Shyamadas Chatterjee

Experimenter Par Excellence!

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Shyamadas Chatterjee was a versatile experimental physicist who followed the tradition of instrument building set up by the pioneers of modern science in India. He was successful in initiating research in many diverse fields in the country with very modest resources.

Introduction

The beginnings of the modern scientific explorations that started in the late nineteen hundreds in Kolkata were characterised by an emphasis on experimental investigations with instruments designed and fabricated locally by pioneers like Acharya Jagadish Chandra Bose [1], Acharya Prafulla Chandra Ray [2], and Sir Chandrasekhar Venkata Raman [3]. This tradition was kept alive by those who immediately followed them, notably Debendra Mohan Bose and his student Shyamadas Chatterjee, first at the University of Calcutta and then at the Bose Institute.

Shyamadas was born on 29 June 1909 in a well-to-do family at Sarsuna, a suburb of Kolkata. He did his schooling in Kolkata, Hazaribagh and Cuttack as his father had a transferable job. He passed his MSc from University College of Science, University of Calcutta in 1932 and joined D M Bose for research at the University.

Early Work

Initially, Shyamadas studied properties of matter, the variation of viscosity and the dielectric constant of liquids under varying electric and magnetic fields. He built most of the instruments himself out of his fellowship money. In 1938, he followed D M Bose to Bose Institute as the senior research fellow. There, he constructed an improved version of the Wilson cloud chamber.

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He even dabbled in chemistry with Priyada Ranjan Ray and Dilip Kumar Banerjee, who became famous chemists on their own.

At the Bose Institute, he started a study of experimental radioactivity and learned the art of making Geiger–Muller counters from Radheshyam Ghosh, who had just returned from Germany after working with Geiger and made GM counters of various sizes and also proportional counters[1]. He used his personal funds for the wires and quench gases that he needed for making these counters. He was versatile and adept at all the techniques of instrumentations, viz., vacuum, glass blowing, machine shop work, electronics, coil winding for magnets, etc.

[1] Proportional counters are gaseous counters similar in construction to GM counters. The value of high voltage required for their operation is lower than for GM counters. They can not only detect ionizing particles but can also measure their energy.

Fission Studies

As the news of the discovery of fission reached Kolkata in 1939, Shyamadas immediately set up an experiment to detect fission and to study neutron-induced reactions in other elements. To pursue studies on fission, he purchased 5 g of U metal with his own money and used an RaBe source for neutrons. He observed fission events using the GM counters he had already made connected to an oscilloscope and took great pleasure in demonstrating these to his seniors and visitors at the Bose Institute.

Continuing his studies on the fission of U, he found that some fission pulses kept getting recorded in his oscilloscope even when the RaBe source was far removed from the vicinity. The results puzzled him and he consulted Satyendranath Bose, who suggested the possibility of cosmic neutrons triggering the fission events. Shyamadas shielded his chambers and the U target thoroughly with Pb and Cd, but even then large fission pulses could be seen at the same rate as before. On learning about this result, S N Bose suggested that perhaps U was fissioning spontaneously. Shyamadas continued his experiments to collect more events so as to make a determination of the lifetime for this mode of decay of U. The value of the lifetime for spontaneous fission turned out to be $\sim 10^{16}$ years, smaller by a factor of 10^6 than the theoretical value of 10^{22} years predicted by the Bohr–Wheeler theory of

fission. Encouraged by S N Bose, Shyamadas submitted a letter to the editor of the journal *Science and Culture*. His thesis supervisor, D M Bose, who was also the editor of *Science and Culture*, was away at Darjeeling at that time and on his return, he made Shyamadas withdraw the letter, as he perhaps felt that such a large discrepancy in the experimental observation with the theoretical value needed further investigations. (This sequence of events was recounted by Shyamadas Chatterjee himself to several of his associates and students [4]). About two months after this event, the discovery of spontaneous fission by G Flerov and K A Petrjak from Russia was announced via the following cable, published in the journal, *Physical Review*[2]:

[2] *Physical Review*, Vol.58, p.89, 1940.

"With 15 plates ionization chambers adjusted for detection of uranium fission products, we observed 6 pulses per hour which we ascribe to spontaneous fission of uranium. A series of control experiments seem to exclude other possible explanations. Energy of pulses and absorption properties coincide with fission products of uranium bombarded by neutrons. No pulses were found with U and Th. Mean lifetime of uranium follows ten to sixteen or seventeen years."

Shyamadas continued to study spontaneous fission of uranium to measure the lifetime of the decay with better precision. He found the value 1.3×10^{16} years as the half-life, which is quite close to the value of 8.4×10^{15} years accepted now, using a new method for detecting the fission pulses. He published his findings in an article in *Science and Culture* in 1944[3]. He used the counters made by him and operated them in the proportional mode that led to the counters being more stable and could record the events over long periods of time without continuous monitoring. Further, he was successful in detecting emission of neutrons from spontaneous fission of uranium and these results were published in articles in *Science and Culture* and *Indian Journal of Physics* during 1944–45. It is important to note that this result was published before the results of G Scharff–Goldhaber and G S Klaiber in USA were known, as their result appeared in *Physical Review* in 1946, in which it is mentioned by the editor that their submission

[3] See this paper reproduced in the Classics section in this issue on page 856.

to *Physical Review* in 1942 was voluntarily withheld during the World War II. Shyamadas submitted his thesis on this subject and was awarded the DSc degree of Calcutta University in 1945. A comprehensive account of this work was published in the *Transactions* of Bose Institute in 1946 (*Figure* 1) [5].

Figure 1. Ionization chamber built by Shyamadas Chatterjee for detection of spontaneous fission of uranium.

