Study of Nuclear Viscosity and Isospin Mixing Utilizing Isovector Giant Dipole Resonance

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The atomic nucleus is a many-body quantum system, which, by the virtue of its intrinsic complexity, mystery and practical applications, remains an exciting entity for physicists. Over the years, various tools have been unearthed to explore deep into the nucleus and study its properties. The isovector giant dipole resonance (IVGDR), a member of a broad family of collective resonances known as giant resonances, is an excellent tool to explore the nuclear properties at extreme conditions. Macroscopically described as the out-of-phase oscillation of proton and neutron fluids, the IVGDR is a highly damped motion characterized by a very short lifetime (10^{-21}-10^{-22} sec). The resonance relaxes by the emission of high-energy γ rays in 10-25 MeV regions depending on the mass of the system. Viscosity of the nuclear matter provides the main mechanism for the damping of the IVGDR and it is inherently related to the width and energy of the resonance [1]. In addition, these γ-transitions, being isovector in nature, are inhibited between the states of the same isospin (I) in self-conjugate nuclei [2].

The present thesis contains the experimental investigations of two crucial properties of the atomic nucleus; namely the ratio of shear viscosity (η) to entropy volume density (s) for finite nuclear matter at finite temperature [3] and isospin mixing at high temperature in the self-conjugate nucleus ^{32}S [4]. Both studies were performed utilizing the IVGDR as a probe. The IVGDR was populated in compound nucleus (CN) reaction by using the ^{4}He beam of energies 28-50 MeV from the K-130 cyclotron at the Variable Energy Cyclotron Centre, Kolkata. The γ rays from the decay of the GDR were detected by using the LAMBDA spectrometer (A), while the CN angular momentum was determined by measuring the low-energy γ-ray multiplicity by using the multiplicity filter (B). Evaporated neutrons were detected by using a neutron time of flight detector (C) for proper determination of nuclear level density (NLD) parameter and nuclear temperature. The low-energy γ rays were also detected by using two clover detectors (D) for observing the isotopic impurity of the targets, if any. The theoretical analysis of the measured data was performed by using the statistical model code CASCADE.

In the first part of the thesis, the shear viscosity for finite nuclear matter was determined from the measured GDR parameters (energy and width), while the entropy density was calculated from the measured NLD parameter and nuclear temperature. Thus, it has been observed

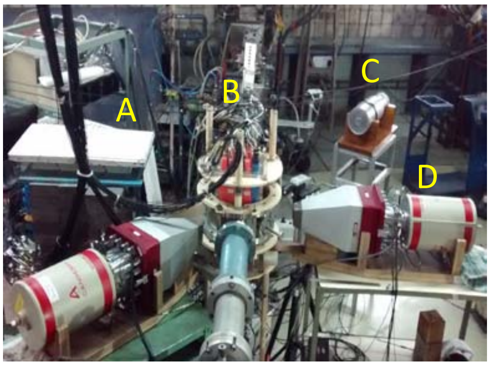

Fig 1: Experimental set-up used for present studies

experimentally (Fig. 2), for the first time, that the nuclear fluid conform to the KSS conjecture [5] and also establishes that strong fluidity is the universal characteristic of the strong interaction of the many-body nuclear systems. This result, along the results of low-temperature quantum fluids, suggests that large fluidity could also possibly be the intrinsic characteristic feature of strongly coupled systems.

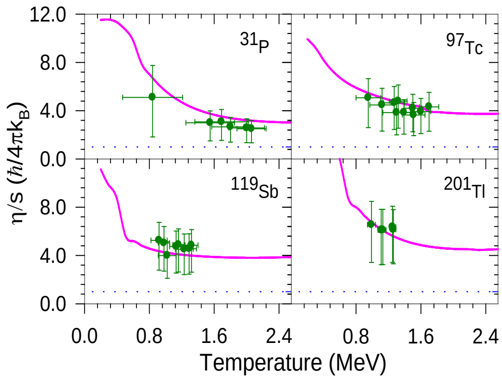

Fig 2: Variation of η/s with temperature for different systems.

The second part of the thesis contains experimental determination of isospin mixing in ^{32}S (Fig. 3). The mixing probability was extracted from the measured ratio of γ-ray cross sections of ^{32}S and ^{31}P. The results indicate that the Coulomb spreading width remains roughly constant with nuclear temperature and angular momentum. The present measurement, along with the other measured data, shows that the isospin becomes a good quantum number with the increase in temperature. However, the measured data is under-predicted by the available theoretical calculation and thus calls for other measurements in the low mass region.

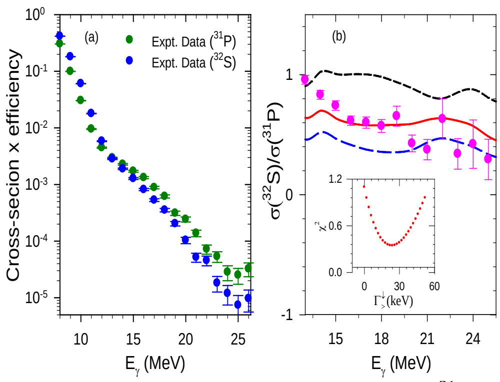

Fig 2: (a) High-energy γ-ray spectra for ^{31}P and ^{32}S. (b) Ratio of high-energy γ-ray cross sections.

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