Study of ^{181}Ta in Zn at room temperature

Vivek Mandot
Associate Professor
Department of Physics
V. K. B. Government Girls College, Dungarpur

Abstract
In the present study the ^{181}Ta in Zn at room temperature was investigated with angular correlation measurement of two gamma rays in a γ–γ cascade. The two detector time differential perturbed angular correlation setup was used for the study. Fast BaF_2 crystals were used for the experiment. The experimental value of electric field gradient we found to be 3.22 $X10^{21}(V/m^{2})$.

Keywords: TDPAC, Ta in Zn, EFG

Introduction
181Hf(β −)181Ta was widely used to study the nuclear quadrupole interaction (NQI) in a variety of compounds, particularly in Hf compounds, Butz et al, 2009. In the present investigation Electric Field Gradient (EFG), due to Zinc host lattice, at the probe nuclei ^{181}Ta has been performed. In a study of ^{181}Ta in Zn, performed by Bedi et al (1978), quadrupole interaction frequency (ν_Q) at room temperature was found to be 746.6 MHz. This value is not much different from the value of ν_Q in HfO_2 at ^{181}Ta observed by Koicki et al (1983). Bhati has suggested that the source ^{181}TaZn might have trapped oxygen, thereby forming HfO_2.
Butz et al (1983) have suggested that the source should be prepared in a short time at higher temperature, thereby preventing the formation of HfO_2 to a large extent. Taking into consideration all the above mentioned results and the fact that the TDPAC system we are using has a better time resolution, study of ^{181}Ta in Zn is performed.

Source preparation and experiment
The (111In→) 111Cd and (181Hf→) 181Ta nuclides are well known, both as native atom or as an impurity in a given system, and are the most used probe-atoms in TDPAC spectroscopy, Daribba et al, 2018. Therefore we chose 181Ta as our probe and to obtain that the spectral pure hafnium was sealed in a quartz capsule at ~ 10^{-4} torr and was sent to Bhabha Atomic Research Centre for neutron irradiation. The material was bombarded by neutron beam flux of ~10^{13} n/sq. cm/sec for two weeks. The radioactivity, thus produced, was annealed and cooled. A small piece of this radioactivity was taken and diffused in Zn metal by standard techniques. A piece of the material was then taken for the study.
This sample was mounted directly in a γ-γ angular correlation setup, consisting of two BaF_2 scintillator coupled with XP2020Q photomultiplier tube detector system. One of the detectors was movable so that the measurements at 90° and 180° with respect to the fixed one could be made. The 133 keV E2 gamma quanta populating the 10.8 nsec $5^+/2$ level of ^{181}Ta at 482keV was detected in one of the detector which was kept fixed. The 482 keV E2+M1 gamma from this state is measured in the other movable detector.
The time spectra recorded at these two angles were stored in separate 1024-channel analyzer. The time resolution of this experimental setup was 0.6nsec. This activity was studied at room temperatures.

Results and Discussion
The spectrum of the annealed source was taken at room temperature. From the measured time spectra the asymmetry ratios R(t) are obtained as (Arends et al, 1980).

