DEBIDAS BASU

(02 September 1917 – 18 August 2005)

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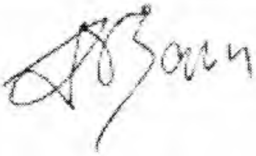

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(1917-2005)

Elected Fellow 1980

INTRODUCTION

Department of Theoretical Physics, Indian Association for The Cultivation of Science (IACS) started in 1950 with the joining of Professor Debidas Basu as Reader and Head of the Department. Professor Basu later became Professor of Theoretical Physics Department and continued in that capacity till 1969, when he assumed the post of the Director at the same Institute. Till the date of his retirement he remained at the post of Director of IACS. He was the founder Fellow of the West Bengal Academy of Science and Technology (FAScT).

Professor Debidas Basu was elected President, Asiatic Society of India in 1969 and was elected FNA in 1980. He was elected member of the Executive Committee of International Conference on the Physics of Electronic and Atomic Collision (affiliated to IUPUP). He was also the Vice-President, Indian Physical Society and Secretary, Indian Science Congress.

FAMILY BACKGROUND AND EDUCATIONAL CAREER

PROFESSOR DEBIDAS BASU, the Pioneer in the Atomic Physics research in India, was born on 2nd September 1917 in a very respectable family at Burdwan, West Bengal. The son of a reputed Advocate, he had his early education at the Town School of the same city. He was a very brilliant student throughout his career and passed Matriculation examination from the Calcutta University in the year 1931. During his study at the MSc in Physics from Calcutta University, he started research under Professor KC Kar on Advanced Acoustics and also on Nuclear Physics. During this period of MSc study he published papers on high energy Nuclear Scattering. After securing 1st Class in MSc in 1940 he joined Professor MN Saha as a Palit Scholar at Calcutta University and at the insistence of Professor Saha he went to Bangalore to work with Professor HJ Bhaba on Quantum Theory of Radiation. In 1946 he received a scholarship from Dublin Institute at the School of Theoretical Physics where he got opportunity to work with Professor Schrödinger, NL and Professor Hietler. He received his PhD degree from the Dublin University's Trinity College in the year 1948.

RESEARCH CAREER

After joining IACS, Calcutta in 1950, Basu started research in the Field Theory and Particle Physics. The first student to get PhD under him was SN Biswas on Particle Physics who consequently became one of the well known Particle Physicists in India. The Theoretical group at the IACS has pursued investigations on Scattering of Electrons by Atoms, Ion-atom Collisions, Scattering of Nucleons by Nuclei, Möller Scattering, weak interaction and elementary Particle Physics, beside Cosmic Radiation.

An attempt has been made through this short memoir to deal with Professor Basu's contribution in brief to various branches of Physics.

A number of different processes are possible when a positive ion beam passes through a gas. There may be elastic collisions in which the mutual kinetic energy of the colliding particles remain unchanged or inelastic collisions which include the possibilities of excitation or ionization either of the gas atom or of the incident ion. A further possibility is partial or full neutralization of the ion beam through electron capture. The electron capture may occur either in the ground state or in the higher excited states, while the residual target may be left in the ground state or it may get excited through the collisions.

With Professor MN Saha, Basu wanted to explain some spectral lines in the Solar Chromospheres. The occurrence of strong helium emission lines of neutral helium atom and the line of wave-length $\lambda 4686\text{Å}$ of ionized He^+ in the lower chromospheres was quite strange and could not be explained for long. At the temperature 6000°K-7000°K prevalent in the chromospheres, helium can exist only in the ground state and since none of its excited states are below 20eV all transitions from the ground level will produce absorption lines in the ultra-violet region and as such these lines will not be observed. The line $\lambda 4686\text{Å}$ of He^+ is more puzzling since this requires energy 75.25eV for ionization of helium atom followed by excitation of relevant level of He^+.

Basu assumed that high energy α-particles generated by nuclear process near the limb of the sun capture electrons some of them in excited orbits during their passage through the solar chromospheres. These electrons then jump down to lower orbits and emit the He^+ lines, the line $\lambda 4686\text{Å}$ is due to transitions from the orbits with n=4 to orbits n=3. Ionized helium atom thus formed captures another electron into an excited orbit of helium atom and subsequent transition of the electron to a lower orbit gives line of the normal helium atom. With this motivation Basu undertook quantum mechanical calculations to determine the cross-sections of electron capture into 2p orbits by α-particles from the ground state of hydrogen atom and this work was the beginning of Atomic Collision research in India. The Atomic Collision Research group at IACS subsequently achieved international recognition under the leadership of Professor Basu. Eminent Physicists like Professor NC Sil, Professor DP Sural, Professor AS Ghosh, Professor S Sarkar, Professor SC Mukherjee and many others worked in this group.

