CHAPTER V

HYPERFINE FIELD MEASUREMENTS

In this chapter the results and experimental details of the present investigations of the measurements on the internal hyperfine fields are given. The following internal hyperfine fields were measured.

(i) Arsenic in iron.
(ii) Arsenic in Cobalt.
(iii) Arsenic in nickel.
(iv) Arsenic in gadolinium.
(v) Hafnium in iron.
(vi) Hafnium in nickel
(vii) Platinum in cobalt
(viii) Platinum in nickel.

In all the reported measurements, a conventional two channel slow-fast coincidence set up having a resolving time $2\tau = 60\text{sec}$ was used. The details of the equipment are given in Chapter IV. The source in all the measurements was viewed by two 1-1/2" dia x 2" length NaI(Tl) crystals mounted on Dumont 6292 photomultipliers.

5.1 Internal Hyperfine Magnetic Fields on Arsenic in Iron, Cobalt, Nickel and Gadolinium Hosts.

The internal hyperfine magnetic fields on arsenic in iron, cobalt, nickel and gadolinium hosts have been measured using the 121.1 - 279.6 keV cascade populated in the decay of
The hyperfine field on arsenic nuclei in iron has been measured previously by Koi\textsuperscript{1)} using NMR technique but the fields on arsenic in cobalt, nickel and gadolinium hosts were not known at the time of measurements. Gadolinium has been chosen as the host material for hyperfine field studies because it is known to be a simple ferromagnet below 293 K. Gadolinium of all the rare earth metals, has a relatively simple magnetic structure and is thus a suitable host material to study the systematics of impurity fields in different ferromagnets and thus is useful for understanding in a better way the origin of these fields.

The electron capture decay of 120.4 d Se\textsuperscript{75} to level of As\textsuperscript{75} has been studied extensively by many workers\textsuperscript{2-3).} A partial decay scheme of Se\textsuperscript{75} is shown in fig. 5.1. A single gamma spectrum of Se\textsuperscript{75} is shown in fig. 5.2. We find from the decay scheme that for 279.6 keV level as the intermediate state, the only available gamma-gamma cascade is the 121.1-279.6 keV cascade. There is also present 135.9 - 264.6 keV cascade with 264.6 keV as the intermediate state. Since the difference between 121.1, 135.9 keV on one side and 264.6, 279.6 keV gamma ray energies on the other side is very small, it is not possible to separate these gamma rays in the singles spectrum. So in the singles spectrum two broad composite peaks are formed corresponding to (121.1 + 135.9) keV and (264.6 + 279.6) keV gamma rays. In addition there is another photopeak corresponding to 402 keV gamma ray.
FIG. 5.1  PARTIAL DECAY SCHEME OF SE$^{75}$.  

$^{120.4\, \text{d}}\text{Se}^{75} 5/2^+$

$E(\text{keV})$  
628.0  429.4  
628.0

$T_{1/2} = (0.326 \pm 0.17) \, \text{msec.}$

$A_s^{75}$

$^{3/2^-}$
Fig. 5.2 Singles gamma spectrum of Se$^{75}$. Gate settings are indicated.
spectrum it can be seen that 135.9 - 264.6 keV cascade will cause interference in the 121.1 - 279.6 keV cascade and also this interfering cascade is about four times as strong as the 121.1 - 279.6 keV cascade. The 135.9 - 264.6 keV cascade itself has almost isotropic angular correlation but its interference reduces the anisotropy of 121.1 - 279.6 keV cascade. The value of R is also affected due to this interference but it has no effect on the rotation of the 121.1 - 279.6 keV correlation pattern since the lifetime of the 264.6 keV level (1.6 x 10^-11 sec) is considerably shorter than that of the 279.6 keV level (4.67 x 10^-10 sec). This point is discussed in detail later on.

5.1.1 Source Preparation:

The radioisotope Se^75 was obtained from Bhabha Atomic Research Centre, Bombay, India in the form of sodium seleno-sulphate in neutral solution. For electroplating selenium on a ferromagnetic host, the source had to be brought in a proper chemical form. The following chemistry was done for this purpose. The neutral source solution was made acidic by adding a few drops of 3N hydrochloric acid. Through this solution sulphur dioxide gas was passed to precipitate out all the selenium (reddish brown precipitate). A few drops of alcohol were added to it for coagulation and the solution was centrifuged. Discarding the supernatant liquid the residue was washed with alcohol and dissolved in minimum amount of aqua regia. The solution thus got was evaporated to dryness. The dried residue was treated with a few drops of concentrated hydrobromic acid and the solution was evaporated gently on a water bath so that selenium is not lost, as it is
volatile in hydrobromic acid. This dried mass was dissolved in 0.1 N hydrobromic acid and used as such for the directional correlation work and for electroplating on iron, cobalt, nickel and gadolinium wires.

The radioactive selenium was electroplated from this solution on 1 cm length of 1 mm diameter spectroscopically pure cobalt, nickel and copper wires by passing 10 mA current for two hours. The anode in each case was a platinum wire. The electroplated portion of the wire was cut, washed with alcohol and water, dried and transferred to a quartz tube. The quartz tube was evacuated and filled with nitrogen and sealed. This tube was then kept at 100°C in a diffusion furnace for thirty hours. To ensure proper diffusion it was necessary to keep the furnace initially at low temperature for a long time because selenium has got low melting point. The temperature of the furnace was then increased to 200°C and kept there for about sixty hours, after which it was raised to 350°C for five hours. The quartz tube was then taken out and heated in a direct flame for melting the wire. The quartz tube, now with the melt inside it in the form of a button, was put in an annealing furnace. The initial temperature of this furnace was kept at 1500°C and 700°C for selenium-cobalt and selenium-nickel sources respectively. This temperature was then brought down very slowly to the room temperature and the annealed sources were used for rotation measurements.
For the preparation of selenium-iron and selenium-gadolinium samples, radioactivity was electroplated on iron and gadolinium wires and both these samples were then diffused in argon atmosphere firstly at 100°C for 13 hours and then at 200°C for 50 hours. The sources were then melted and annealed at 900°C and 400°C respectively for six hours.

5.1.2. Measurements and Results:

The measurements of the hyperfine field on arsenic in gadolinium host were carried out with selenium-gadolinium alloy at the liquid nitrogen temperature. The arrangement for performing the experiment at liquid nitrogen temperature was designed so that drilling a hole in the magnet was avoided and the temperature of the sample was checked to be constant within ±5% throughout the course of the experiment. For the measurement of the temperature, a calibrated Cr-Al thermo-couple was used. The details of the arrangement are given in Chapter IV.

