting volume can readily be made 70% of the total volume. Counter tubes having a diameter of only 10 mm and an 18-cm cathode length permit satisfactory counting in this pressure range and have the advantage of reduced background count. In order to use larger samples of CO_2 in the pressure and voltage range discussed above, tubes with larger diameters may be employed. Satisfactory results have been obtained with a 32-mm I.D. tube having a cathode length of 18 cm.

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Reduction of Undesirable By-Effects in Products Treated by Radiation

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In previous publications (*1*) we have discussed the sterilization and preservation of food in the raw state by use of ultrashort application periods of penetrating electrons as obtained from the Capacitron. In this connection we have already emphasized the importance of having optimum outside conditions during irradiation of various foodstuffs and therapeuticals in order to avoid unspecific side reactions.

While it is accepted generally that corpuscular radiations of all kinds, within their penetration range, are able to inactivate microorganisms and also, in many cases, stop or inhibit enzymatic action, little has been published about the suppression of changes in taste, odor, appearance, etc. of the products so treated.

The ideal would be, of course, to inactivate enzymes and microorganisms without influencing the products to be preserved in any other way. Although this ideal cannot always be achieved, attempts must be made to come as near as possible to such a goal if a preservation and inactivation method by radiation is to be at all successful.

Sterilization and preservation at low temperatures[1] is a problem of fundamental importance. Therefore, it is of great interest to determine if, in principle, undesirable side reactions are something which is inherent in biologically active rays or if these can be minimized with the aid of certain procedures. Many experiments performed by ourselves or other investigators gave foundation to the belief that many of the changes and reactions formerly attributed to the action of rays could be avoided if outside conditions were created which would sterilize in any desired state—raw, partly or fully cooked—with as little damage as possible. It should be kept in mind that the taste and odor changes occurring in food products are, in the last analysis, chemical changes. Such changes would also be harmful, for instance, in the preparation of vaccines by means of radiation. Therefore, vice versa, better antigenicity should be obtained by killing the microorganisms without any chemical changes at all.

In 1913 Duane and Scheuer (*2*) demonstrated that ice irradiated with radon at −183° C did not give rise to any hydrogen peroxide formation whatsoever. More recently Svedberg and Brohult (*5*) have shown that irradiation of hemoglobin and serum albumin with alpha rays at room temperature and at 0° C causes the formation of low molecular substances, as revealed in the ultracentrifuge by a very pronounced polydispersity of the protein. When irradiated at the temperature of liquid air, hemoglobin showed no change whatever, even after exposure to 5 times the doses required to give a noticeable effect at room temperature. Serum albumin was only slightly affected.

We find that in the case of bovine plasma albumin 7,000,000 rep (*3*) in the form of high-speed electrons will produce profound changes in the liquid state, whereas irradiation with the same dosage at −50° C has little effect.[2] However, the lethal action of penetrating electrons is affected only to a minute extent whether microorganisms are treated at room temperatures or in the frozen or deep-frozen state. This fact contributes again to underlining the selective effects possible by employing penetrating radiation.

In the case of many foodstuffs, cooling has a distinctive effect on the exclusion of undesirable side reactions, particularly if this method is combined with a partial evacuation in order to remove as much air as possible during the process of irradiation. We mentioned in our first

[1] The temperature effects caused by penetrating electrons in the absorber are negligible. A dose of 100,000 Roentgen-Equivalent-Physical (rep) is equivalent to 8.5×10^6 ergs/cc, which corresponds to a temperature rise in water of 0.2° C. We find that 600,000 rep constitutes a 100% killing dose for bacteria and spores in foods. This would be equal to a temperature rise of 1.2° C.

[2] We are indebted to Kurt G. Stern, Polytechnic Institute of Brooklyn, for these results, obtained by electrophoresis and ultracentrifuge experiments.