Student Experiment in the Radioassay of Potassium and Uranium[1]

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Because of the applications of nuclear phenomena to chemistry, instruction in the fundamental concepts may be properly included in elementary chemistry courses at the college level. Since nuclear chemistry is, to a large extent, an applied science, a proportionate amount of laboratory practice should be included in any course in which this subject is discussed.

A recent survey of the status of instruction in nuclear chemistry in American colleges and universities (1) has indicated that there exists an urgent need for elementary laboratory instruction in this phase of chemistry.

The following laboratory procedure is one of a group devised in an effort to provide suitable material for student experiments and to encourage the more widespread adoption of laboratory instruction in nuclear chemistry. This experiment illustrates the application of nuclear phenomena in analytical chemistry. The natural radioactivity of potassium and uranium is used as the basis for a quantitative determination of these elements in solid samples.

Equipment

The Geiger counter and electronic circuit required for this experiment have been previously described (2).

The results obtained in this experiment are based on precise activity measurements; therefore, accurate radioassay requires reproducible sample mounting.

A small aluminum dish serves as a suitable container for the samples. The dimensions should be such as to give a maximum activity and to ensure sufficient sample thickness. A container 50 mm. in diameter and 12 mm. high is readily available and proves satisfactory. For counting, the aluminum container is supported by a metal holder which can be inserted into the shelves of a standard tube mount. The arrangement should be such as to bring the sample as close to the counter as possible. Metal discs cut from aluminum sheet to fit the sample pan should be used when collecting the data for the self-absorption curve. By placing the discs beneath the sample, samples of different thicknesses will be identical distances from the counter.

Experimental Procedure

Weigh five portions of potassium chloride—each equivalent to 0.1 gram per square centimeter of the sample pan. The depth of the sample

1. Taken from a thesis submitted to the University of Notre Dame in partial fulfillment of the requirements for the Master of Science degree under the direction of Dr. William H. Hamill and Dr. Russell R. Williams, Jr. (1952).

will be increased from 0.1 to 0.5 g/cm^2 by the successive addition of the five portions. After each increment in thickness, count the sample for a period long enough to collect 1000 counts. Plot the activity in counts per minute against the sample thickness expressed in terms of weight per unit area (g/cm^2). (Figure 1.) From this self-absorption curve determine the sample thickness at which the activity is a maximum for the potassium 40 beta energy. All subsequent measurements should be made on samples of at least this thickness.

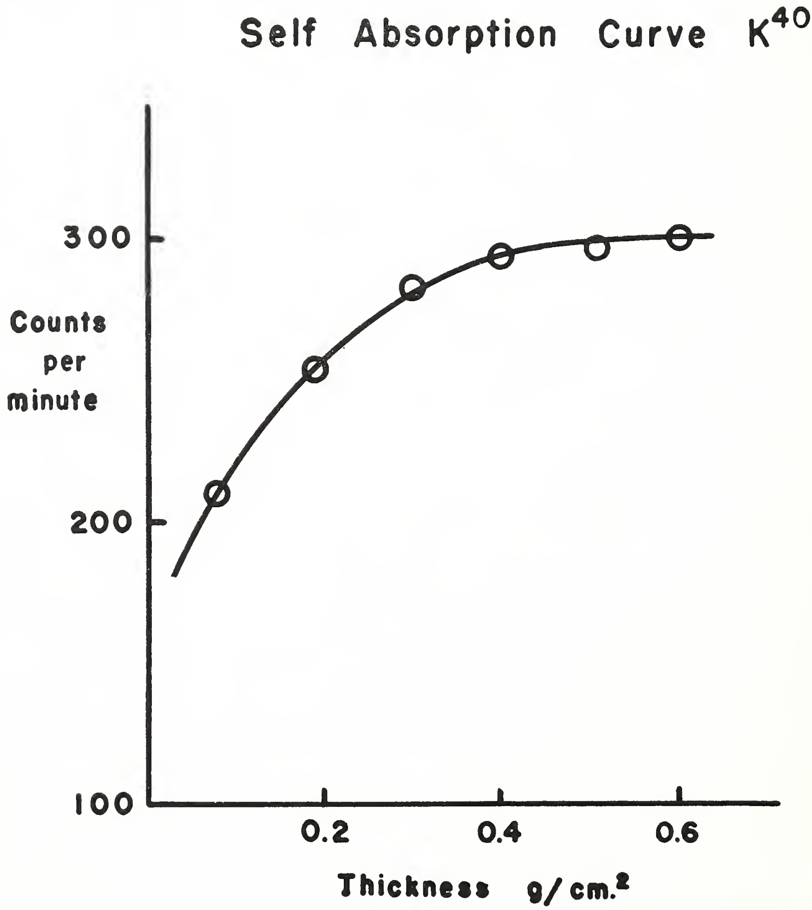

Fig. 1. Self Absorption Curve K^{40}

Several mixtures of potassium and sodium chlorides containing known percentages of potassium should be prepared previous to the laboratory period. Count the mixtures, collecting at least 1000 counts for each sample. Express the results graphically as counts per minute versus percent potassium. Figure 2 is a plot of typical data and illustrates the proportionality between the percent potassium and the activity.