5.1.3. Angular Correlation Measurements:

For unperturbed directional correlation measurements both in free and magnet geometry the liquid source of selenium in hydrobromic acid, put in a perspex source holder 2 mm dia x 4 mm height was used. This source was symmetrically located at 7 cm from each crystal at the point of intersection of the axes of the two crystals. The centering of the source was done to an accuracy of 0.6% from the change in singles counting rate of the movable counter at seven angles. The directional correlation of the 121.1 - 273.6 keV cascade was measured with...
the liquid selenium bromide in free geometry in the absence of external field. This cascade has a strong interference from the 135.9 - 264.6 keV cascade. Therefore the gates for 121.1 keV and 279.6 keV gamma rays were set on the sloping portions of the photopeaks so as to minimize the contribution of this interfering cascade. The counting rate now being sensitive to even small shifts in pulse heights, the counting period at each angle was made very small and the gates were checked frequently throughout the experiment to ensure that the peaks did not shift. The coincidence counts were collected at seven angles between 90° and 180° at an interval of 15° each. A least squares fit of the data corrected for the random coincidences yielded the following correlation coefficients, after solid angle correction, in free geometry:

\[ A_2 = -0.1460 \pm 0.0064 \]
\[ A_4 = +0.0281 \pm 0.0123 \]

Fig. 5.3 shows a least squares fitted curve of the experimental points of the unperturbed angular correlation.

The lifetime of the 279.6 keV level being nearly 5 x 10^{-10} sec, it is reasonable to suspect a time dependent interaction attenuating the \( A_2 \) and \( A_4 \) coefficients of the 121.1 - 279.6 keV cascade. Since copper provides a matrix of cubic symmetry, static and time dependent perturbations are expected to be absent in it. An angular correlation measurement of the 121.1- 279.6 keV cascade was done with selenium-copper source in the same geometry as used in the case of a liquid source. The least squares fit of the data of all
the seven angles gives the correlation coefficients after correction for chance coincidences and geometry:

\[ A_2 = -0.1486 \pm 0.0055 \]
\[ A_4 = +0.0477 \pm 0.0080 \]

The angular correlation results for the 121.1 - 279.6 keV cascade do not differ strongly for the liquid selenium and selenium-copper sources, which indicates that the time dependent perturbation are absent for this cascade i.e. \( C_2 = 1 \).

In order to measure the rotation of the angular correlation pattern, we need the correlation coefficients in the magnet geometry. The directional correlation measurement for the liquid source in this case yielded:

\[ A_2 = -0.1002 \pm 0.0026 \]
\[ A_4 = +0.0180 \pm 0.0035 \]

as the correlation coefficients uncorrected for geometry and scattering. These coefficients were used to calculate rotation \( \omega \) of the angular correlation pattern.

Several measurements of the directional correlation of the 121.1 - 279.6 keV cascade and 135.9 - 264.6 keV cascade have been carried out\(^\text{7-9}\). The results of \( \text{W} \)ond\( \text{e} \)n Bold et al\(^\text{7}\) for the angular correlation of the 121.1 - 279.6 keV cascade are

\[ A_2 = -0.47 \pm 0.02 \]
\[ A_4 = 0 \]

and for the 135.9 - 264.6 keV cascade are

\[ A_2 = -0.011 \pm 0.009 \]
\[ A_4 = 0 \]
The results of Schardt and Winkel\textsuperscript{8)} and Kelley and Wiedenbeck\textsuperscript{9)} are similar. Their results are much larger than our presently measured values. The reason for their large correlation coefficients is that they have been able to remove the interference of the 135.9 - 264.6 keV cascade, almost completely. In all our directional correlation measurements the interference of the 135.9 - 264.6 keV cascade in the 121.1 - 279.6 keV cascade could not be completely removed which has reduced the observed anisotropy. But this is of no real trouble in the rotation measurement as the previous measurements\textsuperscript{10-11)} have shown the 135.9 - 264.6 keV cascade to be nearly isotropic and further the lifetime of the 264.6 keV level (1.6 \times 10^{11} \text{ sec}) is considerably shorter than that of the 279.6 keV level and hence is not expected to add to the rotation of the angular correlation pattern.

5.1.4 \(\omega_C\) Measurements:

The hyperfine field on arsenic in iron has been measured by the integral rotation method and measurements on arsenic in cobalt, nickel and gadolinium hosts have been done by using the integral reversed field method. In the integral reversed field method, the quantity \(R\) defined as

\[
R = 2 \frac{C_{\uparrow\downarrow} - C_{\downarrow\uparrow}}{C_{\uparrow\downarrow} + C_{\downarrow\uparrow}}
\]  

was calculated by collecting coincidence counts on field reversal. As discussed earlier, this quantity \(R\) is related to \(\omega_C\).
From the measured value of $R$, $(\omega\tau)$ was calculated and then the following relation was used to calculate the internal hyperfine fields:

$$\frac{R}{R_0} = \frac{4C_2 C_1 \omega \tau}{1 + (2G_2 \omega \tau)^2}$$

(5.2)

where $C_2 = \frac{3A_2}{4 + A_2}$

Here $g = 0.36 \pm 0.04$ and $\tau = (4.67 \pm 0.43) \times 10^{-10}$ sec, are respectively the nuclear g-factor and lifetime of the 279.6 keV level and $\mu_n = 5.05 \times 10^{24}$ ergs/ gauss is the nuclear magneton. The values of the g-factor and the lifetime are the weighted averages of the previously measured values of the g-factor and the lifetime by Manning and Rogers, Agarwal and C.V.K. Baba, and Shirley and those of the lifetime by Shipley et al, Ritter et al, Verma and Eswaran, and Metzger and Todd respectively.

Various g-factor and lifetime values are given in table 5.1.


**TABLE 5.1**

The various measured values of the g-factor and lifetime of the 279.6 keV state of As$^{75}$ and their weighted means.

<table>
<thead>
<tr>
<th>Value</th>
<th>Reference</th>
<th>$10^{-10}$ References</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.42 ± 0.13</td>
<td>Manning and Rogers$^{10}$</td>
<td>4.03 ±0.30</td>
<td>Shipley et al$^{13}$</td>
</tr>
<tr>
<td>0.33 ± 0.06</td>
<td>Agarwal and C.V.K.$^{11}$</td>
<td>3.03 ±0.43</td>
<td>Ritter et al$^{14}$</td>
</tr>
<tr>
<td>0.35 ± 0.07</td>
<td>Shirley$^{12}$</td>
<td>7.79 ±0.72</td>
<td>Varma and Eswaran$^{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.40 ±0.28</td>
<td>Metzger and Todd$^{16}$</td>
</tr>
</tbody>
</table>

Weighted mean $g = 0.36 ±0.04$  
Weighted mean $= 4.67 ±0.43$

a) Arsenic in iron:

The selenium iron source used for rotation measurements was prepared in the manner described earlier. The atomic concentration of selenium in iron was about 0.3%.

