Michael Polanyi (1891–1976)

Medical Doctor, Chemist and a Philosopher

Michael Polanyi, born in Budapest, Hungary as the son of Mihály Pollacsek and Cecile, née Wohl on 12 March 1891, was trained as a medical doctor. In the very first year of his medical studies, he started publishing research papers. Michael Polanyi corresponded with Einstein on the third law of thermodynamics. Soon after getting his diploma in medicine, he started his research career at the University of Karlsruhe. While on sick leave from the army, he defended his PhD thesis on the theory of adsorption of gases on solids, at the University of Budapest in 1919. He had published 15 research papers by that time; 14 of them were single authored.

In the year 1920, he joined as a research scientist at the Kaiser Wilhelm Institute (KWI) for Fibre Chemistry in Berlin. He started working on X-ray diffraction studies of cellulose and showed that it was polymeric in nature – an idea that was not accepted at that time but turned out to be correct. In 1924, he moved to the KWI for Physical Chemistry and Electrochemistry headed by Fritz Haber. He wrote papers on surface phenomena invoking what would later be called physisorption and dispersion forces. He habilitated at the Berlin University and received the appointment as Privatdozent at the Technische Hochschule Charlottenburg. Eugene P Wigner was his PhD student. He had several international collaborators like Henry Eyring from the United States, Fritz London from Germany, and Juro Horiuti from Japan. Melvin Calvin spent time in Polanyi's lab. Although Wigner and Calvin received Nobel Prizes in later years, Michael Polanyi never received the Prize.

While in Berlin, Polanyi focussed his studies on chemical kinetics – experimental as well as theoretical. An overview of these studies can be found in his book *Atomic Reactions* [1]. The famous flame experiments of his group involving alkali metal vapour and halogen gases were carried out using a simple apparatus consisting of glass tubes. The rate of the reaction was measured by determining the width of the salt deposited. Polanyi and co-workers found that the measured reaction rates for the alkali-halogen reactions were much larger than what was predicted by the collision theory. This implied that the reaction took place much before the atoms and the molecules 'collided' or came in contact with each other. The results were interpreted in terms of what came to be called the 'harpoon mechanism'. This envisaged the alkali atom throwing an electron at the halogen molecule and the resulting alkali metal ion attracting the halide ion Coulombically at distances larger than the collision radius of the species concerned. This would also imply that the resulting alkali halide molecule would be in an extended configuration and would be vibrationally excited. The alkali halide molecule would be

forward scattered too! These implications would be verified in molecular beam experiments by Herschbach and co-workers several years later [2].

The hydrogen analog of these reactions was studied by his son John C Polanyi as a young assistant professor at the University of Toronto three decades later. The son also predicted and showed that the product (HCl) molecules were vibrationally hot. That idea formed the basis for the formation of chemical lasers [3].

John C Polanyi, Dudley R Herschbach, and Yuan T Lee shared the Nobel Prize in Chemistry for the year 1986.

In addition to carrying out experiments on chemical kinetics, Michael Polanyi, along with his collaborator Henry Eyring went on to describe how chemical reactions occurred through motion along the potential energy surface connecting the reactant and product valleys [4]. What was remarkable was that they ventured to describe the motion classically on a potential energy surface given (quantum mechanically) by London (without any proof) and concluded that the energy elevation during the motion on the potential energy surface would account for the activation energy for the reaction.

Michael Polanyi turned down an attractive offer from the University of Manchester in 1932 and stayed put in Berlin. But, because of the unfortunate turn of events and Nazis coming to power, he had to leave for Manchester in 1934 under less than ideal conditions. He pursued his research vigorously in Manchester for the next two decades. Evans and Polanyi published several papers on transition state theory. During the same period, Eyring published profusely on the activated complex theory of chemical reactions. An account of the deliberations on transition state theory can be found in the *Transactions of the Faraday Society* [5].

After World War II, Michael Polanyi became interested in economics and philosophy. In 1954, he relinquished his position as the Chair of Chemistry and took up the Chair in Social Studies in Manchester. It took several years for him to publish his book *Personal Knowledge: Towards a Post-Critical Philosophy* [6]. A smaller book followed with the title, *The Tacit Dimension* [7]. Polanyi argued that there was more to personal knowledge than the sum of facts for a given system.

What was remarkable about Michael Polanyi was that he was an 'outsider' when he started working in frontier areas of chemistry. When he was fully into chemical kinetics, he was an outsider for philosophy. And yet, he made a lasting impact on chemistry as well as philosophy. He seems to have been a loner pursuing curiosity-driven research all along and yet collaborated a lot. He believed in a free atmosphere. It is not clear if he knew what Tagore wrote [8]:

Where the mind is without fear and the head is held high
Where knowledge is free
Where the world has not been broken up into fragments
By narrow domestic walls
Where words come out from the depth of truth.

Acknowledgement

This article is based on the articles written by John Polanyi [9], Dudley Herschbach [10] and Bretislav Friedrich [11].

