CHAPTER I
INTRODUCTION

Since the discovery of Samoilov et al.\textsuperscript{1} in 1959 that diamagnetic gold nuclei dissolved in ferromagnetic iron experience a large magnetic hyperfine field (\textasciitilde1 MOe), the range and usefulness of application of hyperfine fields has increased considerably. The large magnetic fields seen by the impurity nuclei can be favourably exploited to measure the magnetic dipole moments of the short lived nuclear excited states of the impurity nuclei. The hyperfine field measurements are also useful as sensitive probes for the understanding of the Core and Conduction electron wave functions.

A formal solution of the problem of the impurities in ferromagnetic hosts is quite complex and would involve the solution of a many body problem. However, the systematic variations of the signs and magnitudes of the hyperfine fields as a function of the electronic configurations of the impurity atoms (in particular as a function of the atomic number \(Z\)) has provided us the insight to understand the major mechanisms responsible for the origin of these hyperfine fields. The large experimental data currently available with literature enabled many workers to suggest many models for the hyperfine fields. Because of this reason, there has been considerable interest to measure the magnetic hyperfine fields on magnetic and nonmagnetic impurities\textsuperscript{2} in ferromagnetic and paramagnetic hosts. As pointed by Jaccarino, Walker and Wertheim (see page 51), the experimental data with temperature variation of the hyperfine field on the
impurity can be used to detect the possibility of a localized moment around the impurity. It has been our interest to measure the hyperfine fields on dilute diamagnetic impurities in ferromagnetic hosts to have a better understanding of the mechanisms involved.

Many experimental techniques in principle can be used for the hyperfine field measurements. These techniques may broadly be divided into two categories: a) stable nuclei are used (nuclear magnetic resonance (NMR), electron spin resonance, nuclear specific heats etc.), and b) radioactive nuclei are used (perturbed angular correlation, nuclear orientation, Mössbauer effect, nuclear magnetic resonance/nuclear orientation (NMR/NO)). In this thesis, we have used the time differential perturbed angular correlation techniques (TDPAC) for the hyperfine field measurements.

Normally NMR techniques give results of highest accuracy. However, the recent improvements in the TDPAC techniques like the Fourier transform of the auto-correlation function has made it competitive with NMR accuracy. In addition, the TDPAC technique has certain advantages when compared to the NMR in terms of its higher sensitivity and wider applicability in terms of temperature etc. The higher sensitivity of the PAC technique will be particularly helpful for the measurement of the dilute impurity hyperfine fields because the impurity-impurity interactions are negligible.

In the PAC technique of measuring the hyperfine fields one observes the change in the angular correlation pattern of the
nuclear radiation when the intermediate state having a magnetic dipole moment is perturbed by the internal hyperfine fields. In the absence of any external perturbations, the angular correlation of the γ-rays could be expressed as a sum of a series of Legendre polynomials \( N^{3} \). When the intermediate state is perturbed by magnetic field, classically speaking, the dipole moment precesses around the applied field with Larmor frequency. The Larmor frequency and hence the internal hyperfine field could be obtained from the observed change in the \( (\gamma-\gamma) \) angular correlation pattern, if we know the magnetic dipole moment of the nuclear state involved.

For the cases measured in this thesis, cubic hosts were chosen so that the quadrupole effects are small. In addition, the impurities form solid solutions with the corresponding hosts. All the experimental data available in the literature for the impurity hyperfine fields have been plotted as a function of the impurity atomic number for the host matrices of Fe, Co, Ni. Similar plots for Fe host are already available in the literature (see Chapter IV). From the studies of these systematics, we are able to draw some new trends which were not pointed out until now such as: (i) The hyperfine field \( H_{\text{hf}} \) is negative in 3d, 4d and 5d impurities in all the three hosts Fe, Co, Ni except in the 4d series for \(^{39}\text{YFe}, {^{40}\text{ZrFe}} \) and \(^{40}\text{ZrCo} \). (ii) In iron host, the field increases gradually for Ru, Rh and Pd and the maximum value is obtained for Pd. However, the reverse trend is clearly seen for the same impurity metals for the other host matrices.
of Co and Ni.

The magnetic moments of some of the nuclear states are also measured using the TDPAC technique. These values are compared with the existing nuclear models. (see Chapter III).

The nuclear level structure of $^{99}$Ru is studied using Ge(Li) detectors, NaI(Tl) sum-coincidence spectrometers and Ge(Li) detectors in coincidence. These studies resulted in an improved level scheme of $^{99}$Ru. The short nuclear lifetime measurements in $^{44}$Sc, $^{75}$Se, $^{99}$Ru, $^{131}$Cs, $^{133}$Cs, $^{170}$Yb, $^{187}$Re and $^{197}$Au were also carried out. One new value for the 134-keV state in $^{131}$Cs is reported. In other cases the existing errors in the measurements are reduced. The experimental M1, E2 transition probabilities obtained from the present measurements in the 1-forbidden transitions are compared with the predictions of Arima et al. For the remaining cases, the experimental values are compared with the single particle estimates (see Chapter II). Detailed studies on the time resolution of Ge(Li) detectors and scintillation detectors were carried out.