ION-ATOM COLLISIONS

When the relative velocity between the colliding system is large compared to the orbital velocity of the active electrons, the method of Born approximation or Glauber approximation has been used to calculate capture cross-sections into an arbitrary state characterized by the quantum numbers by ions from hydrogen atoms in the ground state.

The process of excitation and capture of an electron in a collision between a heavy ion and an atom is often treated as a one body problem viz. that of an electron in the coulomb field of two centres with the condition that initially the electron is attached to one of the nuclei in the ground state and finally the electron is excited or is captured by the other nucleus. This approximation is possible because the masses of the ion and the atomic nucleus are much heavier compared to that of the electrons. The relative velocity between the two nuclei may be taken as constant except when the incident energy is very small. This is known as the impact parameter treatment.

A variational method, particularly suitable for studying charge transfer processes has been developed. In this method the time dependent total wave function for a system like $(A^+B^+e^-)$ is expanded in terms of the Eigen functions of the system (A^+e^-) and (B^+e^-). The differential equations satisfied by the coefficients of the expansion are obtained by making stationary a variational integral with respect to small arbitrary variations of the coefficients. This method has been extensively applied to study a number of ion-atom collision processes. The calculation of electron capture by protons from atomic hydrogen is extended for higher incident energies by including the effect of the translatory motion of the electron.

One of the important experimental observations in connection with the electron capture process is that at a fixed angle of scattering the capture probability when plotted against the reciprocal of the proton velocity reveals an oscillatory structure with maxima and minima. By applying the theoretical method discussed above it has been possible to reproduce the structure. This problem of electron capture in H^+-H collision at 3° scattering angle has been investigated by the method of molecular state expansion and considering the lowest symmetric and anti-symmetric state of H_2^+.

The impact parameter formulation with a two state approximation has also been used for studying the process of electron capture by proton from molecular hydrogen.

The problem of electron capture by alpha particles passing through hydrogen atom has also been investigated. This problem has special interest as it provides an example of asymmetrical resonance. The calculation of the capture probability for this problem has been made by taking into account all the mutual couplings of the 1s state of the hydrogen atom, the 1s, 2s, $2p_0$ and $2p_{\pm 1}$ states of the ionized helium atom. The number of peaks and valleys obtained theoretically in the capture probability versus incident energy curve is the same as that obtained experimentally. A method based on the technique of Fourier Transform has been developed to incorporate the effect of momentum transfer in the electron capture process. Calculations for the cross-sections of the double electron capture for alpha particle passing through helium have been made using an atomic state expansion. The results are in good agreement with the perturbed stationary state calculations based on molecular state expansion. An investigation has also been made on the He^+- He collision problem, which is complicated due to the presence of three active electrons in the system and is particularly interesting because of the possibilities of excitation of the helium atom to the triplet states by a process of electron exchange and capture into triplet states of helium. It is found that the cross-sections for excitation to and capture into the same state (2^1S, 2^3S) are nearly equal. The process of formation of H^-, as a result of double electron capture by proton from helium atom in which the three travelling atomic orbitals are retained has been studied. The ionization cross-sections of the high energy proton impact on hydrogen atom have also been calculated. For the continuum state wave function of the ejected electrons, the effect of both the nuclei is taken into account.

The Faddeev formalism suitable for three body systems has been modified to study H^+-H collision problem. The effect of 2s state and the proton-proton interaction terms have been incorporated in the calculation and the results obtained are in good agreement with the experimental observations.

An integral form of the close coupling approximation has been developed for application to the scattering of electrons and protons by atoms. This approximation has been applied to study the electron capture process: $H^+ + He \rightarrow H + He^+$.

ELECTRON-ATOM COLLISION

The elastic cross-sections for the scattering of electrons by heavy atoms like Argon, Krypton, Xenon, Mercury and Gold have been calculated. The potential of the target atom as seen by the incident electron is based on the Thomas-Fermi model. Simultaneously, relativistic effects on electron-atom scattering at very high energies have also been calculated retaining up to the second order terms in the Born series. The effect of exchange which is not taken into account by the Born approximation may be included in the first order perturbation method through Born-Oppenhiemer approximation. The effect of polarization of the target atom is very important at low and intermediate energy. In the case of alkali atoms this effect is very dominant. The phase-shift for the electron-cesium atom collision has been calculated using the BKW method in which the effect of the dipole polarization potential is included. In the low energy region, a variational method has been used to investigate the low energy electron-helium collision. The exchange effect has been included explicitly by anti-symmetrizing the total wave function of the system. In another attempt the effect of polarization has been included through an extra dipole potential.

