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K^{40} MEASUREMENTS IN BODY FLUIDS

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HEALTH PHYSICS DIVISION

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ABSTRACT

The use of a recently developed instrument to roughly assess the radioactivity in unconcentrated body fluids is discussed, and the details of K^{40} measurements are given.

K^{40} MEASUREMENTS IN BODY FLUIDS

Wm. M. Hurst

The unavoidable exposure of the human being to radiation sources (cosmic rays, U-Th-Ac isotope series, Ra, K^{40}) occurring in nature, is assessed at approximately 0.6 mrem per day[1]. That value is subject to redetermination when the various factors are measured with greater accuracy. For instance, different values for the total potassium content of an adult human being, ranging from 77 grams to 245 grams, are given in the literature (Table 1). Natural potassium consists of the isotopes K^{39}, K^{40}, and K^{41}, of which the radioactive isotope K^{40} is present at a fixed percentage (0.012%)[2].

The decay scheme of K^{40} and the associated radiation energies have been determined by various workers (private communication from P. R. Bell, ORNL) as consisting of 100 betas of approximately 1.36 Mev maximum energy and 12 gamma rays of 1.462 Mev energy for 112 disintegrations. The beta spectrum is of the forbidden variety.

Bio-assay work with body fluids, to determine the amount of radioactivity present, usually requires a concentration of the fluid and possibly the removal of solids in order that the activity can be detected and measured. If unusually high levels of radioactivity are suspected in the unconcentrated body fluids, a liquid monitoring instrument capable of measuring such activities in a few minutes would be of considerable value.

An instrument having sufficient sensitivity and the calibration unit have been reported[3], and the following account describes work with K^{40} in detail.

The concentration of potassium in urine was estimated at approximately 2 mg K per cc. That value is based upon an ingestion rate of three gm K per day, 90 percent or 2.7 gm K excretion daily in the urine, and a total daily void of 1.35 liters. There is approximately 2.1 mg K per gram of blood[4]. If the K^{40} component of natural potassium in solution is measurable where the solution concentration is 2 mg K per cc, the liquid monitoring apparatus mentioned above should thus measure the K^{40} naturally present in the urine and blood.

A solution containing two milligrams of natural potassium (atomic weight 39.1) per cc was made by adding 2.585 grams of KNO_3 (mol. wt. 101.1) to one-half liter of water. Since the isotope K^{40} constitutes about 0.012 percent of the natural potassium, the solution thus contains 0.24 micrograms K^{40} per cc. The relation between the quantity of an unstable isotope and its activity in disintegrations per second is given by the following expression:

$$1.44 \times T_{1/2} \times \frac{\text{at. wt.}}{6.02 \times 10^{23}} \times \text{dis. per sec.} = \text{grams},$$

where, $T_{1/2}$ is the half-life of the isotope in seconds.

For the case of K^{40}, this reduces to:

$$\text{dis. per sec.} = \text{grams}/4.226 \times 10^{-6} \qquad \text{or}$$

$$\text{microcuries} = \text{grams}/1.563 \times 10^{-1}.$$

A measurement of the activity of the 1.53×10^{-6} microcuries K^{40} per cc solution was made with the calibration unit[3]. The background counting rate when the sample solution cell contained 80 cc of distilled

H_2O was 11 counts per minute. The gross counting rate for an 80 cc sample of the K^{40} solution was 16.4 counts per minute for a 30 minute count resulting in a net count rate of 5.4 ± 0.7 counts per minute. Another measurement was made using a solution concentration of 7.7×10^{-6} microcurie K^{40} per cc, obtaining a net value of 28.4 ± 1.6 counts per minute. The response of the calibration unit to K^{40} in solution is one net count per minute per 0.27×10^{-6} microcurie K^{40} per cc, or one net count per minute per 0.35 milligram natural potassium per cc.

A series of urine samples from one person were measured in the calibration unit with the following results:

Total Void, cc	Net c/m	mg K/cc	gm K per Void
160	12	4.2	0.67
285	9.5	3.3	0.94
165	15	5.3	0.87
170	8	2.8	0.47
350	5	1.7	0.59
175	10	3.5	0.61

The activity measured was assumed to be K^{40} only. The person did not drink between meals, thus tending to raise the average concentration of K. Since one void per day was not collected, a daily integration was not possible.

Table 1

Adult Human Being - Total Potassium Content

Medical Biochemistry, by Everett (page 582)	140 gram
Mineral Metabolism, by Shohl (page 19)	150
Howells' Textbook of Physiology, by Fulton (page 1149)	150
Textbook of Biochemistry, by Harrow (page 402) says 0.35% of total body is potassium, and 0.35% of 70 kg is	245
Foundation of Nutrition, by Rose (page 145)	245
Chemistry of Food and Nutrition, by Sherman; Ca and P in Foods and Nutrition, by Sherman, (page 4) both state that 0.35% of total body weight is potassium, for 70 kg that is	245
Scientific American, August, 1949 (page 16-21)	175
Elements of Physical Biology, by Lotka (page 197) says 0.11% of total body is potassium, and 0.11% of 70 kg is	77

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2 Mullins, L. J., Zerahn, K.: "Distribution of Potassium Isotopes in Biological Material", J. Biol. Chem., 174, 107 (1948)

3 Hurst, Wm. M.: "Monitoring of Liquids for Radioactivity", ORNL-1155

4 Everett, M. R., Hoeber, Paul B.: "Medical Biochemistry", (1946)