An external magnetic field of 7.5 kOe was applied to polarize the sample. The true coincidence counts collected at seven
angles between 90° and 180° at regular intervals were least
squares fitted into the equation

\[ W_f(\theta, H) = 1 + \frac{b_2}{\sqrt{1 + (2\omega_C)^2}} \cos 2(\theta - \omega_C) \]  

(5.4)

which gave the following results

\[ b_2 = 0.084 \pm 0.010 \]

and \( \omega_C = 0.244 \pm 0.043 \) rad. \( b_2 \) is related to the correlation
coefficients \( A_2 \) through eq. 3.8. Fig. 5.3 shows the plot of
the unperturbed and perturbed angular correlation pattern. From
this \( \omega_C \) value, the hyperfine field on arsenic in iron was
deduced to be

\[ H_{Fe}^{AS} \text{ (Room Temperature)} = + (305 \pm 69) \text{ kOe} \]

The direction of the shift of the angular correlation pattern
yields a positive sign of the field.

Koi et al.\(^1\) have earlier reported the value of the
hyperfine field on arsenic in iron \( H_{Fe}^{AS} \) (4.2°K) = 339.1kOe.,
using the nuclear magnetic resonance technique. The sign of
the field is unknown in this measurement. Recently Chopra
et al.\(^17\) have also measured the hyperfine field on arsenic in
iron to be \( H_{Fe}^{AS} \) (Room Temperature) = (318.8 ± 32.7) kOe. Our
measured value of the hyperfine field is in agreement with
these values within experimental errors.
Fig. 5.3 Angular displacement of the directional correlation of 1211-279.6 ke cascade of a +75 in a transverse internal field. The symbol o denotes unperturbed W(θ) and A denotes a perturbed W(θ).
b) **Arsenic in cobalt and nickel.**

For the measurement of the hyperfine fields on arsenic in cobalt and nickel, several sources of selenium-cobalt and selenium-nickel with atomic concentration of selenium in between 0.1 - 0.2% were prepared.

Since the $\lambda_4$ coefficient for the $121.1 - 279.6$ keV cascade is nearly zero, the two detectors were kept at $135^\circ$ with respect to each other. An external magnetic field of 7.5 kG was used to polarize the internal fields in each alloy. The field was reversed every ten minutes. After correcting the coincidence counts for chance contribution which was about 3%, the quantity $R_1$ was obtained in each case. From the measured value of $R_1$, $\omega_T$ was calculated. Table 5.2 shows the summary of all the measurements of arsenic in cobalt and nickel.

**Table 5.2**

Summary of $R$ and $\omega_T$ measurements in arsenic-cobalt and arsenic-nickel alloys. The samples I and II differ only in the atomic concentration of selenium in the host.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>$R$</th>
<th>$\omega_T$</th>
<th>Weighted mean $\omega_T$</th>
<th>$\mu_{\text{effective}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-Co</td>
<td>Sample I</td>
<td>-0.0542 $\pm$ 0.0087</td>
<td>0.205 $\pm$ 0.033</td>
<td>0.206 $\pm$ 0.027 $\pm$ 259.7 $\pm$ 46.5</td>
</tr>
<tr>
<td></td>
<td>Sample II</td>
<td>-0.0555 $\pm$ 0.0112</td>
<td>0.213 $\pm$ 0.043</td>
<td></td>
</tr>
<tr>
<td>As-Ni</td>
<td>Sample I</td>
<td>-0.0288 $\pm$ 0.0038</td>
<td>0.097 $\pm$ 0.013</td>
<td>0.103 $\pm$ 0.010 $\pm$ 128.6 $\pm$ 20.3</td>
</tr>
<tr>
<td></td>
<td>Sample II</td>
<td>-0.0330 $\pm$ 0.0050</td>
<td>0.112 $\pm$ 0.017</td>
<td></td>
</tr>
</tbody>
</table>
From the measured values of the hyperfine fields were deduced to be

\[ H_{\text{Co}}^\text{As} \ (\text{Room Temperature}) = + (252 \pm 45) \text{ kOe} \]

\[ H_{\text{Ni}}^\text{As} \ (\text{Room Temperature}) = + (121 \pm 20) \text{ kOe} \]

The sign of the hyperfine field in each case was found from the sense of rotation of the angular correlation pattern. As this work was published, Chopra et al. also reported the hyperfine fields on arsenic in cobalt and nickel hosts. Their measured values are

\[ H_{\text{Co}}^\text{As} \ (\text{Room Temperature}) = + (248.9 \pm 27.6) \text{ kOe} \]

\[ H_{\text{Ni}}^\text{As} \ (\text{Room Temperature}) = + (87.5 \pm 9.9) \text{ kOe} \]

Their measured value of the hyperfine field on arsenic in cobalt is in agreement with our measured value but field on arsenic in nickel is lower.

c) Arsenic in gadolinium:

For the measurement of the hyperfine field of arsenic in gadolinium, two samples of selenium-gadolinium alloy were prepared. The atomic concentration of selenium in each alloy was between 0.1 to 0.2%. The directional correlation measurements with the As-Cd alloy in the magnet geometry yielded

\[ A_2 = -0.1115 \pm 0.0048 \]

\[ A_4 = +0.0174 \pm 0.0058 \]
These results are similar to the one for the liquid source in the magnet geometry. Also because of the short lifetime of the nuclear state, electrical interactions were assumed to be absent and $G_2$ was taken to be unity. The detectors were kept at an angle of 135° with each other and an external polarizing field of 5 kG was applied in a plane perpendicular to that of the detectors. The quantity $R'$ defined in eq. (5.1) was measured from the change in coincidence counting rate for field up and down directions. The weighted average of $R'$ from these samples was found to be

$$R = -0.037 \pm 0.003$$

This value of $R'$ corresponds to a rotation $\omega_{\chi}$ as

$$\omega_{\chi} = 0.135 \pm 0.011$$

Using the $g$-factor and lifetime values of the 279.6 keV level, the internal hyperfine field acting on arsenic in gadolinium was found to be

$$H_{AS}^{Gd} (77^\circ K) = -(166 \pm 27) \text{kG}.$$  

The sign of the field is known from the sense of rotation of the angular correlation pattern.

5.1.5 Discussion of the Results:

In fig. 5.4, the hyperfine fields in iron, cobalt and nickel have been plotted against the host magnetic moments. The plot shows that the hyperfine fields in the case of arsenic are roughly proportional to the host moments suggesting an inductive mechanism due to 3d electrons.
FIG. 5.4 THE VARIATION OF THE INTERNAL HYPERFINE FIELDS ON ARSENIC IN IRON, COBALT AND NICKEL WITH THE HOST MAGNETIC MOMENT.
Stearns\(^{19}\) has proposed a model on the origin of the hyperfine fields in iron, cobalt and nickel hosts, based on the volume overlap polarization model. Since arsenic belongs to a class of 4 s-p impurities and also its atoms do not develop a moment, therefore the expression for the hyperfine field on a solute atom, eq. 2.17, becomes

\[
H_z = H_{\text{V}} + H_{\text{X}} 
\]

(5.5)

Since \(H_z\) has been found to be roughly proportional to the host and we know that \(H_{\text{V}}\) is also proportional to the host\(^{19}\), hence \(H_{\text{X}}\) will also be proportional to the host. Using our presently measured values of the hyperfine fields on arsenic in iron, cobalt and nickel hosts, the various contributions to the hyperfine field on the basis of Stearns\(^{19}\) overlap polarization model have been found. These contributions are given in table 5.3.

