Decay Rate of ^{7}Be Under Compression

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Introduction

^{7}Be decays by electron capture and its decay rate is known to change [1] in different chemical environments having different electron affinities. Density functional and Hartree-Fock calculations can account [2] for such changes. However, there are very few studies [3] of the change of decay rate of ^{7}Be under compression and the observed relatively large increases of decay rate under compression have not been quantitatively understood so far. The increase of ^{7}Be decay rate under compression has significance in both geophysics and nuclear astrophysics such as solar neutrino problem [2]. Hensley et al. [3] compressed ^{7}Be by applying external pressure on ^{7}BeO lattice with the help of a diamond anvil cell. It was found [3] that the decay rate of ^{7}Be increased by 0.6% by the application of 27 GPa pressure. Another way to study compressional effect on ^{7}Be is to implant the radioactive atoms in the octahedral and tetrahedral spaces of a small lattice (Pd) and large lattice (Pb). It is expected [4] that ^{7}Be in Pd (lattice parameter=3.89Å) would be significantly more compressed compared to ^{7}Be in Pb (lattice parameter=4.95Å). The increase of total electronic kinetic energy of ^{7}Be in ^{7}BeO lattice under an external pressure of 27GPa is =1.5 eV compared to the ambient condition. On the other hand, the increase of total electronic kinetic energy of ^{7}Be implanted in a Pd lattice compared to that implanted in a Pb lattice is about 15 eV, if we assume that the lattice remains undisturbed as ^{7}Be sits in the interstitial space of the lattice. However, as ^{7}Be goes to the interstitial site, the lattice should adjust its parameters to minimize the total energy, thus reducing the pressure on ^{7}Be ion. The pressure on ^{7}Be is still expected to remain substantially high for ^{7}Be in Pd lattice. Hence, the change of decay rate of ^{7}Be under relatively high compression could be studied by implanting ^{7}Be in small Pd and large Pb lattices.

On the basis of density functional calculations [5], no significant difference in decay rate of ^{7}Be is expected in Pb and Pd catcher foils, because Pb and Pd have similar electron affinities and the increase of electron density at the nucleus due to the expected compression should not be significant. However, relatively significant increase of decay rate of ^{7}Be in Pd compared to Pb is expected due to the possible quantum Anti-Zeno effect [6]. The purpose of the experiment is to probe any such significant increase of decay rate of ^{7}Be in Pd compared to that in Pb.

Experiment

A 7 MeV (500 nA) proton beam from Variable Energy Cyclotron, Kolkata was used to bombard a 400 μg/cm^{2} LiF target evaporated on 1.5μm thick aluminum foil. ^{7}Li(^{1}H,n)^{7}Be reaction produced ^{7}Be with 1-3 MeV kinetic energy and these ^{7}Be ions were implanted in Pd and Pb foils placed behind LiF target. The implantation on each catcher foil was done for 10-12 hours. There was no significant nuclear reaction between Pb and proton, as the Coulomb barrier for lead was higher than the incident beam energy. However the interaction of proton with Pd produced long-lived Pd isotopes and their associated γ-ray lines. We waited for about a month for the decay of the short-lived radioactive elements. Then we alternately placed ^{7}Be implanted Pb and Pd foils in front of a HPGe detector (efficiency = 80%). ^{7}Be decays by electron capture to ^{7}Li. There is about 10% probability that the decay would go via the first excited state of ^{7}Li and a 477.6 keV γ-ray photon would be emitted. The intensity of the 477.6 keV γ-ray was monitored with time along with 1173.2 keV and 1332.5 keV γ-ray lines from a standard ^{60}Co source. We counted for 24 hours, then saved the singles γ-ray spectrum and restarted counting. A precision electronic pulser was counted by a scaler and used as a clock. The counting continued for about 5 months.

Results

In Fig. 1(a) and 1(b), we show typical γ-ray spectra of ^{7}Be implanted Pb and Pd catcher foils. In the γ-ray spectrum of Pb catcher foil, the most prominent peaks are 477.6 keV peak from ^{7}Li and two γ-ray peaks (1173.2 keV and 1332.5 keV) from ^{60}Co. In the γ-ray spectrum of Pd catcher foil, we see γ-ray lines from long-lived Pd isotopes in addition to γ-ray peaks from ^{60}Co and 477.6 keV γ-ray line from ^{7}Li. We also see natural background 1460 keV γ-ray line from ^{40}K. The ratio of the intensity of 477.6 keV line to the sum of the intensities of 1173.2 keV and 1332.5 keV lines was monitored with time to cancel out the dead time effect of the data acquisition system.

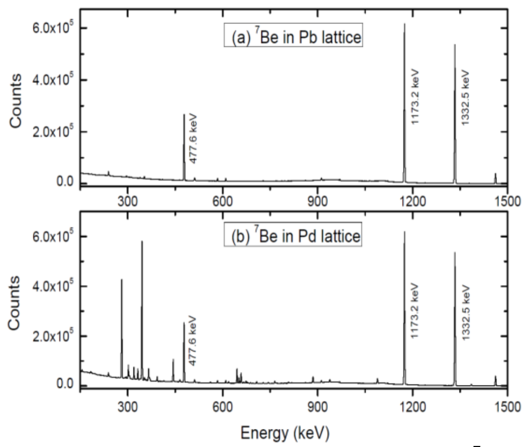

Fig. 1(a) & 1(b) Typical γ-ray spectra of ^{7}Be implanted Pb and Pd catcher foils.

Outlook

We expect to obtain high precision measurements of half-life of ^{7}Be in Pb and Pd catcher foils from this experiment and determine the change of decay rate of ^{7}Be under high compression. The data analysis is currently in progress and the final result will be presented in the Conference.

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