Irving Langmuir - a pioneering industrial physical chemist

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Dr. Irving Langmuir - a U.S. industrial physical chemist working in early 1900s was the pioneer of fundamental research in industrial environment. He was the first scientist to show how fundamental research can improve the quality of products and thus increase profits for industrial enterprises.

More than that Dr. Langmuir was an experimentalist par excellence and in the same league as Michael Faraday, Thomas Edison etc. The scope and breadth of his inventions are breathtaking and include discoveries of atomic hydrogen, atomic hydrogen welding, surface chemistry (he is the father of surface science), thermionics, fundamental studies in high temperature heat transfer, gas-filled incandescent light bulbs, plasma physics (he coined the word plasma), high vacuum pumps, smoke generators and cloud seeding among others. He also made tremendous contributions to music recording, submarine detection and weather modification. He received the Nobel Prize in Chemistry in 1932 for surface science and was the first industrial scientist to receive such an honor.

In fact all his discoveries led to new areas of research both applied and fundamental with their effects being felt even today. Though Thomas Edison is the father of light bulb, it was Langmuir's work which made it possible to produce an extremely efficient, long lasting and cheap light bulb that we know today. Thus Irving Langmuir can easily be called the father of modern lighting. Similarly the pioneering work of Linus Pauling on the nature of chemical bond was completely inspired by Langmuir's papers in 1920s in which he had introduced the concepts of electrovalency and covalency.

Early Years

Irving Langmuir was born on 31 July 1881 in New York to Charles and Sadie Langmuir. He had 3 brothers and since his father was in insurance business which took him frequently to Europe, he traveled extensively on the continent with his parents. From an early age his

parents encouraged him to be a careful observer of nature and to keep detailed records of these observations. This practice he continued all his life and kept detailed diaries of his work. At the age of 11 when his poor eyesight was detected and rectified, a whole new world opened for him and his life-long delight in observing the minutiae of nature dates from this time.

Irving Langmuir's early education took place in schools both in Europe and U.S. In 1903 at the age of 22 he graduated in metallurgical engineering from Columbia University. This engineering training was very useful to him later on in his scientific work. Langmuir was greatly influenced by his older brother Arthur who helped him set up a chemistry lab in his room and kindled in him a love of science. Langmuir loved chemistry and this love of chemistry made him do a Ph.D. in this subject in Germany. In early 1900s Germany was in the forefront of research in basic sciences and it was but natural that Irving Langmuir should study in the best universities there. He chose Gottingen University because of its strong emphasis on science and mathematics and did his Ph.D. in 1906 under Walther Nernst-a future Nobel Laureate. This decision to work under Nernst was a fortunate one because Langmuir learned both theory and experimental work which later on became the foundation of his career.

After finishing his Ph.D. Irving Langmuir joined Stevens Institute of Technology for research and teaching. However his 3 years at Stevens were extremely frustrating as he could neither do proper research nor was the quality of students such as to make him enthusiastic about teaching.

In 1909 Langmuir spent a summer vacation doing research at the General Electric (GE) Company in Schenectady, New York. The visionary director of GE research labs Dr. Willis Whitney saw the potential of Langmuir and persuaded him to join GE. Whitney offered him freedom and funds to do basic research, and after looking at the capabilities of GE's fabrication facilities Langmuir easily consented. Thus in 1909 started a remarkable career of Langmuir at GE which lasted till 1950 when he retired. Till his death in 1957 Langmuir remained as a consultant to GE.

GE Years

Irving Langmuir started his GE research as an extension of his Ph.D. work which was on the dissociation of gases in low pressure atmosphere near high temperature filament. GE at that time was trying to manufacture electric light bulbs but these bulbs with tungsten filament would easily burn out in short time. Besides the glass would blacken and nobody had a clue to what was happening.

Right from Thomas Edison downwards everybody had claimed that if a perfect vacuum is produced within the bulb then it will last for a long time. However Langmuir quickly understood that vacuum is not the solution but something else must be happening. So in a remarkable series of simple experiments he found out that residual water which was coming out of glass bulb was dissociating into hydrogen and oxygen near high temperature tungsten filament which in turn dissociated the hydrogen molecule into hydrogen atoms. These extremely reactive hydrogen atoms embrittled the tungsten which easily disintegrated and the tungsten atoms evaporated and deposited on the glass thereby blackening it. His research showed that filling the bulb with a non-reacting gas like argon could solve all the problems and this was the advent of the modern electric light bulb.