**Table 5.3**

Hyperfine fields on arsenic in iron, cobalt and nickel (all fields in kOe except \(H_{\text{NS}}\))

<table>
<thead>
<tr>
<th>Element</th>
<th>(H_{\text{NS}}) (kOe)</th>
<th>(V_{\text{NS}})</th>
<th>(H_z) (Expt)</th>
<th>(H_{\text{V}})</th>
<th>(H_{\text{X}})</th>
<th>(H_{\text{NS}})</th>
<th>(P_{\text{V}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>+305</td>
<td>544</td>
<td>842</td>
<td>0.112</td>
<td>0.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>7.5</td>
<td>13.1</td>
<td>Co</td>
<td>+252</td>
<td>401</td>
<td>647</td>
<td>0.036</td>
</tr>
<tr>
<td>Ni</td>
<td>+121</td>
<td>138</td>
<td>257</td>
<td>0.034</td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
$H_{\text{ns}}^Z$ (Col. 2) is the hyperfine coupling constant of atom $Z$ i.e., the hyperfine field at a nucleus of atom $Z$ due to one polarized ns electron and $V_z$ (Col. 3.) is the atomic volume i.e. atomic weight divided by density. Col. 6 gives the $H_{\Sigma}^Z$ contribution to the hyperfine field which has been calculated using the relation

$$H_{\Sigma}^Z = \frac{H_{\text{ns}}^Z}{H_{\text{host}}^Z / 4S}$$  \hspace{1cm} (5.6)

The value of $H_{\text{host}}^Z$, which have been used in the calculation are - 145 kOe, - 117.5 kOe and -44 kOe respectively for Fe, Co and Ni hosts. True hyperfine field values have been obtained from measured $H_z$ values (Col. 5) by subtracting $4/3 \pi M_s$ contribution as 7, 6 and 2 kOe respectively for Fe, Co and Ni hosts. The $H_{\Sigma}^Z$ contribution has been subtracted from these true hyperfine field values to get volume overlap contribution $H_{\Sigma}^Z$ (col. 7). Since the hosts, Fe, Co and Ni all have essentially the same atomic volumes, so the volume misfit of any solute atom in any of these hosts is approximately the same. Hence the $H_{\Sigma}^Z$ contribution and the polarization will be proportional to the host moment. Col. 8 gives the derived polarization ($H_{\Sigma}^Z / H_{\text{ns}}^Z$).

In col. 9 are given the polarization calculated on the basis of volume misfit model of Stearns. The polarization has been calculated by fitting derived polarization in the equation

$$P_{\text{v}}(z) = C \left( V_z - V_0 \right) \hspace{1cm} (5.7)$$
where \((V_z - V_0)\) is the volume misfit of the solute atom in the Fe matrix and \(V_0\) is the volume available to the solute atom upon removing an Fe atom from the lattice and \(C\) is an ordinary constant. In the same units as that of \(V_z\) (Col.3) the values of \(V_0\) and \(C\) come out to be 10 and 0.01 respectively.

A comparison of Col.8 and Col. 9 shows that the experimental values of the hyperfine field gives a polarization greater by a factor of 3 than those obtained on the basis of volume overlap model. According to Stearns\(^{18}\), the reason for this increased volume overlap term could be that the d levels of the impurity atom may be so close to the Fermi level of the hosts that they can cause a resonance state (virtual level) in the 4s-p bands. This could lead to an enhancement of the 4s electron density which is shielding the excess charge on the solute atom and thus an increased volume overlap term.

The values of the hyperfine fields predicted on the basis of Balabanov and Delyagin model\(^{20}\) for arsenic in iron, cobalt and nickel hosts are \(H_{As}^{Fe} = +150\, kOe\), \(H_{As}^{Co} = +116\, kOe\) and \(H_{As}^{Ni} = +40.83\, kOe\). The magnitude of the hyperfine fields for arsenic in all the three hosts, predicted on the basis of this model is not in agreement with the measured values. The sign of the hyperfine field is predicted correctly. Since this model is quite empirical, therefore one can not explain the large deviation in the observed values of the fields.

The fields of the 4s-p region of the periodic table have been summarized in table 5.40. Only two hosts, viz iron and
Table 5.4

Hyperfine fields in kOe for impurities in iron and nickel hosts (No temperature correction has been made in any case since the purpose is to emphasize trends) Arsenic fields are from present measurements.

<table>
<thead>
<tr>
<th>Element</th>
<th>Co²⁷</th>
<th>Ni²⁸</th>
<th>Cu²⁹</th>
<th>Zn³⁰</th>
<th>Ga³¹</th>
<th>Ge³²</th>
<th>As³³</th>
<th>Sb³⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>-287.2¹</td>
<td>-234.2²</td>
<td>-212.7²</td>
<td>-95(15)²</td>
<td>110(3)²</td>
<td>+70(3)²</td>
<td>+305(69)²</td>
<td>+705(70)²²</td>
</tr>
<tr>
<td>Nickel</td>
<td>-120(1)²</td>
<td>-76(1)²</td>
<td>-47.2²</td>
<td>-</td>
<td>-12.5(2)³</td>
<td>+33.0(15)²²</td>
<td>121(20)²²</td>
<td>-</td>
</tr>
</tbody>
</table>
nickel have been taken because cobalt follows essentially the same trend. These fields show an interesting trend as exhibited in fig. 5.5. Hyperfine fields of atoms upto Zn are negative, as is expected from their metallic character. For Ge, As and Se, the 3d shell is complete and 4s, 4p are filling.

One might expect the induced fields to become quite small after the 'magnetic' 3d shell and the 4s shell are filled; but the fields change sign and become quite large. This trend can be associated with two distinct parameters.

a) The change from metallic to non-metallic character.
b) The filling of the 4p shell, because the fields follow the number of unpaired 4p electrons and are likely to exhibit a maximum near the middle of the shell. The fields do show a maximum in the middle of the 4p shell, as can be seen from the available curves of the fields in iron versus atomic number (one has, of course, to extrapolate the curve from Z = 35 to Z=38, the measurements in which region are not known).

The sign of the hyperfine field in case of Ga has been found by K. Krolis et al.\(^2\) to be negative and in accordance with the expectation. It will be of interest to have measurements of fields in this region viz for Br and Kr. Unfortunately no suitable cascade for PAC measurements is available here.

