AN-400 keV VAN DE GRAAFF ACCELRATOR

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The most powerful tool for nuclear research is an accelerator which is a device for accelerating charged particles to high velocities. The beam of high velocity particles thus obtained is allowed to impinge on "Targets" consisting of other nuclei in bulk matter. All the bombarding particles lose energy gradually to the electrons in the target material, but occasionally one of them makes a direct collision with a target nucleus. Such a collision results either in a scattering of the incident particles or else in a nuclear transmutation in which case another kind of particle is emitted and a new nucleus remains in place of the original one. A study of these collisions helps us in learning something about the constitution and structure of the interacting nuclei.

1. The Van-de-Graaff Accelerator

The technique of bombarding nuclear targets with high velocity nuclear projectiles was first employed by Lord Rutherford who used the high energy alpha particles emitted from naturally radioactive substances and reported in 1919 the first nuclear transmutation involving conversion of nitrogen into oxygen by alpha bombardment. Early fifties witnessed the development of three different types of accelerators which provide controlled high energy particles for nuclear transmutations and related developments and discoveries. These incldue the Cockraft walton generator, the Van-de-Graaff generator, and the Cyclotron since then higher and higher energies have been achieved through these and other (e.g. linear accelerator, intersecting storage ring etc.) techniques. However all along the Van-de-Graaff accelerator has been one of the most valuable tools for nuclear studies mainly because of its precise energy control.

The first such accelerator going up to 1.5 MeV was invented by Prof. Robert J. Van-de-Graaff at Princeton university in 1931 and demonstrated a potential difference of more than one million volts between the terminals of two belt charged generators. The first such accelerator in India was installed in 1962 at the Bhabha Atomic Research Centre in Trombay with an energy of 5.5 MeV and the second with an energy of 2 MeV came at I.I.T., Kanpur. The model AN-400, is the first such machine at an Indian university (Banaras Hindu University, Varanasi and Panjabi University, Patiala). All these machines have been supplied and installed by High Voltage Engineering Corporation, U.S.A.

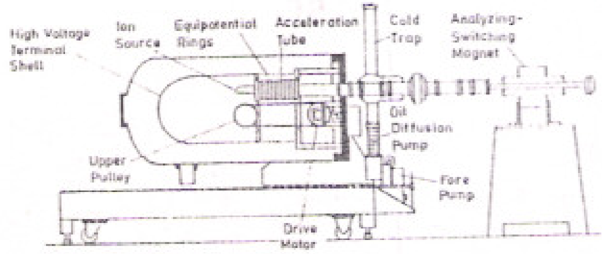
1.1 Principle of operation

The operation of a Van-de-Graaff positive ion accelerator involves three major steps: generation of a high d.c. potential; production and acceleration of positive ion beam; measurement and regulation of the ion beam energy.

The Van-de-Graaff accelerator operation can be explained in its essential outline as follows with reference to the schematic diagram shown in figure 1.

An insulating belt runs over two pulleys one in the high voltage terminal and the other at the base of the machine. Electric charges are sprayed into this rapidly moving belt and mechanically moved up to the top roller where they are removed from the belt thus charging up the insulated terminal at the top. The voltage of this top terminal can be controlled by resistors or corona discharge to reach the desired value. Between the terminal and the ground is placed the accelerating column, and the voltage gradient down both the charging belt and the accelerating column is kept constant by a set of metal rings supported by insulators. The structural parts of the Van-de-Graff accelerator are made up of material that can bear a fair amount of high voltage breakdown without being damaged.

Ions of various masses and charges emerge form the "Ion source" through a very small hole and are accelerated down the column, one of the important design considerations in a Van-de-Graaff generator is to supply enough pumping speed to keep high vacuum through out the accelerating column even in the presence of



Simplified Drawing of the Accelerator

considerable amount of gas streaming down from the ion source. Focusing of the ion beam before, during and after acceleration is also of utmost importance. Van-de-Graaff generator can accelerate any charged particle for nuclear physics work, protons and deutrons are ordinarily used, while for industrial purposes electrons are often used either directly or else to provide a source of high energy X-ray. The direct electron beam can be brought out of the accelerating tube through a thin foil and used for biological experiments.

2. Van-de-Graaff of Banaras Hindu University

The deparmtnet of Physics, Banars Hindu university has acquired this machine from High Voltage Engineering corporation, U.S.A. through U.S.A - India government $12 million loan scheme. The machine was installed in the year 1973 and it is still in operation and used for research as well as teaching.

The 400 kV Van-de-Graaff positive ion accelrator is horizontally mounted and is also provided with analysing and switching magnet and a scattering chamber. It produces an intense, well collimated beam of positive ions, homogenous in energy and has the following performance rating:

1. Accelerating Voltage 200 - 400 KV (commonly adjustable)
2. Beam Current 10 -150 micro Amps. (continuously adjustable)
3. Beam Diameter 1 cm maximum (for 90% of beam current) (at standard target distance)
   From this machine one can get pulse beam and has the following performance ratings:
4. Pulse Beam Current 10 - 100 micro Amps. Amplitude
5. Pulse Duration 10 - 20 micro seconds
6. Pulse Repetition Rate 1 - 10,000 pulse/second
7. Pulse Rise & Decay time 3 micro second maximum

The machine can be converted to work as an electron accelerator as well with standard components. Although the energy of the primary beam is limited to 400 keV only, this machine, through the use of appropriate nuclear reactions, can serve as the source of high energy neutrons (upto 16 MeV through T (d,n) reaction), protons (the reaction D(He$_3$,p) has a Q value of 18.34 MeV) and gamma rays. Particularly it can provide a high intensity (better than 10^{10} neutron/second) neutron beam.

(5) Ion-atom collision

The study of inner shell ionisation of atom due to charged particle impact is important in both the basic as well as applied fields. In the past few years, extensive work has been done regarding the K- shell ionization of atoms due to charged particle impact. L- shell ionization, on the other hand, is comparatively less studied specially in the low energy region. The proton induced L X-ray spectra of various atoms in energy range of 200 - 350 keV have been recorded[1].

This Van-de-Graaff accelerator has also been used for teaching and demonstration to M.Sc. (final), nuclear physics students. A few examples or topics of such M.Sc. project work are the following:

(i) Measurement of fast neutron flux produced through the T (d,n) reaction,

(ii) Accelerator system calibration,

(iii) Neutron-Proton mass difference, etc.

For details of the above M.Sc. experiments one may consult the book [2] entitled "Accelerator Nuclear Physics".

Reference

1) D.N. Tripathi, K.N. Pandey, L. Chaturvedi and D.K. Rai, Indian J. Phys. 69B (1995) 121-131.

2) William D. Bygrave, Paul A Treado, James M. Lambert "Accelerator Nuclear Physics" Fundamental Experiments with a Van-de-Graaff Accelerator. High Voltage Engineering Corporation Burlington, Massachusetts 01803, USA.