References

[1] M Polanyi, *Atomic Reactions*, Williams and Norgate, London, 1932.

[2] D R Herschbach, Nobel Lecture, *Angew. Chem. Int. Ed. Engl.*, 26, 1221, 1987.

[3] J C Polanyi, Nobel Lecture, https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1986/polanyi-lecture.html

[4] H Eyring and M Polanyi, On Simple Gas Reactions, *Z. Phys. Chem.*, Vol.B12, pp.279–311, 1931; English translation in *Z. Phys. Chem.*, Vol.227, pp.1221–1245, 2013.

[5] *Transactions of the Faraday Society*, 34, pp.1–48, 1938.

[6] M Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy*, The University of Chicago Press, Chicago, 1958.

[7] M Polanyi, *The Tacit Dimension*, The University of Chicago Press, Chicago, 1966.

[8] Rabindranath Tagore, *Gitanjali*.

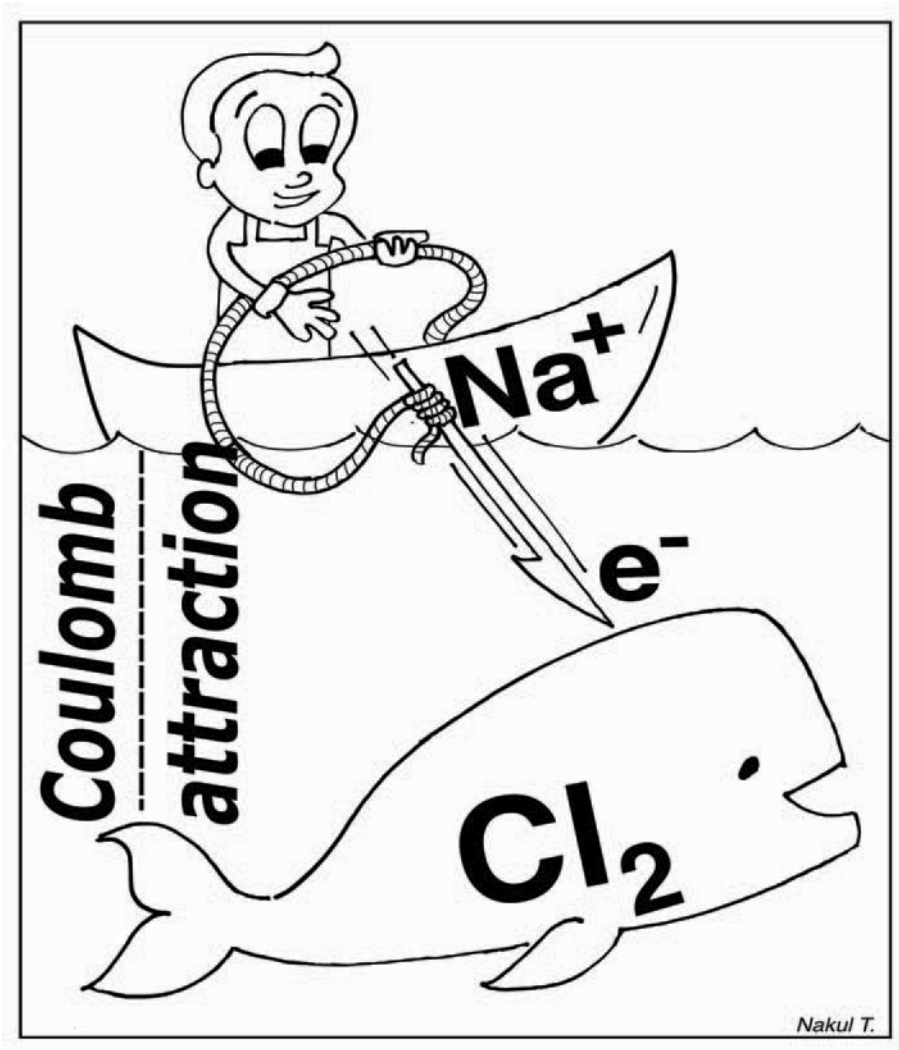
[9] J C Polanyi, Michael Polanyi, the Scientist, *Z. Phys. Chem.*, Vol.227, pp.1215–1219, 2013.

[10] D R Herschbach, Michael Polanyi: Patriarch of Chemical Dynamics and Tacit Knowing, *Angew. Chem. Int. Ed.*, Vol.56, pp.2–13, 2017.

[11] B Friedrich, Michael Polanyi (1891–1976): The Life of the Mind, *Bunsen-Magzin*, 18. Jahrgang, 5/2016, pp.160–167, 2016.

N Sathyamurthy
Honorary Professor
Jawaharlal Nehru Centre for Advanced Scientific Research
Bengaluru
Email: nsathyamurthy@gmail.com

The Harpoon Mechanism



The harpoon mechanism of chemical reactions as proposed by M Polanyi and co-workers.

Cartoon By: *Nakul Teke*