Campbell\(^2\) has modified the Daniel Friedel theory of conduction electron polarization and predicted the hyperfine fields on s-p impurities in gadolinium. For s-p impurities
HYPERFINE FIELDS FOR SOLUTE ATOMS IN Fe (FILLED CIRCLES), Ni (OPEN CIRCLES) HOST VERSUS ATOMIC NUMBER. CONNECTING LINES HAVE BEEN DRAWN TO EMPHASIZE TRENDS.

SOLUTE ATOMIC NUMBER

Co  Ni  Cu  Zn  Ga  Ge  As  Se

+800
• IRON HOST
+600
⊙ NICKLE HOST
+400
+200
0
-200
-400

27  28  29  30  31  32  33  34
SOLUTE ATOMIC NUMBER

FIG. 5.5 HYPERFINE FIELDS FOR SOLUTE ATOMS IN Fe (FILLED CIRCLES), Ni (OPEN CIRCLES) HOST VERSUS ATOMIC NUMBER. CONNECTING LINES HAVE BEEN DRAWN TO EMPHASIZE TRENDS.
in gadolinium, the comparison of experimental results and Campbell's predictions are given in ref. 25. Arsenic belongs to a class of s-p impurities in the 4 s-p region. Besides our measurement of the hyperfine field on arsenic in gadolinium, there is one more measurement available in this region i.e. for the hyperfine field of selenium in gadolinium. The magnitude of the field is

$$H_{\text{Se}}^{77\text{K}} = 271 \pm 68 \text{ kOe}$$

It is difficult to comment on the systematic trend with only two measurements in this region. For better understanding, further measurements in this region will be helpful.

5.2 Internal Hyperfine Magnetic Fields on Hafnium in Iron and Nickel

Many previous measurements of hyperfine fields at hafnium (Hf) nuclei in iron are available. In all, but one, earlier measurements of hyperfine fields, implantation perturbed angular correlation technique (IMPACT) was used. Results of IMPACT experiments for the hyperfine field of Hf in iron are: $-300 \pm 60 \text{ kOe}$, $-286 \pm 40 \text{ kOe}$, $-510 \pm 150 \text{ kOe}$, $-507 \pm 60 \text{ kOe}$, and $-140 \pm 10 \text{ kOe}$. All these measurements were performed at 300°K. In one experiment $^{178}\text{Fe}$ and $^{180}\text{Hf}$ samples were melted in an induction furnace and Mössbauer experiments were performed. The results of this experiment for the hyperfine field value are: $606 \pm 70 \text{ kOe}$ at 4.2°K and $547 \pm 60 \text{ kOe}$ at 77°K for $^{178}(1 \text{ at.%) - Fe alloy and } 334 \pm 40 \text{ kOe at } 4.2°K$ for
Hf\textsuperscript{180m} (1 at.%) - Fe alloy. For the hyperfine fields on Hf in nickel, results of the two IMPACT experiments are: -65 kOe\textsuperscript{30} and -60 $\pm$ 10 kOe\textsuperscript{31}. We see from above that all the perturbed angular correlation experiments were performed with implanted sources and Mössbauer experiment was performed on diffused sources. Since there was a large difference in the reported values of the hyperfine fields, we thought it worthwhile to prepare Hf-Fe and Hf-Ni samples by diffusion and perform perturbed angular correlation experiments.

The integral perturbed angular correlation technique (IPAC) has been used in the present measurements. The isotope used was Lu\textsuperscript{177} (6.7 d) whose decay scheme is shown in fig. 5.6. The singles spectrum of Lu\textsuperscript{177} is shown in fig. 5.7. The 208-113 keV cascade was used for directional correlation and precession measurements. The hyperfine field acting on Hf nuclei in iron and nickel was determined using the known $g$-factor of the 113 keV state.

5.2.1. Source Preparation:

Radioisotope Lu\textsuperscript{177}, as lutecium chloride, was obtained from Bhabha Atomic Research Centre, Bombay, India. For directional correlation measurements, the source was used as such. For rotation measurements different samples of Hf-Fe and Hf-Ni were prepared. Since Hf belongs to a class of rare earths, therefore some difficulties were experienced in preparing the samples. For the preparation of Hf-Ni alloy, lutecium chloride having a specific activity of 18 Curie/gm Lu was used.
$^{7/2^+}_{177} \text{Lu} \rightarrow 6.7 \text{d} \rightarrow \beta^- \rightarrow ^{9/2^+}_{71} \text{Y} \\
9/2^+ \rightarrow 321 \text{ keV} \rightarrow 208 \text{ keV} \\
11/2^- \rightarrow 250 \text{ keV} \rightarrow 137 \text{ keV} \\
T_{1/2} = 0.5 \text{ n sec.}

FIG. 5.6 DECAY SCHEME OF $^{177}$Lu.
FIG. 5.7 SINGLES GAMMA SPECTRUM OF Lu$^{177}$ GATE SETTINGS ARE INDICATED.
It was electroplated on a 0.1 mm thick spectroscopically pure nickel foil by passing 8 mA current for 10 hours. Actually many electroplated samples were prepared for Hf-Ni and diffusion was tried at various temperatures and for varying lengths of time. Ultimately it was found that 600°C is the suitable temperature at which diffusion is possible and a sample giving a good counting rate could be prepared. Also it was observed that 80% of the activity had evaporated during melting. The amount of Hf which goes into nickel was estimated to be in between 0.1-0.4 % by weight. Also for higher concentration of Hf, alloy making was not possible. For the preparation of the Hf-Fe sample, we used a high specific activity (~200 Curie/gm Lu) Lu$^{177}$ source. Lutecium activity was electroplated on a 0.1 mm thick spectroscopically pure iron foil and diffused at 600°C for 60 hours. Again, on melting, it was found that 80% of the activity had evaporated and the amount of Hf going in iron was found to be inbetween 0.05 -0.1% by weight. For impurity concentrations inbetween 0.1-0.3%, some activity was found to diffuse in iron and for impurity concentration higher than 0.3% diffusion in iron was not possible. The samples were then annealed at 650°C for 12 hours. Annealed samples were washed with HCl till there was no surface activity. Then these samples were used for rotation measurements.

