## Elements (Periodic table)-Nuclei-Solids: Condensed Matter Physics probed with excited nuclei

**Prof. S. N. Mishra**
Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai

### Abstract

Modern periodic table has helped understanding the foundation of science, physics and chemistry alike. Elements in solid state exhibit variety of interesting phenomenon in many domains – structural, electronic, magnetic etc. Much of exciting physical processes are governed by many body electron-electron correlation. Investigations of solid state properties are most commonly examined through macroscopic experimental techniques like X-ray diffraction, transport and magnetization measurements. These techniques reveal the gross features with no details on dynamics. Microscopic investigations are often important for complete understanding of static and dynamic solid state properties. Nuclei in excited states, especially those with nanosecond life time (isomers) through hyperfine interactions serve as powerful microscope for studying solid state phenomenon at short length and time scales. In this talk I shall try to give an overview on the application of high spin nuclear isomers to problems in condensed matter physics, with illustrative examples from experiments carried out at the Pelletron accelerator at TIFR, Mumbai.

## Extension of periodic table and Search for Super Heavy Elements

**Dr. B.S. Tomar**
Raja Ramanna Fellow, Bhabha Atomic Research Centre, Mumbai
& Institute Chair Professor, Homi Bhabha National Institute, Mumbai

### Abstract

The first experiments towards extension of periodic table beyond Uranium were carried out by Enrico fermi in 1934 immediately after the discovery of neutron. Though these series of experiments ultimately led to discovery of fission, the element Z=93 was discovered by the group led by G.T.Seaborg, soon afterwords. This in turn facilitated the discovery of heavier actinides owing to their chemical similarity with their lanthanide counterparts in ion exchange separations of individual members of actinide series.

While the elements upto Z=100 were discovered in neutron induced reactions on lighter elements, higher Z elements were discovered in reactions induced by charged particles on lower Z targets. Till today elements up to Z=118 have been discovered in high energy, high intensity accelerators, though their production rates have been gradually falling down from 1 atom per hour for elements around 108 to 1 atom per day for element 118. Due to decreasing cross sections from micro-barns to nano barns and pico-barns. The major challenge in producing these heavier elements is the competition from fission process, whose probability increases with $Z^2/A$, as a result of which the nuclei, even though formed, do not survive long enough to be monitored by the detectors.

Two approaches have been followed for synthesis of superheavy elements, namely relatively low Z projectiles bombarding long lived actinides, such as, U238, Pu244, Cm248 (hot fusion) and heavier

projectiles bombarding relatively lighter targets, such as, Pb208, Bi209, etc, the latter being close to doubly magic (82,126) proton and neutron numbers and hence the compound nucleus is expected to be formed with lower excitation energy (Cold fusion) and hence high survival probability towards fission.

Based on the shel model calculations, there is expected to be another island of stability around Z=114 and N=188, and which are called as super heavy elements (SHE). Experiments were carried out in the past on separation of SHE from minerals of their lighter homologues, but without success. On the other hand, the experiments with heavy ion reactions using accelerators are in progress to look for SHE in the vast amounts of fission products and other lower Z products. While the scientists are already in the region of SHE, the isotopes produced are too short lived to study their chemistry. It may require some innovative approach to reach the long lived isotopes (if at all they exist) of SHEs.

## Role of shell structure in Nuclear Physics

**Dr. D.C. Biswas**

Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai

### Abstract

The periodic Table is a remarkable demonstration of the fact that the chemical elements are not a random cluster of the entities but instead display trends and lie together in families. It is arguably a very important concept in chemistry, both in principle and in practice. In 1869, Mendeleev proposed the periodic law and constructed the periodic table of elements. At that time the structure of the atom was unknown and Mendeleev's idea to consider that the properties of the elements were in some way related to their atomic masses was very imaginative one. Mendeleev also had the foresight to leave gaps in the periodic table for elements unknown at that time and predict their properties from the trends that he observed among the properties of related elements. Mendeleev's predictions were proved to be astonishingly correct when these elements were discovered later.

It is easy to visualize the significance of quantum numbers and electronic configurations in periodicity of elements. In fact, it is now recognized that the periodic law is essentially the consequence of the periodic variation in electronic configurations, which indeed determine the physical and chemical properties of elements and their compounds. It is well known that the electrons in an atom move in single-particle orbits corresponding to various energy levels of the attractive Coulomb potential set up by the nucleus from the centre of the atom. The levels belonging to each group are said to form a shell. In fact, it is well known that the periodicity of the chemical properties of various atoms occurring in the same columns of the periodic table is precisely explained by the shell structure of the electron configurations.

