known to predict, with assurance, the metabolic fate of such complex compounds in biological systems. We may suppose, however, if bottom-dwelling organisms feeding on these complexes in the sea water are responsible for deposition of manganese and iron hydroxide along with appreciable quantities of numerous other trace elements, that these organisms are able to metabolize the organic part of the complex molecule and reject the inorganic part. It can be imagined that by this process a concentration of inorganic ions is built up within or in the neighborhood of the living organisms. The ions, freed of their organic complexing agent which protected them from hydrolysis, then precipitate as hydroxides in the sea water. The metabolic processes of the organisms might not be able to compete successfully with all reactions involved in forming especially stable complexes, but it would seem from the variety of trace elements present in these deposits that complexes of appropriate stability are common.

From this hypothesis, a number of inferences can be drawn.

1) If manganese-rich deposits are being formed today by living biological agents, it should be possible to detect metabolic activity in fresh samples. A generation time of about 2 weeks is suggested by calculations based on the following assumptions: rate of deposition, 1 mm/1000 years; organism 1 μ thick having the same composition as *Escherichia coli*; 2 moles of amino acid used per mole of manganese deposited. Faster deposition, as advocated by Goldberg and Arrhenius (*2*), would reduce the generation time proportionally.

2) If temperature has no limiting effect on quality or quantity of nutrients, then, as in any other biological system, there should be an optimum growth temperature.

3) If the rate of growth is solely a function of the rate at which nutrients are supplied by the moving bottom currents, then it should be possible to recognize differences in abundances in areas swept by currents and in areas where the currents are known to be minimal. On a small scale, this effect might be detected by detailed examination of the geometry of individual samples.

4) If the various organic complexes that provide material for trace-element deposition have a sharp inverse dependence of their stability on temperature, then, in general, the detailed composition of the deposits should become simpler with increased temperature of formation.

5) Elements that do not form organic complexes or that already are strongly complexed inorganically will be missing from the deposits.

6) If it is correct that complex molecules are required for trace-element deposition on the sea floor, then their importance in other chemical and biological processes in the sea is to be expected.

This hypothesis affords plausible explanations for a number of well-established facts about the manganese-rich deposits of the sea floor. (i) A mechanism is provided for effecting vast concentration of a wide variety of trace elements from sea water. Fluctuations in composition reflect changes in the nutrients. (ii) The concentrated product is poorly organized crystallographically, partly because of the variety of elements in it, but more particularly because of the manner of disperse formation on a minute size-scale basis. (iii) From an analysis of the Challenger Expedition report (*6*) it is seen that the probability of finding manganese-rich deposits is high (.45) in water between 34° and 38°F and low (.076) in water that is now warmer than 38°F; no manganese nodules can be identified in the hundreds of photographs (*7*) of the Mediterranean and Red Sea floors where the temperatures are about 56° and 72°F, respectively. Such findings are consistent with the needs of an organism living on a starvation diet. Deposits of this type are thus naturally associated with an ice age. (The deposits on the Blake Plateau where the bottom temperature is now 45°F may no longer be increasing.) (iv) The presence of extensive adherent coatings of manganese-rich deposits on basic igneous rocks and their scarcity on lime, and, in nodules, the common nuclei of sharks' teeth, earbones of whales, fragments of previous nodules, and so forth, merely reflect the needs of the organisms for certain types of materials on which to attach (*8, 9*).

Note added in proof: In *Nature* (in press), J. W. Graham and S. C. Cooper give additional evidence bearing on the hypothesis of this report.

JOHN W. GRAHAM
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

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Spiral Capillary Plastic Scintillation Flow Counter for Beta Assay

Abstract. Tracer counting of beta emitters in aqueous solution was performed with a detector fabricated from a plastic scintillator capillary. The detector exhibits low gamma background and reproducible detection efficiency, and it requires minimum sample preparation. Counting efficiencies were determined for aqueous solutions of P^{32}, Na^{22}, and C^{14} and for $C^{14}O_2$ gas.

Efforts to achieve rapid and reproducible methods of sample preparation for measurement of low-energy alpha and beta emitters in gaseous form or in solution are often fraught with difficulties. For scintillation counting it is usually necessary to have the sample in a form soluble in, or miscible with, a liquid scintillator solution. Obtaining such samples presents problems of solubility and quenching action which are frequently difficult to circumvent. The suitability of various solvent systems has been investigated by Hayes (*1*), while Kallmann has suggested the use of naphthalene to reduce quenching (*2*). Furthermore, liquid scintillators which will accommodate small percentages of aqueous solution have been developed (*3*). Davidson (*4*) has recently reviewed the practical aspects of internal liquid scintillation counting. For very low C^{14} activities the synthesis of organic samples to give suitable solvents or diluents has been reported (*5*). The counting of suspensions of insoluble active samples in liquid scintillators (*6*) and scintillating gels (*7*) avoids many of the problems inherent in internal liquid scintillation counting but is not generally applicable to aqueous solutions. Schram (*8*) has recently counted aqueous solutions on plastic scintillator sheets.

Nevertheless, most of these methods require additional sample preparation and standardization of the scintillator solution with respect to efficiency (*1*). Significant and often variable amounts of quenching are encountered in the use of different samples or special solvent mixtures (*4, 9*).

In the work discussed in this report we investigated the use of a plastic scintillator capillary for direct counting of aqueous solutions containing weak beta emitters such as C^{14}. By a suitable choice of geometry, a wall thickness sufficient to interact with most of the beta energy can be employed, with a bore diameter which will not give serious self-absorption at low beta energies. Increasing the wall thickness limits the length, and hence the volume, of the capillary but increases the height of the pulse from high-energy emitters. Decreasing the bore of the capillary decreases self-absorption but reduces the volume and hence the total counting rate.

