Chapter I

INTRODUCTION

The information concerning the nuclear structure and nuclear forces was obtained mainly from the study of radioactive decays and nuclear reactions. Slowly the main interest in nuclear physics shifted from the investigation of nuclear force to that of nuclear structure. Gamma ray spectroscopy is often used in the field of radioactivity and several developments in nuclear theories were ushered in by the low energy phenomena occurring in this field. The absorption and scattering of nuclear radiation in matter leads to the study of phenomena which branch out in many directions. Most of the nuclear physics research depends on the measurement of the energy of radiations emitted by nuclei undergoing energy transitions. As a result, nuclear structure
investigations greatly depend on the techniques of accurate energy measurements.

Scintillation counting, one of the oldest radiation techniques, was outdated by the rapid growth and development of electronic counting techniques with the gas filled chambers. But it regained its former dominating role with the availability of the sensitive photomultiplier tube (PMT). On the other hand semi-conductor detectors with their outstanding progress more or less replaced the gas filled counters because of their increased stopping power and occasionally the scintillation counter by their excellent energy resolution in many nuclear science applications of high energy resolution gamma ray spectroscopy.

A brief review of gamma ray spectroscopy with thallium activated sodium iodide (NaI(Tl)) and germanium detectors (both Ge(Li) and HPGe) along with their characteristic properties like response function, linearity, resolution and detection efficiency etc., is given in chapter II. Scintillation spectroscopy began with the discovery and development of high efficiency NaI(Tl) detectors [1]. The availability of multichannel analysers developed them from an instrument for detection of radiation to a device for measuring the energy and intensity of that radiation. Along with the properties of this detector, the necessity and advantages of using large NaI crystals are also mentioned in the same chapter.

The development of semi-conductor materials for radiation detection boosted the gamma ray spectroscopy and have replaced NaI(Tl) detectors in many investigations due to their
excellent energy resolution. It was demonstrated that by an ion drifting technique, large size germanium detectors could be manufactured. Initially the available detectors were of comparatively smaller size having lower efficiency. Therefore, Freck and Wakefield [2] (see ref [1]), through the process of Lithium compensation on p-type germanium, developed lithium drifted Germanium (Ge(Li)) detectors for gamma ray spectroscopy. Moreover a major contribution to semi-conductor gamma ray spectroscopy was the development of high purity germanium resulting in fabrication of thick germanium detectors without lithium compensation [1,3].

Since the gamma ray interactions are identical in the case of Ge(Li) as well as HPGe detectors, the characteristic properties are the same for both detectors of same size and shape. This is discussed in chapter II alongwith the methods for continuum reduction. A discussion on the determination of gamma ray intensities with gamma detectors has also been given in the last part of this chapter. The relative merits of NaI(Tl) and germanium gamma ray spectrometers are also discussed in the end of this chapter.

Neutron Activation Analysis (NAA), as a technique, was developed by Hevesy and Levy [4] and it is based on the interaction of neutrons with an isotope of interest giving rise to a radioactive product nuclide whose concentration can be estimated by measuring the characteristic radiations emitted by the product(s) using suitable detectors (see ref [5]). The study of nuclear reactions induced by neutrons yielded significant
contributions to our knowledge of nuclear force, nuclear reaction mechanism and practical applications of nuclear physics. In short, NAA is based on the quantitative detection of gamma rays produced in samples by neutron induced radioactivity.

This technique has been employed for measurement of half-lives of short lived isotopes such as $^{116m}$In, $^{27}$Mg, $^{51}$Ti and $^{28}$Al obtained by bombarding $^{115}$In, $^{27}$Al, $^{51}$V and $^{28}$Si respectively with neutrons. A study of elemental analysis of some samples (such as SRM 1633a and coinage metal) has been done by making use of this technique. A reinvestigation of the relative intensities of gamma rays emitted by $^{116m}$In has also been done. A detailed description of the experimental procedure for the above applications of NAA are given in chapter III along with the description of the 5 Ci $^{241}$Am-Be neutron source, and the 157 cm$^3$ HPGe coaxial detector with its associated electronics.

For many purposes the accurate determination of photon intensities can be of greater value than the determination of energies. Precise measurement of the gamma ray intensities with gamma detector necessitates an accurate determination of the Full Energy Peak Efficiency (FEPE). Therefore, its determination with a high degree of accuracy is very important. The experimental determination of FEPE at discrete energy values is a simple but tedious procedure with accuracies within a few percent. This could be done by employing a set of calibrated standard gamma sources of known strengths which cover a wide range of energies. The determination of the FEPE of a 157 cm$^3$ co-axial HPGe detector and that of a 2"x2" NaI(Tl) detector has been discussed in this...
chapter. It is also possible to calculate (empirically) the FEPE of the germanium detectors by knowing its dimensions and the required absorption co-efficients. Ray Gunnik [6] developed a method for determining the FEPE of co-axial germanium detectors by using manufacturers specifications. We employed this method for the determination of FEPE of our 157 cm$^3$ HPGe co-axial detector.

The experimental determination of FEPE is somewhat complicated as one needs to maintain good and reproducible geometry and to account for the absorption effects. The semi-empirical approach provides a reasonably accurate way to obtain the FEPE in which all geometrical and relative scaling factors may be treated empirically. An investigation regarding the validity of analytical functions for the FEPE of a 3"x3" NaI(Tl) detector has been done recently by Sudarshan [7]. We have also discussed the validity of some analytical functions for representing the FEPE data of a 2"x2" NaI(Tl) detector in the energy region ranging from 59.5 to 1408.03 KeV. Along with this, the variation of the measured resolution with photon energy for the 157 cm$^3$ HPGe coaxial detector and two NaI(Tl) detectors (3"x3" and 2"x2"), are described in the same chapter.
References