A modified form of the Eikonal approximation which is the basis of the Glauber model of multiple scattering has been applied to hydrogen, helium, lithium and sodium atoms as the target. The results are in good agreement with the experimental data at intermediate and high energies. An integral form of the close coupling approximation in the momentum space which has some definite advantages over the conventional integro-differential approach has also been developed.

A formulation for handling the three body problem in the exact manner was suggested by Faddeev. However, one cannot solve the Faddeev equations exactly with the known mathematical techniques. An approximate and simplified form which satisfies the unitarity and is also able to include the effects of coupling to all physical states has been developed. The effect of exchange has also been included through the proper anti-symmetrization of the wave function. The modified form of the Eikonal approximation has also been employed to investigate the positron scattering by hydrogen, helium, lithium and sodium atoms. For positron-helium scattering the results are in closed agreement with observed findings below the positronium-formation.

The formation of positronium (e^+e^-) and positronium negative ion ($e^-e^+e^-$) in positron-hydrogen molecule collisions has also been investigated in the Born approximation. The problem is complicated because of the presence of two centres in the hydrogen molecule and dependence of the cross-sections on the orientation of the inter-molecular axis.

ELEMENTARY PARTICLE PHYSICS

To explain the forces operating within the nucleus, Yukawa postulated the existence of mesons, which play the same role as photon does in quantum electrodynamics. Unlike photon, meson has a rest mass and the spin of π-meson is zero. It was later observed that when a nucleus disintegrated a bewildering variety of short lived particles which apparently do not exist within the atoms of ordinary materials, was created. Some of these particles could not be properly characterized and were called 'strange' particles. The new particles along with neutrons, protons and p ions are now called hadrons (strongly interacting particles). A classification scheme for them was first proposed by Gell-Mann and Nishijiama and further, many of them were grouped together on the basis of their spin and parity assignments and those were put in the irreducible representations of SU (3) group, which gave interesting theoretical predictions; some of them were verified later experimentally.

(a) Nucleon Scattering

In the theory of nucleon-nucleon scattering, the symmetrical Möller-Rosenfield (MR) interaction has the special advantage that by eliminating the $1/r^2$ singularity it admits of a solution of the Schrödinger equation for the deuteron problem which fixes uniquely the two constants of the MR interaction. The third constant involves the mass of the □-meson that generates the field. The three constants of the MR interaction being thus fixed, it has been found that the theoretical values of the total scattering cross-sections agree reasonably well with the experimental findings of neutron-proton scattering at 280MeV neutron energy, provided the influence of radiation is properly taken into account.

The cross-sections for the reactions $p+p \rightleftharpoons \pi^{+}+d$ decide that the π-meson which is responsible for the nuclear force has spin value zero: other experiments indicate that the π-meson probably obeys the pseudo-scalar field equations. The pseudo-vector interaction of the pseudo-scalar meson field is characterized by prominence of the tensor force which does not exist (in the non-relativistic limit) in the MR interaction; it is interesting to see to what extent the pseudo-scalar meson field is capable of explaining the angular distribution of the neutrons scattered by protons both in the low and high energy regions. In the low energy region the theoretical results calculated in the non-relativistic approximation has been compared with the experimental values of the neutron-proton scattering at 90MeV energy and it has been concluded that a reasonable though not quite satisfactory approach to the experimental values is obtained if Serber's charge combination is introduced in place of the charge symmetric theory and further the interaction in the momentum representation is so chosen that the static potential in the coordinate system is free from δ-function. This problem has been further investigated making relativistic calculations with second order matrix elements.

The high energy proton-proton scattering shows an angular isotropy. None of the mesonic interaction as derived from the field theoretical considerations can explain this phenomenon. The relative importance of the different components of the pseudo-scalar interaction in relation to their contributions to the value of the differential cross-sections has been studied. The results indicate that it is not possible to explain in a simple manner the angular isotropy of the proton-proton scattering at high energies of the various proposed phenomenological potentials between two nucleons the 'hard Core' potential model of Jastraw which gives the isotropic scattering, yields better agreement with experimental observation than any other, though on theoretical grounds it has not been possible to justify the existence of a 'hard Core' in the case of the singlet states. It has been suggested that the δ-function potential which occurs naturally in the field theoretical interaction may be regarded as the analogue of the 'hard Core' potential which Jastraw assumes adhoc in the singlet state only. It is shown that the inclusion of the δ-function term in the pseudo-scalar interaction helps to explain the isotropy of scattering of one nucleon by another and the fact that the scattering cross-section is independent of the incident particle. It has been observed that if the differential cross-section for the p-p scattering is calculated with the tensor part of the pseudo-scalar interaction, it agrees reasonably well with the experimental data at 340MeV. Further, the tensor force alone explains qualitatively the independence of the scattering cross-section with the energies of the incident particles. However, the tensor force term does not give any scattering of the singlet state. The relative contributions of the different parts of the tensor force have been considered and it has been found that the interaction potential term which contains $1/r^3$ singularity shows at high energies a better tendency towards qualitative isotropy than due to other terms. Moreover, it is found that the tensor force term of pseudo-scalar interaction which involves the sum of $1/r$, $1/r^2$ and $1/r^3$ singularities gives better agreement with the experimental results at 340MeV than what has been obtained with $1/r^3$ term alone.

