STUDIES IN NUCLEAR SPECTROSCOPY

A Thesis
Submitted to
the Faculty of Graduate Studies
University of Manitoba

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
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August 1951

PREFACE

The work to be described was carried out at the University of Manitoba during 1949, 1950, and 1951.

The writer wishes to express his sincere thanks to Dr. R. W. Pringle for his interest and direction; to the Research Council of Ontario for assistance in the form of a scholarship during 1950-51; to Professor K. I. Roulston for his advice on electronic matters; to Mr. S. Bird and Mr. C. Kubin for their cooperation in the construction of the beta spectrometer vacuum chamber, field measuring device, etc.; and to Drs. Fitch and Russell of the National Research Council who supplied highly purified rare earth samples.

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SUMMARY

In part A the development and some of the applications of a gamma ray scintillation spectrometer, utilizing a NaI-Tl crystal as a scintillator, are described. After using standard sources of I^{131}, Co^{60}, radium, and Po-Be to evaluate the performance of the spectrometer, the gamma ray spectra of Po^{210}, K^{40}, naturally occurring La^{138}, neutron activated gold, Cd neutron capture gamma rays, neutron activated Pd, and Ir^{192} were investigated. Experimental results obtained are presented for each of the above emitters.

In part B the assembly and initial testing of a semi-circular focussing beta ray spectrometer employing scintillation counters is described.

INTRODUCTION

The discovery of radioactivity in 1896 by Becquerel (1) signalled the beginning of a new era in physics. The above date was in effect the birthdate of what is now called "nuclear physics". Later studies gave rise to a fairly successful model of the atom (2) containing a nucleus. It is in this nucleus that the observed radiations apparently have their origin.

From the earliest days physicists have been concerned with the nature of these radiations. It has been the hope that with improved techniques and the collection of refined measurements, a successful nuclear model will be evolved, just as the collection of accurate atomic spectra data gave rise to a successful atomic picture.

This study of the radiations from atomic nuclei, along with the study of the nuclear changes that result is now the basis of "nuclear spectroscopy". Thus we speak of alpha ray spectra, beta ray spectra, and gamma ray spectra when the energy distributions of α- rays, β- rays, and γ- rays, respectively, of a given radioactive emitter are determined. At present there are several more or less standard techniques for studying these spectra. It is the purpose of this thesis to report on certain studies in both gamma and beta-ray spectroscopy.

One of the earliest approaches to these nuclear spectroscopy studies was the absorption technique. By placing various absorbers between the radioactive source and the detector (a charged electroscope for example) it was possible to distinguish the three types of radiation mentioned (α, β, γ) by their penetrability. Thus it was found that α - particles were very easily absorbed, β - particles were considerably more penetrating, and the γ - radiation extremely penetrating or "hard". The degree of absorption or the so called absorption coefficient determined in such an experiment was used in the energy determination of the radiation being studied. These absorption techniques were refined to a very high degree and their application has yielded invaluable results. (see for example (3), (4), (5).) Indeed this method is still a very powerful one, and many current applications of it are to be found in the present day literature. A paper illustrating methods now being used in gamma-ray absorption studies has recently been given by Davisson and Evans (6).

The present day use of such absorption methods in the beta-ray field is, however, somewhat limited. For, with the application of magnetic fields (the method first used to deflect the charged alpha and beta particles) the construction of beta-ray spectrometers, which focus electrons of a definite momentum on a detector, has now reached an advanced stage and these instruments are in general capable of giving much more accurate results than the absorption technique. However, in certain special cases, for example with very weak sources, one may apply the latter method.

It must be noted that in general the absorption technique has a great advantage in experimental simplicity. On the other hand the experimental results thus obtained are sometimes quite difficult to interpret and great care must be taken, particularly in attempting to analyse an absorption curve of an emitter with a complex spectrum.

As pointed out above, the advent of magnetic β-ray spectrometers (a recent type will be described in part B of this thesis) has made the problem of obtaining β -ray spectra considerably easier. Spectrometers, similar in principle, have been applied for precision measurements of α -ray spectra. Fortunately, there exists a very profitable application of such β -ray spectrometers to γ-ray studies. In a great many cases the γ -rays of a given emitter are internally converted thus giving rise to a monoenergetic group of electrons. If the energy of such a "conversion line" of electrons is determined in a β-ray spectrometer, addition to this energy of the appropriate electron binding energy gives us the gamma ray energy. Such sharp conversion lines are usually easily identified in a spectrometer run. If the γ-ray is not internally converted, use of an appropriate thin radiator near the source gives rise to "external" conversion electron lines or photoelectron lines. Here the γ-ray energy is obtained in a similar manner, i.e. by adding the appropriate electron binding energy (for the radiator) to the photoelectron line energy. The above method of studying γ-ray spectra is today one of the more accurate available. The study of such conversion lines gives us not only very accurate energies, but also, relative intensities and conversion coefficients. (See for example reference (7).) There still remain some experimental difficulties; for example obtaining sufficiently strong, very thin, and uniform sources. The improvement of instrumental resolution is still another problem; it has been attacked quite successfully with some of the recent instruments. It must also be noted that most magnetic spectrometers can be efficiently used in a restricted region of gamma ray energy. Low energy studies, in the region of a few Kev., require special techniques and specially designed spectrometers. Still other magnetic spectrometers (i.e. pair spectrometers) have been designed to cover the high energy region (about 4-15 Mev.).

The use of the cloud chamber is another method of attacking nuclear spectroscopy problems. This method, whereby a charged particle leaves its "path" to be observed (possibly in a magnetic field), has been applied with much success in alpha and beta ray studies. In the case of gamma ray studies the "path" of the gamma ray is observed by virtue of the ionization effects due to charged particles produced (photoelectrons, electron pairs) as the quantum interacts with the gas in the chamber. The determination of a spectrum by this method is in general a quite difficult process, for large numbers of tracks must be observed and studied in order to obtain satisfactory statistics. More recently cloud chambers of special design have been of great help in high energy cosmic ray and meson studies. (See for example reference (8))

The application of a proportional ionization chamber is still another method of attack for certain special problems. It has been used successfully in the study of alpha ray spectra and in the study of low energy beta ray spectra. With the methods previously mentioned one usually encounters