5.2.2 Measurements and Results:

For rotation measurements an external magnetic field of 12.5 kG was applied in a plane perpendicular to the plane of the detectors.
5.2.3 Angular Correlation Measurements:

Directional correlation measurements of the 208-113 keV cascade with liquid lutecium chloride were performed in free geometry with the source located at a distance of 10 cm from the detector. The centering of the source was done to an accuracy of 0.7% from the change in singles counting rate of the movable counter at seven angles. In the singles spectrum there are three photopeaks corresponding to 113 keV, 208 keV and 321 keV. The gates for 113 keV and 208 keV gamma rays were set at the photopeaks with 3 volt window width on either side, and the positions are shown in fig. 5.7. The coincidence counts were collected at seven angles between 90° and 180° at an interval of 15° each. A least squares fit of the data yielded the following coefficients after solid angle corrections:

\[ A_{22} = -0.164 \pm 0.013, \quad A_{44} = 0 \]

Results of the angular correlation of the 208-113 keV cascade with liquid source in free geometry are shown in fig. 5.8. We also performed the directional correlation measurements with the liquid source in the magnet geometry and obtained the values for the correlation coefficients as

\[ A_{22} = -0.146 \pm 0.016; \quad A_{44} = 0 \]

In both these cases, it was assumed that \( G_{22}(\infty) = 1 \) for a liquid source because the source used was in a very dilute form.
FIG. 5.8 DIRECTIONAL CORRELATION OF THE 208-113 keV CASCADE IN Hf$^{177}$. 
The directional correlation measurements were also performed with the unpolarized Lu-Fe sample and the polarized Lu-Fe sample in the magnet geometry. The correlation coefficients obtained are

\[ A_{22} \, G_{22} = -0.106 \pm 0.013 \, ; \, A_{44} \sim 0 \, \text{(unpolarized)} \]
\[ A_{22} \, G_{22} = -0.136 \pm 0.016 \, , \, A_{44} \sim 0 \, \text{(polarized)} \]

The results of the angular correlation measurements in magnet geometry are uncorrected for scattering in the geometry. A comparison of the results of the angular correlation for the unperturbed Lu-Fe sample with the liquid source gives us the attenuation coefficient \( C_{22} \) as \( C_{22} = 0.73 \pm 0.06 \). The attenuation of the correlation is attributed to the presence of randomly oriented electric quadrupole interactions.

5.2.4 \( \omega \angle \)-measurements:

Rotation measurements were carried out with the Hf-Fe and Hf-Ni samples using the integral reversed field method. Since for the 209-113 keV cascade, \( A_{22} \sim A_{44} \), the detectors were kept at 135° with each other and the quantity \( 'R' \) was calculated for each case. The measured value of \( 'R' \) after correcting for chance coincidence contribution, which was of the order of 5%, was used for getting the rotation. The results of our \( 'R' \) and \( \omega \angle \) measurements are summarized in table 5.5. The values of the hyperfine fields acting on Hf
Table 5.5.

Summary of 'R' and 'ωC' measurements in hafnium-iron and hafnium-nickel.

<table>
<thead>
<tr>
<th>Level (keV)</th>
<th>C</th>
<th>Host</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>113</td>
<td>(7.5±0.2)10⁻¹⁰ sec Fe 0.0641±0.0055 0.230±0.040</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ni   0.0321±0.0055 0.11±0.020</td>
<td></td>
</tr>
</tbody>
</table>

nuclei in iron and nickel were extracted from 'ωC' using the following values of the g-factor and lifetime C of the 113 keV state of Hf⁷⁷⁷: g= +0.232±0.006 and C=(7.5±0.2) 10⁻¹⁰ sec. The g-factor value is the weighted average of the results of the three directional correlation experiments using external fields³³⁻³⁵. The lifetime of the 113 keV state is also well known³⁶. Our measured values of the hyperfine fields are

\[
\begin{align*}
H_{Fe}^{Hf} &= -(277±47) \text{ kOe} \\
H_{Ni}^{Hf} &= -(126±23) \text{ kOe}
\end{align*}
\]

All the available measurements of hyperfine fields of Hf in iron and nickel are summarized in table 5.6.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Method of Measurement</th>
<th>Hyperfine Field (kOe)</th>
<th>Reference</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu\textsuperscript{177} Fe</td>
<td>IMPACT</td>
<td>-(300±60)\textsubscript{300°K}</td>
<td>27</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>W\textsuperscript{178} (1%) Fe</td>
<td>Mössbauer Effect</td>
<td>(606±70)\textsubscript{4.2°K} (547±60)\textsubscript{77°K}</td>
<td>32</td>
<td>Diffused source.</td>
</tr>
<tr>
<td>Hf\textsuperscript{180} (1%-Fe) Mössbauer Effect</td>
<td></td>
<td>334\textsubscript{4.2°K}</td>
<td>32</td>
<td>Diffused source.</td>
</tr>
<tr>
<td>Lu\textsuperscript{177} Fe</td>
<td>IMPACT</td>
<td>-(286±40)\textsubscript{300°K}</td>
<td>28</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Hf\textsuperscript{176,178,180} Fe</td>
<td>IMPACT</td>
<td>-(510±150)\textsubscript{300°K}</td>
<td>29</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Hf\textsuperscript{180} Fe</td>
<td>IMPACT</td>
<td>-(507±60)\textsubscript{300°K}</td>
<td>30</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Lu\textsuperscript{177} Fe</td>
<td>IMPACT</td>
<td>-(140±10)\textsubscript{300°K}</td>
<td>31</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Lu\textsuperscript{177} Fe</td>
<td>IPAC</td>
<td>-(277±47)\textsubscript{300°K}</td>
<td>This work</td>
<td>Diffused source.</td>
</tr>
<tr>
<td>Hf\textsuperscript{176,178,180} -Ni</td>
<td>IMPACT</td>
<td>=65\textsubscript{300°K}</td>
<td>30</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Lu\textsuperscript{177} Ni</td>
<td>IMPACT</td>
<td>-60±10\textsubscript{300°K}</td>
<td>31</td>
<td>Implanted source.</td>
</tr>
<tr>
<td>Lu\textsuperscript{177} Ni</td>
<td>IPAC</td>
<td>-(126±23)\textsubscript{300°K}</td>
<td>This work</td>
<td>Diffused source.</td>
</tr>
</tbody>
</table>
5.2.5 Discussion of the results:

Our measured value of the hyperfine field of Hf in iron is in good agreement with the measurements of Becker et al.\(^27\) and Hübel et al.\(^28\) but does not agree with the measurements of Brenn et al.\(^29\) and Murnick et al.\(^30\) who obtain higher values for the field. Mössbauer measurements of Steiner et al.\(^32\) also give higher values. Results of Brooker et al.\(^31\) are lower than our value. However our measured value of the hyperfine field of Hf in nickel is higher than the two earlier measurements\(^20,31\). On the basis of Stearns\(^19\) overlap polarization model, the various contribution to the hyperfine field on Hf in iron and nickel are given in table 5.7.

Table 5.7.