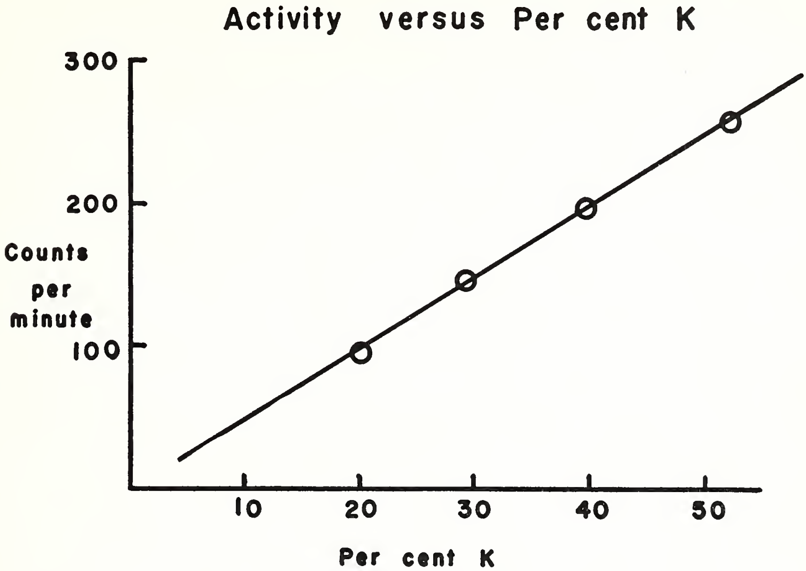

Fig. 2. Activity versus percent potassium.

Obtain from the instructor unknown samples containing potassium. Measure the count rate and from the proportionality plot determine the percent potassium.

Discussion of Results

The radioactivity of potassium is due to the isotope of mass number 40 which has an abundance of 0.011% of naturally occurring potassium. K^{40} decays by the emission of beta particles, positrons, and gamma rays. The weak beta particles are easily absorbed by the sample. With each increment in sample depth, the activity approaches a maximum. The activity remains constant with a further increase in thickness because the radiations from the bottom of the sample are completely absorbed by the sample itself. The self-absorption curve for the K^{40} beta energy illustrated in Figure 1 shows a maximum activity at a sample thickness of about 0.4 g/cm^2.

Students must appreciate the importance of reproducible geometry. The orientation of the sample with respect to the counter and sample area and depth must be constant so that the count rates may be compared validly.

The precision of the measurements, determined by the number of counts collected, is limited by the length of time available for the experiment. Collection of 1000 counts gives a probable error of 3%. For uniform accuracy, the same number of counts should be collected for each sample. The counting time, therefore, depends on the potassium content of the mixtures.

Student results have shown that the percent of potassium can be determined with reasonable accuracy. All of the results have been within 2% of the calculated values.

In view of the current widespread interest in prospecting for uranium ores, it is appropriate for students to apply this method of analysis to the determination of uranium. The beta particles emitted by UX_2, which is produced by the disintegration of uranium 238, give an activity which is proportional to the uranium content of the samples. Suitable samples can be prepared from uranyl nitrate and sand or soil. Measured amounts of the salt are dissolved in a few milliliters of dilute nitric acid and then mixed with the sand to give samples containing varying percentages of uranium. The high specific activity of uranium permits the determination of amounts as low as 0.005 percent.

The results have shown that laboratory instruction in nuclear chemistry is feasible on the undergraduate level and within the means of small colleges as well as universities.

Literature Cited

1. WILLIAMS, R. R. JR., AND W. H. HAMILL. 1952. Nuclear Chemistry in the Curricula of American Colleges and Universities. J. Chem. Ed. **29**: 332.
2. HAMILL, W. H., R. R. WILLIAMS, JR., AND R. H. SCHULER. 1949. Laboratory Exercises in Nuclear Chemistry. J. Chem. Ed. **26**: 210, 310, 667.