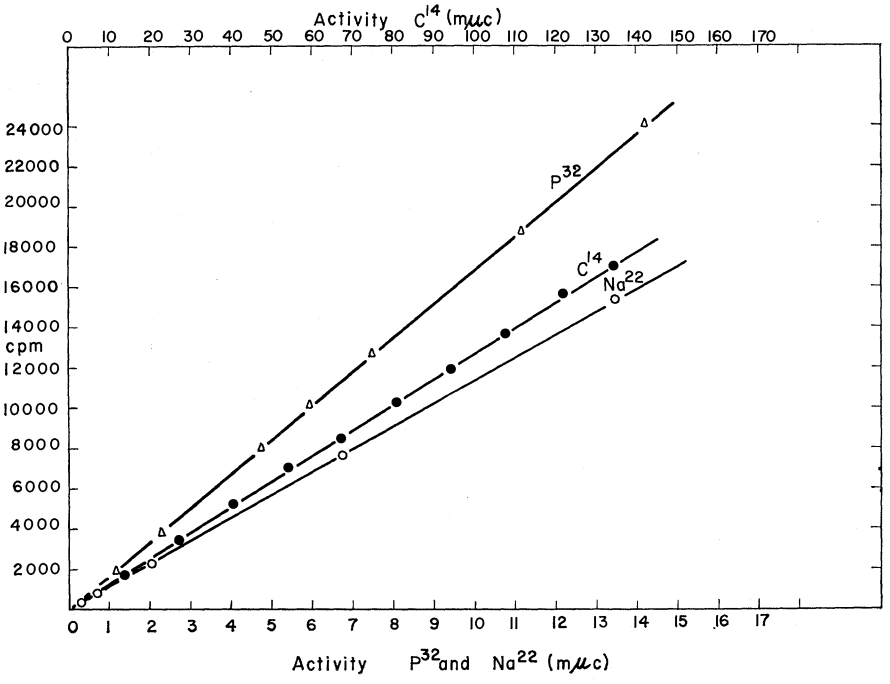

Fig. 1. Linear dependence of counting rate on activity of three beta emitters in a spiral scintillation flow counter.

Several spiral scintillation flow counter assemblies were furnished to us by Nuclear Enterprises. The final unit, representing a good compromise with respect to the factors noted above, consisted of a length (approximately 1 m) of plastic scintillator capillary wound into a tight spiral 1¾ in. in outside diameter. The capillary was 1.5 mm in outside diameter and 0.6 mm in inside diameter and had a volume of 0.269 cm^3. The capillary was encapsulated in Silicone fluid (Dow Corning 200, 60,000 centistokes) and was fitted with a white plastic reflector.

A scintillation counting assembly employing a Dumont 6292 photomultiplier and conventional electronic circuits, without phototube refrigeration or anticoincidence circuitry, was used in our tests. A linear amplifier and an integral discriminator, set at the lowest level commensurate with tolerable photomultiplier noise, were employed.

Measurements were made on solutions of $C^{14}O_3^{--}$, $P^{32}O_4^{---}$, and Na^{22}; the corresponding maximum particle energies were 0.155, 1.702, and 0.54 Mev, respectively. The results of experiments with these systems are shown in Fig. 1. The desired linearity between counting rate and activity was obtained for each of these isotopes. Counting efficiencies of 76.4 percent for P^{32}, 51.4 percent for Na^{22}, and 5.7 percent for C^{14} were obtained. The stated specific activities (corrected for decay) were checked by internal liquid scintillation counting. The background counting rates, without lead shielding, were 68, 78, and 222 count/min for Na^{22}, P^{32}, and C^{14}, respectively. In order to determine the limits of detection, some measurements were taken with the detector surrounded by a 2-in. lead shield. A background count for Na^{22} of 12 count/min was obtained. On the assumption that a detection limit determined by true sample count is equal to background, this indicates a limit of 10 μμc. Some measurements were also made with $C^{14}O_2$ gas, for which a detection efficiency of 58.3 percent was obtained.

The spiral capillary was rinsed with water after each measurement and checked for residual activity. Only the phosphate solutions showed some residual counts, due to absorption on the walls. It was found that the residual activity could be removed by rinsing with a Versene chelate solution.

The measurements were made to investigate the applicability of this detector to rapid, routine assays with standard equipment, and to compare its performance with that of other methods of scintillation counting. Certain features of this technique are noteworthy: (i) inorganic solutions or biological fluids can be counted without further sample preparation; (ii) the detector's efficiency is constant, is not influenced by quenching effects due to impurities or differences in counter filling compositions, and is not time-dependent; (iii) the gamma background is low, due to the small detection volume, and discrimination against background is possible; (iv) 4-π detection geometry is employed; (v) colored solutions can be used, since light is collected from the outside walls of the capillary; (vi) in flow experiments the counting rate is independent of the rate of flow.

Although internal liquid scintillation counting appears to be indicated where larger volumes of sample are required in order to obtain a sufficiently high counting rate, in over-all performance the detector is comparable to most scintillation and gas counters. Some further improvement in detection efficiency is no doubt feasible through elaboration of electronic techniques, and indeed this will be essential if counting of tritium in solution is to be attempted. It is nevertheless clear that this simple assembly has good potentialities for tracer assays with solutions or gases of the majority of beta-emitting isotopes. The speed with which measurements may be obtained with this spiral counter and the reproducibility of measurements so obtained suggest that this detector may prove useful in a variety of studies, particularly in the biological and chemical fields, where it may seem undesirable to use more elegant and elaborate detection methods for the assay of large numbers of samples (*10*).

B. L. Funt
A. Hetherington
Chemistry Department,
University of Manitoba, Winnipeg

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