<table>
<thead>
<tr>
<th>Element</th>
<th>(H_z^{ns} (\text{kOe}))</th>
<th>(\text{Host} H_z^{(\text{Exptl})})</th>
<th>(-H_z^{ns})</th>
<th>(H_z^{ns})</th>
<th>(H_z^{ns}/H_z)</th>
<th>(\text{P}_v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>-277</td>
<td>558.3</td>
<td>281</td>
<td>0.036</td>
<td>0.057</td>
<td></td>
</tr>
<tr>
<td>Hf</td>
<td>7.7</td>
<td>15.7</td>
<td>Ni</td>
<td>-126</td>
<td>141.0</td>
<td>15</td>
</tr>
</tbody>
</table>

A comparison of Col.8 and Col. 9 tells us that the experimental values of the hyperfine fields give a polarization less than that calculated on the basis of volume misfit model.
On the basis of Shirley model\textsuperscript{36}, the predicted values of the hyperfine fields for Hf in iron and nickel are $H_{\text{Hf}}^{\text{Fe}} = -470$ koe, $H_{\text{Hf}}^{\text{Ni}} = -115$ koe. Our measured value of the hyperfine field on Hf in iron is lower than the predicted value but on Hf in nickel is in good agreement.

The values of the hyperfine fields, predicted on the basis of Balabanov and Delyagin model\textsuperscript{20}, for Hf in iron and nickel hosts are $H_{\text{Hf}}^{\text{Fe}} = 186$ koe and $H_{\text{Hf}}^{\text{Ni}} = 51$ koe. The magnitude of the hyperfine fields for Hf in iron and nickel, predicted on the basis of this model are lower than the measured values. Also, the predicted sign of the field is positive contrary to the measured negative sign.

5.3 Internal Hyperfine Magnetic Fields on Platinum in Cobalt and Nickel Hosts.

Previous measurements of the hyperfine magnetic fields on platinum (Pt) nuclei in cobalt and nickel hosts have been done with NMR and Mössbauer methods\textsuperscript{37-39}. Murnick et al\textsuperscript{40} performed IMPACT experiments on Pt nuclei in cobalt and nickel hosts. Recently King et al\textsuperscript{41} determined the $g$-factor of the 317 keV state using Pt-Ni alloy. No PAC measurement with Pt-Co alloy was available, therefore we thought it worth while to measure the hyperfine fields on Pt in cobalt and nickel hosts using perturbed angular correlation technique. The $g$-factor of the 317 keV state is well known. We have also measured the $g$-factor of this state (described in Chapter VI of the thesis) using the internal
hyperfine field of Pt in iron and then used this value in determining the hyperfine fields on Pt in cobalt and nickel hosts.

The measurements were carried out using the integral reversed field method. The isotope used was Ir$^{192}$ (74.2 d) whose decay scheme is shown in fig. 5.9. From the decay scheme, it can be seen that there are several gamma-gamma cascades with 317 keV level as the intermediate state. Of all the cascades, 468-317 keV is the strongest and hence was used for angular correlation and rotation measurements.

5.3.1 Source Preparation

The radioisotope Ir$^{192}$ was obtained from Bhabha Atomic Research Centre, Bombay, India in the form of Sodium Chloro-iridate in HCl solution. This solution as such was not suitable for electroplating. Therefore conc. H$_2$SO$_4$ was added to it and fumed. The fuming process was repeated 3-4 times to remove Cl ions because the presence of Cl ions decreases the efficiency of electroplating. Finally, iridium was dissolved in an aqueous solution of H$_2$SO$_4$ and NH$_4$OH (pH=3) and electroplated on speckpure cobalt and nickel wires by passing 10 mA current for 6 hours. The electroplated Ir-Co and Ir-Ni samples were diffused in argon atmosphere at 600°C for 40 hours. The samples were melted and annealed at 600°C for 10 hours. The annealed samples were washed with HCl to remove all the surface activity and were used for angular correlation and rotation measurements.
FIG. 5.9 PARTIAL DECAY SCHEME OF Ir$^{192}$. 

$^{77}$Ir$^{192}$  74.02 d 

$\beta^-$

4$^+$  588.7

3$^+$  308.4

4$^+$  604.4

2$^+$  468

$T_{1/2} = 34.5$ p sec.

2$^+$  296

316.5

78Pt$^{192}$  0

0
The amount of radioactive impurity in each alloy was approximately 5.3%. 

5.3.2 Measurements and Results:

Fig. 5.10 shows the singles gamma spectrum of Ir$^{192}$ along with the position of the gates. An external polarizing field of 7 kG was applied on the samples perpendicular to the plane of the detectors.

5.3.3 Angular Correlation Measurements:

Directional correlation measurements of the 468-317 keV cascade were carried out with the liquid source in a scattering free geometry and also in the actual geometry used for the measurement of 'R'. Source to crystal distance was 10 cms from each counter. The centering of the source was done to an accuracy of 0.5% from the change in singles counting rate of the movable counter at seven angles. The coincidence counts were collected at seven angles between 90° and 180° at an interval of 15° each. A least squares fit of the data corrected for random coincidences, yielded the following correlation coefficients after solid angle correction:

\[ A_2 = 0.085 \pm 0.005 \quad \text{free geometry} \]
\[ A_4 = 0.005 \pm 0.007 \]
\[ A_2 = 0.074 \pm 0.002 \quad \text{actual geometry} \]
\[ A_4 = 0.005 \pm 0.005 \]
FIG. 5.10 SINGLES GAMMA SPECTRUM OF $^{192}\text{Ir}$ GATE SETTING ARE INDICATED.
Fig. 5.11 shows the results of our angular correlation measurements for the 468-317 keV cascade. Results of the angular correlation coefficients for the 468-317 keV cascade as measured by other workers are:

\[ A_2 = 0.102 \pm 0.004 \] \hspace{1cm} \text{Simons et al}^{43)}

\[ A_4 = 0.005 \pm 0.005 \]

\[ A_2 = +0.099 \pm 0.019 \] \hspace{1cm} \text{Johns et al}^{44)}

\[ A_4 = -0.005 \pm 0.026 \]

\[ A_2 = 0.100 \pm 0.004 \] \hspace{1cm} \text{Hirose et al}^{45)}

\[ A_4 = 0.003 \pm 0.007 \]

Our measured values of the correlation coefficients are slightly lower than the theoretical coefficients for the 4-2-0 cascade and the measured values of the correlation coefficients for the same cascade. The reason for the same may be due to the contribution of the high energy gamma rays in the 468 keV channel. Two major contributions from high energy gamma rays are possible, the 468 keV channel may accept a very small portion of the highly anisotropic 604-317 keV angular correlation or a contribution from the 588-(296)-317 keV cascade. Since the 604-317 keV cascade has the same 317 keV level as the intermediate state, our correlation coefficients and 'R' value is attenuated by the same factor and final result remains unaffected. The contribution of the 588-(296)-317 keV cascade is about 4% of the total counting rate (from the \( \beta \) and \( \gamma \) intensities of the decay scheme) and its effect is neglected,
being within the experimental errors. The window widths of the single channel analysers were kept 2 volts each so that the contribution of interfering gamma rays is reduced. Also it was ensured by checking the gate positions at frequent intervals throughout the course of the experiment that the settings for the unperturbed and perturbed angular correlation experiments are the same and the counting period was also kept small.

