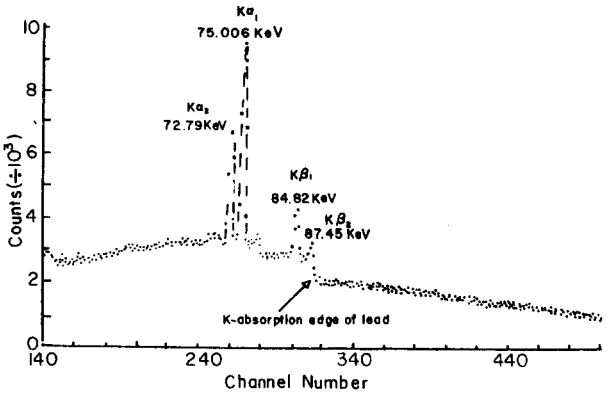

Fig. 3. Spectrum of transmitted gamma rays by a lead absorber. The source of the radiations is a neutron source that emits continuous energy gamma rays. A small absorption edge due to the gold coating on the detector is also visible. The four peaks are the characteristic x rays of lead.

agree very well with the published results in the literature.[5] The break in the absorption curve is due to the sudden increase in the absorption coefficient at the K-absorption edge of lead.

With the sources we used, as is evident from Fig. 2, it is not possible to determine the K-absorption edge. However, it is possible to determine the K-absorption edge with good precision if a neutron source, such as a Pu–Be source, is available in the laboratory.

The neutron source available in our laboratory is a 5-Ci Pu–Be source. The source is kept in a container of 2 ft diameter and 3 ft height and the container is filled with wax. This container is surrounded by boron impregnated plastic blocks. Thus the source is very well shielded for neutrons. The electromagnetic radiations in the 1-keV–1-MeV range coming through the shielding are the radiations of interest to us. These radiations have a continuous energy distribution. The spectrum of x rays from our neutron source obtained with a 84.1 mg/cm^2 lead absorber placed in front of the detector is shown in Fig. 3. The spectrum shows a discontinuity in the curve due to the K-absorption edge. The energy corresponding to this discontinuity is determined to be 88.0 keV, which compares very well with the published value of the K-absorption edge of lead.[5]

During this experiment, the neutron sources remain in the container and the detector and the absorber are placed outside the shielding. The source-to-detector distance is approximately 2 ft 5 in. The measured radiation dosage at the detector is 0.3 mr/hr and the students are advised not to stay close to the experimental system during accumulation of the data.

Thus in this experiment with equipment available in advanced laboratories, students become familiar with certain fundamental ideas regarding the interaction of electromagnetic rays with matter, such as the exponential decrease in the intensity with absorber thickness, variation of the coefficient of absorption with energy and the effect of the K-absorption edge on the absorption coefficient.

[1]R. T. Overman and H. M. Clark, *Radioisotopes Techniques* (McGraw-Hill, New York, 1960), pp. 243–244.
[2]J. L. Duggan, F. D. McDaniel, and J. G. Hehn, *Advanced Experiments in Nuclear Science, Vol. 1* (North Texas State University, 1970).
[3]D. Halliday, *Introductory Nuclear Physics* (Wiley, New York, 1960), p. 164.
[4]W. Kiszenick and N. Wainfan, Am. J. Phys. **42**, 161 (1974).
[5]*Radiological Health Handbook* (Division of Radiological Health, U.S. Department of Health, Education and Welfare, Washington, DC, 1960).

Moseley's law

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H. G. J. Moseley studied the dependence of energy of characteristic x rays on the atomic mass number. The results of these studies were discussed in two historic papers published in 1913.[1,2] His discovery of a linear relationship between the energy of the characteristic x rays and the square of atomic number of the material enabled him to predict the places of the rare earth elements in the periodic table. The assignment of atomic number 27 to cobalt and 28 to nickel was one of the results of Moseley's studies.

Experiments on confirmation of Moseley's law are appropriate for undergraduate modern physics laboratories. Two types of such experiments are done in laboratories. One uses continuous x rays from x-ray machines to excite characteristic x rays from samples. The energies of the characteristic x rays are then determined by x-ray diffractometry.[3] In the second type of experiments, radioactive sources are used to excite the characteristic x rays and determine their energy by proportional counters.[4] Even though the first method gives better results, in terms of accuracy, in the ability to resolve the $K\alpha_1 - K\alpha_2$ lines, etc., this method demands sophisticated instruments of high cost such as a diffractometer and considerable time in performing the experiment using several elemental samples. The second method is simple but lacks accuracy.

In a recent article we have reported a simple method to study variation of absorption coefficient of x rays in matter as a function of energy.[5] In that article we mentioned a method of determining the energy of x-ray absorption edges. The purpose of this note is to show that this experiment can be effectively used to confirm Moseley's law. Moreover, it has the advantages of the two methods discussed above: the accuracy of the first type of experiments and the simplicity of the second type of experiments.