Polarization studies of the colliding particles and the emitted photons in the Bremstrahlung and Möller scattering have also been carried out. The differential cross-section of the collision between a longitudinally polarized electron and a nucleon polarized in the same or opposite direction has been investigated. Investigations have also been made for the circular polarization of Bremstrahlung for the cases, (i) when only the target proton is polarized and (ii) when only the electron is polarized. It is found that in the high energy limit the scattering is minimum or maximum when the longitudinal polarizations of initial electrons are in the same sense or in the opposite sense.

(b) Nuclear Physics

In nuclear physics, investigations have been made on the phenomenon of α-decay, scattering of nucleons and electrons by nuclei and nuclear bound state problems.

The study of α-radioactivity has played an important role in identification and classification of nuclear levels for the heavy nuclei. A systematic study of the α-ray spectra of different elements has been undertaken. The study brings out the fact that in α-ray spectra there exists both positive and negative trends in the $\log\lambda$ versus E relation. These negative trends run counter to the α-decay theories of Gamow and others and the discrepancy factor, λ theo/λ obs, is shown to be in general, of the order of 10^3 which in some cases it exceeds 10^{13}. The analysis suggests that λ should depend on another parameter apart from the energy E, nuclear radius (r_o) and charge(Z). A method of calculation of the penetration probability of alpha particles, through a potential barrier with Woods-Saxon type nuclear field has been given for arbitrary value of the angular momentum of the emitted alpha particles. Among the various models that are used for an approximate description of the situation in nuclear physics, the optical model has been quite successful, in that it combines the essential features of both the independent particle and the compound nucleus models. The optical model applied to obtain results for the scattering of low as well as high energy nucleons by nuclei. Proton-nucleus scattering has been studied in the Born approximation with nuclear potential of Woods-Saxon form along with a Coulomb part arising from the uniform charge distribution of the nucleus. For high energies the spin orbit interaction has been considered.

Cosmic Radiation

The cosmic ray consists of a variety of elementary particles. Its impact on different earthly materials produces several elementary particles and their study yields valuable information on nuclear forces. The knowledge of cosmic ray flux in space is also important in space research.

Hadronic Phenomenology

Professor Basu also started some investigations on high energy hadronic phenomenology using some semi empirical models. The CERN ISR and LBL BEVALAC high energy interaction results have been used for modeling. Bose type distribution was proposed for charged particle distribution in pp, pi-p, K-p and antiproton-proton interactions. The multiplicity distribution was found to obey KNO scaling.

Astroparticle Physics

Various high energy accelerator results on pp, pi-p, K-p and antiproton-proton interactions have been analysed to predict new scaling model. Several secondary cosmic particles like, p, pions, kaons and antiproton spectra have been derived. A new type of scaling model was obtained from the fitted data available from BEVALAC. The sea-level muon energy spectrum and primary cosmic spectrum available from Goddard Space Flight measured results have been used as input. It was found that the energy spectrum of sea level muons depends explicitly on the average value of Feynman variable x, whose most probable value is estimated and found to be 0.18.

RETIREMENT DAYS

After the retirement from service on 31st August 1980, Professor Basu started taking active interest on Science and Philosophy and delivered talks on this subject at various august gathering. Professor Basu used to keep very good and cordial relations with his students and colleagues. The staffs and scholars of the institute (IACS) have tremendous regards for him. He had great likings for many subjects other than physics. He used to take special interests for paintings and contemporary arts. He wrote a few articles on analysis of paintings published from Kolkata. Though he was a bachelor, he built a big house at Santoshpur, in the southern fringe of Kolkata. He had a plan to make an Institute of Theoretical Physics in that house. But unfortunately, his death came so sudden that his plan could not be materialized. Professor Basu passed away on 18th August 2005, at the age of 88 years.

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SUNIL CHANDRA MUKHERJEE
Formerly Senior Professor in Theoretical Physics
Indian Association for Cultivation of Science
Jadavpur, Kolkata-700032 (WB)
Phone (Res.): (033) 24713926
Mobile: (0)9433467825
E-mail: s.c.mukherjee@gmail.com; sunil@europe.com

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