5.3.4. Measurements:

Since $A_4$ coefficient for the 468-317 keV cascade is small, the detectors were kept at 135° with respect to each other. The precession of the 317 keV level for Pt-Co and Pt-Ni samples was deduced from the relative change in coincidence counting rates between field 'up' ($C_{up}$) and 'down' ($C_{down}$). The measured value of $R$ was corrected for chance coincidence contribution which was about 5%. Results of our $R$ and $\omega$ measurements for Pt-Co and Pt-Ni alloys are given in table 5.8.

**Table 5.8**

Summary of $R$ and $\omega$ measurements in platinum-cobalt and platinum-nickel alloys.

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>Level</th>
<th>Host</th>
<th>$R'$</th>
<th>$\omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{192}\text{Pt}$</td>
<td>317 keV</td>
<td>Cobalt</td>
<td>0.0104±0.0013</td>
<td>0.0504±0.0060</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nickel</td>
<td>0.0048±0.0007</td>
<td>0.0234±0.0034</td>
</tr>
</tbody>
</table>
The available lifetime values of the 317 keV-level are given in Table 5.9. The value by de Boer et al (46) is about 25% lower than the other two values which are in excellent agreement with each other. We have used the weighted average of these two values reported in refs. 47 and 48. \( \tau = (5.0 \pm 0.3) \times 10^{-11} \) sec in calculating the internal hyperfine fields. The value of the \( g \)-factor of the 317 keV level was measured under similar conditions with a Pt-Pd alloy (details of the experiment are given in Chapter VI of the thesis) and its value has been obtained to be

\[ g = 0.25 \pm 0.03 \]

This value is in good agreement with the previous available results (48-53). Using the values of the lifetime and the \( g \)-factor,
the internal hyperfine fields acting on Pt nuclei in cobalt and nickel hosts have been extracted from the respective $\omega_T$ values, as:

$$H_{Pt}^{Co} \ (\text{Room temperature}) = -(808 \pm 100) \text{ kOe}$$

$$H_{Pt}^{Ni} \ (\text{Room temperature}) = -(380 \pm 60) \text{ kOe}.$$ Murnick et al. performed IMPACT experiments with Pt$^{194}$ in cobalt and nickel hosts and their results $H_{Co}^{Pt} / H_{Fe}^{Pt} = 0.72 \pm 0.05$ is higher than our measured value $H_{Co}^{Pt} / H_{Fe}^{Pt} = 0.63 \pm 0.07$. But their value for $H_{Ni}^{Pt} / H_{Fe}^{Pt} = 0.30 \pm 0.04$ is in agreement with our measured value $H_{Ni}^{Pt} / H_{Fe}^{Pt} = 0.30 \pm 0.05$. Results of King et al. for the rotation $\omega_{Co}$ of Pt in nickel ($\omega_C = 0.036 \pm 0.04$) are larger than our measured value.

All the previous measurements of the hyperfine magnetic fields on Pt nuclei in cobalt and nickel hosts along with the present investigations are summarized in table 5.10

**Table 5.10**

Summary of the hyperfine field measurements on platinum nuclei in cobalt and nickel hosts.

<table>
<thead>
<tr>
<th>Host</th>
<th>Impurity Percentage</th>
<th>Hyperfine Field (kOe)</th>
<th>Method</th>
<th>Temperature</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>-770 ±70</td>
<td>Möss.</td>
<td>29°C</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>-860 ±30</td>
<td>Möss.</td>
<td>4.2°C</td>
<td>38</td>
</tr>
<tr>
<td>Cobalt</td>
<td>&lt; 2.0</td>
<td>-830</td>
<td>S.E.</td>
<td>4.2°C</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>~ 0.6</td>
<td>-808 ±100</td>
<td>PAC</td>
<td>R.T.</td>
<td>This work.</td>
</tr>
</tbody>
</table>
Table 5.10 (Contd.)

<table>
<thead>
<tr>
<th>Host</th>
<th>Impurity Percentage</th>
<th>Hyperfine Field (T)</th>
<th>Method</th>
<th>Temperature</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>&lt; 2.0</td>
<td>3.0</td>
<td>-340</td>
<td>90</td>
<td>Möss.</td>
</tr>
<tr>
<td></td>
<td>~ 0.6</td>
<td>2.0</td>
<td>-360 ±40</td>
<td>Möss.</td>
<td>4.2 K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6</td>
<td>-380 ±60</td>
<td>S.E.</td>
<td>4.2 K</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PAC</td>
<td>R.T.</td>
</tr>
</tbody>
</table>

5.3.5: Discussion of the results:

Our measured value of the hyperfine magnetic field on Pt nuclei in cobalt and nickel is in good agreement with the previous NMR and Mössbauer values.

Pt belongs to the upper region of the 5d transition series and the solute atom develops a localized moment. In addition to the CEP contribution to the hyperfine field, core polarization by localized moment also contribute strongly.

Information obtained on the basis of Stearns' overlap polarization model is given in Table 5.11. Since the solute

Table 5.11

Hyperfine Fields on platinum in cobalt and nickel
(all fields in kOe except H^ns)

<table>
<thead>
<tr>
<th>Element</th>
<th>H^ns (kOe)</th>
<th>Co</th>
<th>Host (Exptl)</th>
<th>H^z</th>
<th>H^2</th>
<th>H^2/H^ns</th>
<th>H^-ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt</td>
<td>16.0</td>
<td>-380</td>
<td>293</td>
<td></td>
<td></td>
<td>856</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>9.1</td>
<td>-380</td>
<td>293</td>
<td></td>
<td></td>
<td>856</td>
<td></td>
</tr>
</tbody>
</table>
atom develops a moment, therefore information regarding $H^*$ cannot be obtained.

On the basis of Shirley model\(^{36}\), the $H_{\text{CPE}}$ and $H_{\text{CP}}$ contributions to the hyperfine fields are given in table 5.12.

<table>
<thead>
<tr>
<th>Element</th>
<th>Host</th>
<th>$-H_{\text{CPE}}$</th>
<th>$-H_{\text{CP}}$</th>
<th>$\mu$</th>
<th>$\mu^{36}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co</td>
<td></td>
<td>739</td>
<td>6.9</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Pt</td>
<td>Ni</td>
<td>230</td>
<td>150</td>
<td>0.13</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Col. 5 gives the derived localized moments on the basis of present measurements and in col. 6 are given values from ref. 36 for comparison.

The value of the hyperfine fields predicted on the basis of Balabanov and Delyagin model\(^{20}\) for Pt in cobalt and nickel are $H_{\text{Pt}}^{\text{Co}} = -1100$ kOe and $H_{\text{Pt}}^{\text{Ni}} = -386$ kOe. The sign of the hyperfine field is predicted correctly. The measured value of the hyperfine field on Pt in cobalt is lower than the predicted value on the basis of this model while that for Pt in nickel is in good agreement.
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