Cosmic Rays

Another area of study which interested Shyamadas during this period at Bose Institute was the study of cosmic rays at sea level as well as at the high altitude station of the Bose Institute at Darjeeling. He measured the distribution of atmospheric neutrons at different altitudes, the influence of solar flare on cosmic ray intensity, large cosmic ray bursts and the production of penetrating showers in Pb and Fe. During 1949–51, Shyamadas went to Ottawa on receiving a post-doctoral fellowship of the National Research Council of Canada. He continued his work on the ionizing power of cosmic rays at sea level and diurnal variations in cosmic ray intensity as well as the measurements of possibilities of spontaneous fission in other nuclei, emission of neutrons in reactions induced by deuterons. He also built instruments like the circular GM counter for his own experiments as well as for others in Canada and USA. This was very much appreciated by his peers as seen in the cable received by him from Merle Tuve, then director of the Institute of Terrestrial Magnetism, Carnegie Institution, USA on the eve of his departure from USA in 1951: "We greatly appreciate the splendid counters you made in record time. We will always remember your magnificent spirit of selfless cooperation and hope we can reciprocate...".

Radiocarbon Dating

In 1954, Shyamadas pioneered the setting up of the first radiocarbon dating laboratory in India at Science College, University of Calcutta. He had visited the radiocarbon dating laboratory at Heidelberg, Germany and got a design of the glass apparatus from Heidelberg that was used for the conversion and purification of the sample to gaseous form for analysis. With his setup, he successfully dated archaeological samples from Pandu Rajar

Dhibi at Burdwan, West Bengal and showed them to be belonging to the Chalcolithic habitation in that region during 1100–1000 BC. He also dated samples from the ramparts of ancient Pataliputra. He also got the samples crosschecked by Henrik Tauber at the Copenhagen radiocarbon dating facility. His versatility can be gauged from the fact that at that time he also investigated the properties of electret-forming materials and metal semiconductor contacts with other colleagues. In this process, he trained a band of young experimentalists who carried on his legacy.

Hot Springs

Shyamadas got the inspiration to study radon and helium emanations at Bakreswar hot springs, from S N Bose who was asked by then chief minister of West Bengal B C Roy to investigate the hot spring. Shayamadas, with his group, went to Bakreswar with his counters braving the hazardous journey from Kolkata and found that the gas emanating from the hot spring contained copious amounts of radon and the water also had dissolved radon. Shyamadas knew that radon was a decay product of radium in the uranium decay chain and hence, helium would also be present as an end product of the decay series. He wanted to evaluate the concentration of helium in the gas he had brought from Bakreswar and in this he got help from Merle Tuve in the form of drawings and details of the apparatus for measurement of helium. The method used the adsorptive property of activated coconut charcoal at liquid nitrogen temperature and then measuring the volume of helium released on warming up. He got the equipment built in his laboratory at Science College (*Figure* 2). This was the first equipment to be built in India for measurement of helium content in a mixture of gases. With this, he determined the He content of the gas sample from Bakreswar to be 1.8 volume percent and this was reported in *Science and Culture*. His team continued the measurements of relative abundance of rare elements from emanations from different thermal springs in India, searching for the origins of such emanations. His experimental station at Bakreswar was later taken over by the Department of

Figure 2. Shyamadas Chatterjee measuring radon contents using electroscope built by him.
Courtesy: Debashis Ghose

Atomic Energy and efforts to extract helium from the thermal spring were successful.

A special underground laboratory was made for cosmic ray research as well as a radiocarbon dating facility.

At Jadavpur University

Shyamadas moved to Jadavpur University as the first Head of the Department of Physics in 1956. With his usual zeal, he got busy in setting up the laboratories. A special underground laboratory was made for cosmic ray research as well as a radiocarbon dating facility. He got a machine tool workshop, a glass blowing workshop, electronics shop and other facilities for fabrication of precision instruments. He also took keen interest in modernising the undergraduate and post-graduate curriculum and donated many instruments from his personal collection to the post-graduate laboratory for use of the students.

Shyamadas continued the measurements of cosmic rays and radon concentrations in the atmosphere and in rain water and in different minerals. Some of his findings were published in the journal *Nature*. During the atmospheric tests of atomic bombs and hydrogen bombs in the early 1960s, he used his equipment to measure the composition and identify components of radioactive fall-out over Kolkata. Along with these, he continued his efforts to improve the performance of Geiger counters through detailed investigations on the nature of pulse formation. He also laid the foundation for work on condensed matter physics at Jadavpur University through his studies on magneto-electret materials, micro- and poly- crystalline materials, semiconductor surfaces and metal-semiconductor contacts. During this period, he was a Visiting Professor at the Technical University, Munich, Germany during 1963–66.

Shyamadas retired from Jadavpur University in 1967 and moved to the Indian Association of Cultivation of Science. He remained active in research and continued the measurements of environmental radioactivity and detailed study of isotopic abundances of gases emanating from thermal springs. He also pursued his scientific interests in his personal laboratory that he set up in his own house. It was run by the S D Chatterjee Foundation, which he set

up and to which he bequeathed all his instruments. He was elected a Fellow of the Indian National Science Academy in the year 1955.

Shyamadas Chatterjee was truly an innovator and initiated research in many fields in India throughout his lifelong passion for science. He pioneered the measurement of environmental radioactivity and radiocarbon dating in India and also introduced study of fission phenomena in India. It is indeed remarkable that for each of these studies, he used instruments designed and built in his laboratory. He was a master instrument builder in the tradition of Acharya Jagadish Chandra Bose, a tradition that we seem to have forgotten today.

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Suggested Reading

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