These experiments which lasted for 8-9 years led Langmuir to develop very high vacuum pumps, produce atomic hydrogen and laid the foundation of surface science since the adsorption of hydrogen at the glass surface was first discovered in these experiments. He also developed atomic hydrogen welding process which has since been developed into tungsten arc welding.

With his work on incandescent light bulbs, Langmuir also started looking at other phenomena like electric discharges in gases and under high vacuum. Thus he developed very thoroughly the whole field of thermionics and introduced the concept of “space charge” which limits the flow of electrons from emitter. This led to his work on plasma (a word he coined) physics. He also introduced the concept of electron temperature and invented the diagnostic method of measuring both the temperature and density of plasma with an electrostatic probe now called Langmuir probe and commonly used in plasma research. His work on plasma research paved way for the developments in electron physics, astrophysics and thermonuclear fusion.

But the research that earned Langmuir the Nobel Prize in 1932 was in the field of surface chemistry. In a series of experiments done with the help of his colleague Dr. Katherine B. Blodgett, Langmuir studied thin films and how substances are adsorbed on the surface. The studies led to clarification of the true nature of surface adsorption and established the existence of monolayers. Monolayers are surface films of single atom or molecule thickness which have peculiar, two-dimensional qualities. Thin layers on surfaces such as living membranes are important in the action of enzymes, toxins, antitoxins and other biological substances. This discovery led to the possibility of measuring molecular sizes of viruses and toxins, a significant step forward in the eyes of biologists. Langmuir also developed experimental techniques for the study of proteins. The studies on monolayers also led to the development of almost perfectly transparent and non reflecting glass made by placing a thin film of a fluorine compound on the surface. His work on monolayers also led to their use for suppressing the evaporation of water from lakes and ponds and led to tremendous water savings from such bodies.

Dr. Langmuir was also involved in the war efforts both during the first and second world war. In the First World War he worked on submarine detection systems which led him to the work on enhancement of the quality of musical recording. Thus he collaborated on music recording with the famous conductor Leopold Stokowski. This was also an outcome of lifelong love of classical music that Langmuir had. During Second World War he developed smoke generators so that ground troops and equipment could be protected from air raids. Similarly his work on de-icing of air craft wings led him to the pioneering research on cloud seeding. Together with his GE colleague Vincent Schaefer, Langmuir developed the theory and did large-scale experiments on rain-making using dry ice pellets and silver iodide. On many experiments on rain making Langmuir flew his own plane. This research in weather modifications led to tremendous controversy during the early 1950s. Nevertheless cloud seeding is today an established process for rain creation during drought conditions.

“Science as fun”, was one of Langmuir’s cardinal tenets. In his later years he always said that everything that he did was for the fun of it. That fun nevertheless was generously provided and financed by the visionary GE director Dr. Whitney.

To my mind one of the greatest achievements of Langmuir - Whitney partnership at GE was the development of concept of fundamental research in an industry for the benefit of

mankind. Before Langmuir, Thomas Edison had done industrial R&D but it was of "trial and error" type. Langmuir was the first industrial scientist to bring in the rigor of deep scientific methods to development of useful devices. Fundamental research in industrial environment was therefore successfully pioneered at GE. As a consequence of this success, other corporations and government agencies started investing huge funds in basic research. This was therefore the forerunner of Bell Labs, Xerox Parc and now Google research labs. Irving Langmuir was the first industrial scientist to get the Nobel Prize. Since then quite a number of scientists working in Bell Labs, IBM and other industrial enterprises have won it.

Irving Langmuir's inventions were characterized by tremendous simplicity of experiments. Thus all his discoveries regarding surface science, atomic hydrogen, high vacuum pumps and plasma came from a humble incandescent light bulb. Similarly his pioneering work on liquid surface films came from a simple trough now called Langmuir-Blodgett trough. So did the pioneering work on cloud physics, which led to the understanding of vapor condensation and ice formation in clouds, was done in a home refrigerator. Simple experiments, with tremendously powerful brain to extract maximum information from them, together with the application of sophisticated science and mathematics were the hallmark of Langmuir's discoveries.