The experimental setup uses a Ge(Li) detector for the detection of gamma rays. The signals from the detector are amplified and analyzed by a multichannel analyzer. The

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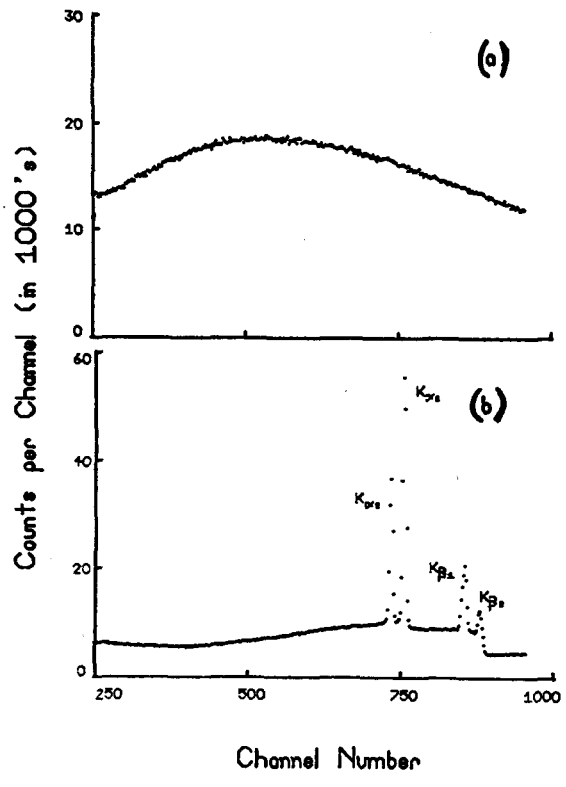

Fig. 1. (a) Energy distribution of x rays from a neutron source. Channel 1000 corresponds to 277.7 keV. (b) Energy distribution of x rays with a lead absorber in front of the detector. Absorption edge and the characteristic K rays of lead are seen in this figure.

system is calibrated using sources Se^{75} and Ba^{133}, which emit several gamma rays in the energy range (35–136 keV) of interest. This calibration curve is used to determine the energies of the characteristic x rays. A neutron source is used as a source of primary x rays. As shown in Fig. 1(a), the radiations coming through the wax shielding from a neutron source has a continuous energy distribution ranging from 0 to 200 keV. These x rays are used to excite the characteristic x rays of the sample under study.

In this experiment the Ge(Li) detector is kept about 2 ft from the source (outside the shielding). Foils of materials under study are kept in front of the detector. The energy distribution with a lead foil in front of the detector shows several characteristic peaks and a clearly visible absorption edge [Fig. 1(b)]. From their positions (channel number) using the calibration curve, energies of the absorption edge and the x rays are determined. The energy of the various x rays as a function of z is plotted in Fig. 2.

Thickness of the foils are not critical in these experiments. We have used thicknesses ranging from 11.8 to 444.9 mg/cm^2. In some cases, where metal foils were not available, we have used oxide powders kept between cellophane tapes.

Spectra of a sufficient number of foils to verify Moseley's law can be obtained in a laboratory class period of 2–3 hr.

[1]H. G. Moseley, Philos. Mag. **26**, 1024 (1913).
[2]H. G. Moseley, Philos. Mag. **27**, 703 (1914).
[3]W. Kiszenick and N. Wainfan, Am. J. Phys. **42**, 161 (1974).
[4]C. Hohenemser and I. M. Asher, Am. J. Phys. **36**, 882 (1968).
[5]P. J. Ouseph, K. D. Hoskins, J. I. Berman, and A. J. Bolander, Am. J. Phys. **50**, 275 (1982).

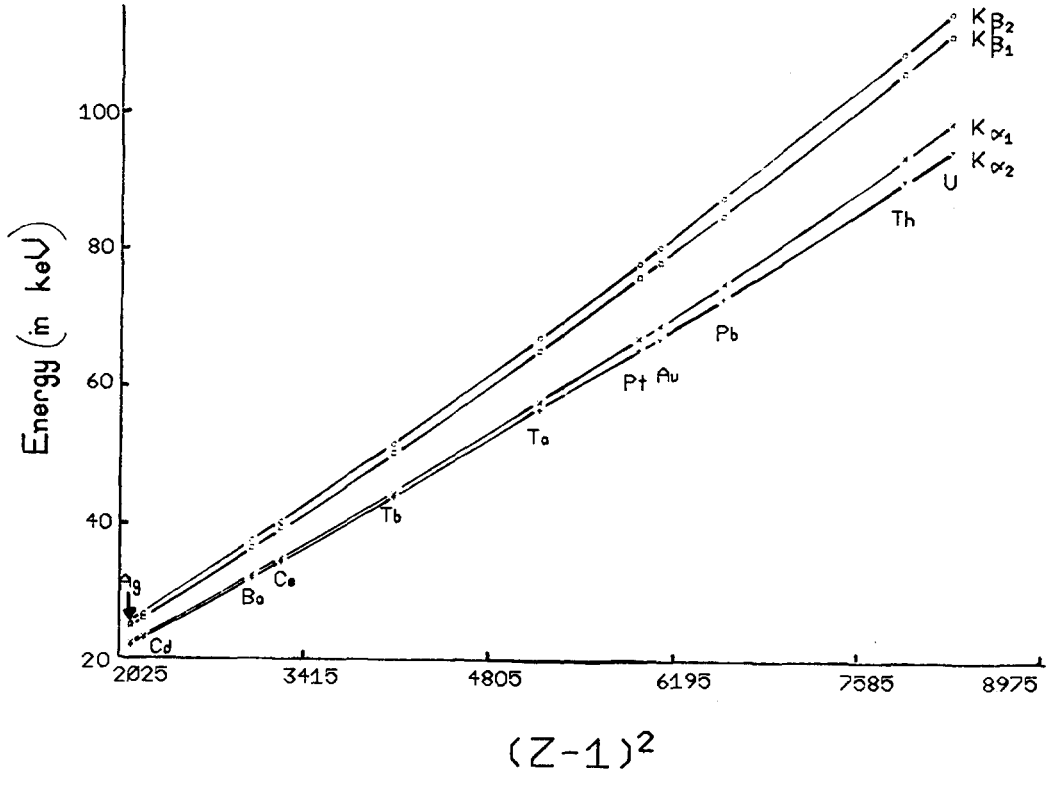

Fig. 2. Plot of energy of x rays versus $(Z-1)^2$. Experimental points correspond to energies of characteristic x rays of Ag, Cd, Ba, Ce, Tb, Ta, Pt, Au, Pb, Th, and U.