Following the concept of the atomic model, the evidence of shell structure was obtained for the atomic nucleus also in the year 1949. It was found that the role analogous to that of inert gases in atomic physics is played in nuclear physics by a set of nuclei having either the neutron or proton number equal to 2, 8, 20, 50, 82 and, 126. These nucleon numbers with a shell closure are usually called "magic numbers". The first excited state of even nuclei having N or Z equal to the magic numbers occurs at an energy that is unusually large as compared with the same excitation energy of neighboring nuclei. To obtain the magic numbers, Mayer and Haxel Jensen, and Suess suggested that a spin-orbit potential should be added to the centrally symmetric potential. All these facts provide direct evidence on the existence of shell structure in the nucleus. The magic numbers mark the filling up of a group of close-lying levels belonging to a shell; in

analogy with the atomic physics, we therefore expect these nuclei to be very stable, and harder to excite when compared with their neighbors.

Mendeleev's periodic law spurred several areas of research during the subsequent decades. Work on the radioactive decay series for uranium and thorium in the early years of twentieth century was also guided by the periodic table. At present 118 elements are known, of which the recently discovered elements are synthesized and research for search of new elements are continuing. Scientists found a systematic way to organize their knowledge by classifying the elements, which would rationalize known chemical facts about elements and also prediction of new ones for undertaking further study. Although minute quantities of some transuranic elements occur naturally, they were all first discovered in laboratories. Their production has expanded the periodic table significantly, the first of these being neptunium, synthesized in 1939. Many of the transuranic elements are highly unstable and decay quickly, they are challenging to detect and characterize when produced. In 2010, a joint Russia–US scientists claimed to have synthesized six atoms of tennessine (element 117), making it the most recently claimed discovery. It, along with nihonium (element 113), moscovium (element 115), and oganesson (element 118), are the four most recently named elements, whose names all became official on 28 November 2016.

## Modified Bulk Substrate For Tera Hertz (THz) Sources and Detectors

**Prof. S.S. Prabhu**

Department of Condensed Matter Physics and Material Science, Tata Institute of Fundamental Research

### Abstract

We will describe here photoconductive material for THz emission and detection with sub-picosecond carrier lifetime made by C12 (Carbon) irradiation on commercially available semi-insulating (SI) GaAs. We are able to reduce the carrier lifetime of SI-GaAs down to sub-picosecond by irradiating it with various irradiation dosages of Carbon (C12) ions. With an increase of the irradiation dose from ~10^12 /cm2 to ~10^15 /cm2 the carrier lifetime of SI-GaAs monotonously decreases to 0.55 picosecond, whereas that of usual non-irradiated SI-GaAs is ~ 70 picosecond. This decreased carrier lifetime has resulted in a strong improvement in THz pulse emission and detection compared with normal SI-GaAs. Improvement in signal to noise ratio as well as in detection bandwidth is observed. The sources become more robust and can work at high voltages. Carbon irradiated SI-GaAs appears to be an economical alternative to low temperature grown GaAs for fabrication of THz devices.

# Workshop on 150 years of the Periodic Table

**Organised by**
**Department of Physics, University of Mumbai in collaboration UGC-Special Assistance Programme**

**3rd November, 2018, 11 am to 6 pm**
**Marathi Bhasha Bhavan auditorium,**
**University of Mumbai, Kalina, Santacruz (East). Mumbai 400 098**

**Convenor: Prof. V.A. Bambole**
**Co-Convenor: Prof. M. Hemalatha**

**Schedule of the Programme**

| Time | Programme | Invited Speaker |
|---|---|---|
| 10:15 – 11:15 | Registration | |
| 11:15 – 11:30 | Inauguration ceremony | |
| 11:30 – 11:45 | Tea break | |
| 11:45 – 12:30 | Talk 1: Elements (Periodic table) - Nuclei - Solids: Condensed Matter Physics probed with excited nuclei | Prof. S.N. Mishra |
| 12:30 - 13:15 | Talk 2: Extension of periodic table and Search for Super Heavy Elements | Prof. B.S. Tomar |
| 13:15 - 14:00 | Lunch break | |
| 14:00 - 14:45 | Talk 3: Role of shell structure in Nuclear Physics | Prof. D.C. Biswas |
| 14:45 – 15:30 | Talk 4: Modified Bulk Substrate For Tera Hertz (THz) Sources and Detectors | Prof. S.S. Prabhu |
| 15:30 – 18:00 | Poster session by research students | |
| 16:30 - 1800 | Distribution of Participation Certificates | |