A classical example of a simple experiment is the paper on the speed of deerfly that Langmuir published in 1938 in the journal Science. An entomologist had estimated that the deerfly traveled at nearly 1200 km/hr since it appeared as a blur when traveling. In remarkable order of magnitude calculations and a simple string and mass experiment Langmuir showed that at 40 km/hr the fly became a blur and at 60 km/hr it simply vanished! This paper of Langmuir was typical of his desire to rectify any sloppiness in reporting about natural phenomena. For a Nobel Laureate to write a simple article with the back of envelope calculations required a great courage and guts but to Langmuir the most fundamental scientific discoveries and simple facets of nature were equally important.

Langmuir as a person

Dr. Langmuir was a very gregarious person. He loved company of intelligent men and those who loved outdoors. Thus he had life long friendships with science luminaries

like Lord Rutherford, Neils Bohr, etc. and his co workers at GE who were enthusiastic about outdoor activities.

Dennis Gabor - another close friend and the father of holography who got the Nobel Prize in 1971 called Langmuir as the most harmonious of human spirits. He wrote that Langmuir was the sanest and the most well-adjusted genius he had ever seen. Vincent Schaefer-his colleague at GE and the inventor of cloud seeding recalled that Langmuir was happiest when teaching youngsters and always loved to be surrounded by school children whom he presented with intellectual and physical challenges.

Throughout his long and active life Langmuir maintained a great youthful love for outdoors. He once hiked 52 miles in a single day and climbed the Matterhorn Mountain in Europe with little preparation when he was 40 years of age. Besides he was an expert skier, skater and sailor. He learnt to fly and got his pilot license at the age of 50 in 1930 when civil aviation was just coming up. He was also a great friend of Charles Lindbergh. His curiosity for nature knew no bounds and lot of his inventions came out of his curiosity and desire to find out the underlying causes. For example, after observing windrows of drifting seaweed in the Sargasso Sea he discovered a wind driven surface circulation in the sea which is now called the Langmuir circulation.

Anything that Langmuir did was done with great passion and with his inexhaustible energy and very sharp mind nature revealed her secrets to him. His concentration was legendary and quite often he would be called an absent-minded professor since he would be completely absorbed in thinking about a problem. An example of this was in 1931 at the age of 50 he took his nephew to observe bubble formation in water holes on a frozen lake. They laid flat on their stomachs on the ice bed watching the bubbles come up in the water hole. His nephew recalled later on “I was about fifteen at that time and though his intense interest communicated to me, the ice was mighty cold to lie on. I got up but uncle Irving was impervious to the cold or too absorbed to notice it and he just lay there watching with the magnifying glass those bubbles until he was all watched out!”

Langmuir had 229 publications and 63 patents to his credit. Besides the Nobel prize he received 21 medals and awards from the most prestigious societies and academies of the world. He also received honorary doctorate degrees (total of 15) from some of the most

prestigious universities like Harvard, Oxford, Princeton etc. He was nominated Man of the Year by TIME magazine in 1932 and was on the cover of TIME and many other magazines. He died on August 16, 1957 in Woods Hole, Massachusetts, USA after a series of heart attacks. He was survived by his wife Marian (whom he married in 1912) and a son and daughter (both adopted).

Posthumously he was honored by naming the Atmospheric Research Lab in New Mexico after him. His house in Schenectady was declared a National Historic Landmark in 1976. American Chemical Society journal for surface science is called Langmuir and it has also instituted an award in his name. A mountain in Alaska is named Langmuir to honor his life long interest in mountain climbing and skiing.

Suggested reading

1. "Langmuir, the man and the scientist", Vol. 12, Collected Works of Irving Langmuir, (Ed. C. Guy Suits), Pergamon Press, 1962.

2. Irving Langmuir, www.woodrow.org/teachers/ci/1992/Langmuir.html.

3. Irving Langmuir – the Nobel Prize in Chemistry. www.nobel.se/chemistry/laureates/ 1992/langmuir–bio.html.