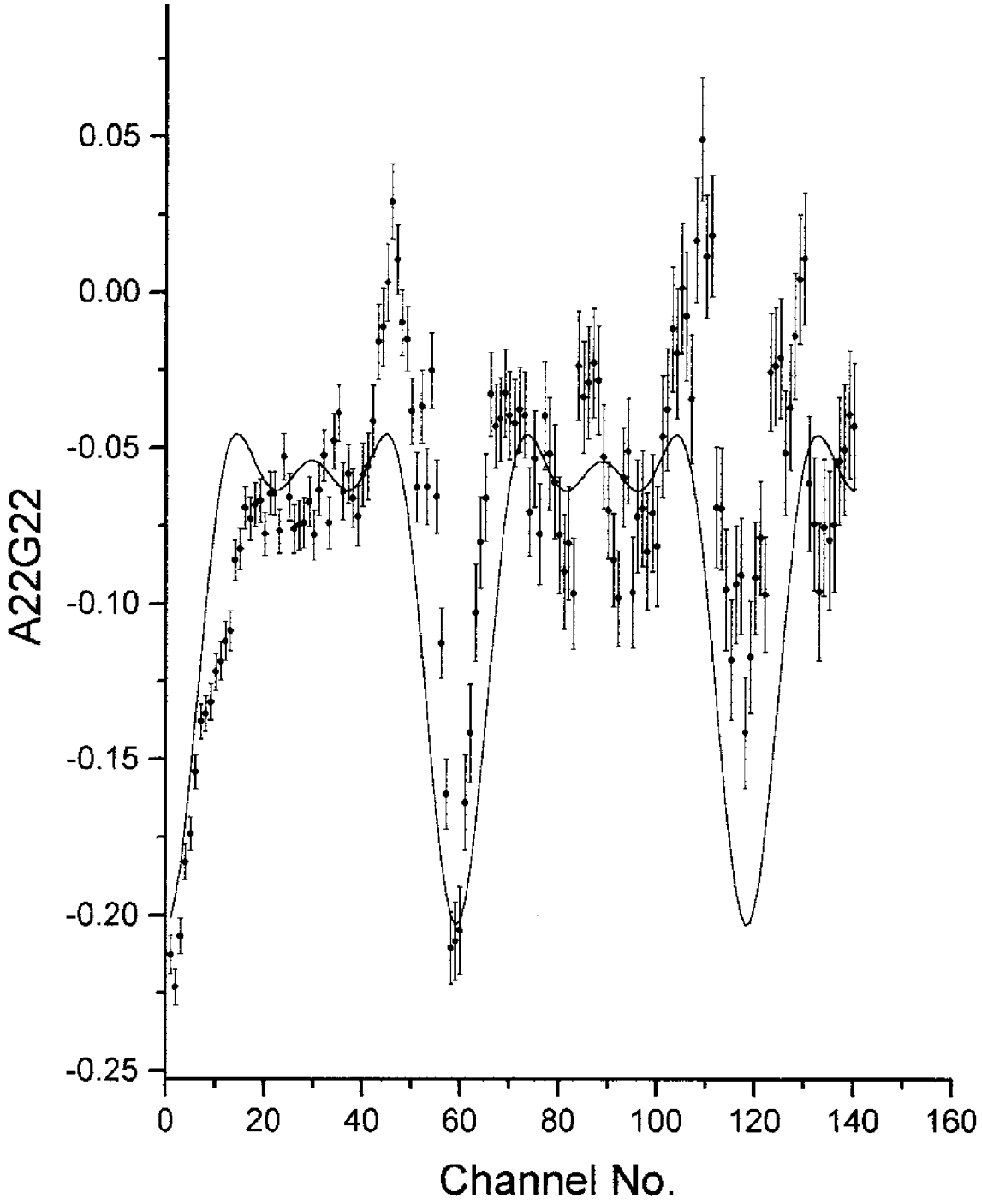


Figure 1: TDPAC spectrum of ^{181}TaZn at room temperature (1ch = 0.6ns)

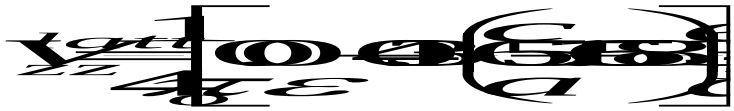
The TDPAC spectrum of ^{181}TaZn at room temperature is shown in the Figures 1. In the figure, the solid line represents the least squares fitted spectrum. The spectrum shows a unique frequency at room temperature. The asymmetry parameter was taken as zero. The frequency, the EFG and other parameters are listed in the Table 1.
In the present study, the results of the fitted parameter show the maximum amplitude A_{22} at room temperature to be -0.145 showing that most of the probe nuclei are at the substitutional sites. ν_Q is observed to be 196.66MHz , V_{zz} is 3.22 X10^{21}(V/m^2) and ω_o is observed to be 185.35MHz

Table 1: Fitted parameters for Zn with ^{181}Ta probe

Temperature	Amplitude	ν_Q (MHz)	V_{zz} (V/m^2) X10^{21}	ω_o (MHz)

300K	-0.145	196.66	3.22	185.35

As the Zn lattice site is hcp, an axially symmetric EFG is expected. For hcp metals, a theoretical calculation for EFG can be made, using the well-known formula given by Das and Pomerantz (1961) for point charge contribution to V_{zz}^{latt}



Here c and a are the lattice parameters along the principal axes. Lattice spacing for Zn at room temperature are well documented by Bodenstedt et al (1978) and Pearson (1958). From these values of lattice parameters and the effective valence Z= 2, we calculated the contribution to the field gradient and is shown in Table 2.
The effective field gradient at the site of Hf -Ta nucleus can be given as

assuming all charges contributing to field gradient are outside the probe ion. Here, γ_∞ is the Sternheimer antishielding factor and for Hf its value is taken as γ_∞ = -61 (Feiock and Johnson, 1969). This value of EFG is also tabulated in the Table 2.

Table 2: Parameters for Zn

T(K)	a(Å)	c/a	V_{zz}^{latt} (V/m^2) (10^{20})	$V_{zz}^{latt}eff$ (V/m^2) (10^{21})	ν_Q (MHz)
300	2.6711	1.8787	-1.6062	-9.9586	603.57

Conclusion

There is a large difference in experimentally observed electric field gradient and theoretically calculated values. This difference in the trends of ionic and observed values indicates an additional electronic contribution but to conclusively predict the results more studies at different temperatures is required.

References:

Arends A. R., C. Hohenemser, F. Pleiter, H. De Waard, L Chow & R. M. Suter, 1980, Hyperfine Interactions **8**, 191
Bedi S. C., R. G. Pillay and S. H. Devare, 1978, Hyperfine Interactions **5**, 161
Bhati A. K., N. Aggarwal, S. C. Bedi and H. S. Hans, 1985, Hyperfine Interactions. **23**, 125
Bodenstedt E. and B. Perscheid, 1978, Hyperfine Interactions **5**, 291
Butz T., A. Lerf, A. Hubler, H. Gierisch, S. Saibene and J. O. Besenhard, 1983, Hyperfine Interactions **15/16**, 925
Butz T., S. K. Das and Y. Manzhur, 2009, Z. Naturforsch. **64**a, 103 – 111
Darriba G. N., E. L. Muñoz, A. W. Carbonari, and M Rentería, 2018, Experimental TDPAC and Theoretical DFT Study of Structural, Electronic, and Hyperfine Properties in (111In) 111Cd-Doped SnO2 Semiconductor: Ab Initio Modeling of the Electron-Capture-Decay After-Effects Phenomenon, J. phys. Chem., **122**(30), pp 17423–17436
Das T. P. and M. Pomerantz, 1961, Phys. Rev. **123**, 2070
Feiock F. D. and N. R. Johnson, 1969, Phys. Rev. **187**, 39
Koicki S. K. and B. Cekic, 1983, Hyperfine Interactions **14**, 105
Pearson W. B., 1958, A handbook of lattice spacings and structures of metals and alloys, part 2 (Pergamon Press, New York), 886