Bretislav Friedrich

TRIBUTES TO AND REMINISCENCES OF MICHAEL POLANYI (1891 – 1976)

On October 5, 2016 the "Michael Polanyi Symposium: Connecting Science and the Humanities"[1] was held to celebrate the rich legacy of one of the luminaries who set up their laboratory in Weimar Berlin. The symposium took place at the Technische Universität Berlin but was also supported by the Freie Universität Berlin, the Humboldt Universität zu Berlin, as well by the Fritz-Haber-Institut der Max-Planck-Gesellschaft. Greeted by the presidents and other representatives of the said institutions, the symposium presented full-length talks by Dudley Herschbach, Mary Jo Nye, and Istvan Hargittai that covered much of Michael Polanyi's many-faceted scholarship ranging from physical chemistry to philosophy. After a break, co-sponsored by the British and Hungarian Embassies, a "Tributes and Reminiscences" session took place, with contributions by Gerhard Ertl, Joshua Jortner, John Polanyi (via video), and Peter Toennies (substituted by Adi Ding). While the full-length talks have been published in Angewandte Chemie and Structural Chemistry, the presentations by Gerhard Ertl, Joshua Jortner and John Polanyi are reprinted below.

The Michael Polanyi Symposium was organized by Bretislav Friedrich and Ludger Wöste, and the materials related to the symposium, including a video-recording of the full program, can be found at a dedicated website http://indico.rz-berlin.mpg.de/indico/event/3/.

GERHARD ERTL[2]

With a degree in both medicine and physical chemistry to his credit, Michael Polanyi arrived in Berlin in 1920, at age 29. After a stint, mainly in early polymer science, at the Kaiser Wilhelm Institute for Fiber Chemistry, he moved, in 1923, to the neighboring KWI for Physical Chemistry and Electrochemistry. The latter institute was directed by Fritz Haber, after whom it would be named in 1952. Polanyi became the head of a newly founded Department of Physical Chemistry (Chemical Kinetics and Quantum Mechanics). The subsequent decade was to become the 'golden age' of the institute, whose merits were largely based on the work of Michael Polanyi and his collaborators. Polanyi's activities – both theoretical and experimental – comprised problems in adsorption (for which he developed a theory in competition with Langmuir's), heterogeneous catalysis (the famous Horiuti-Polanyi mechanism for reactions of hydrocarbons), flame reactions and gas phase reaction kinetics. Most spectacular, however, was the founding of reaction dynamics in a famous paper co-authored by Polanyi's postdoc Henry Eyring, entitled *"Über einfache Gasreaktionen."* The idea was that a reacting system passes over a multidimensional potential energy surface spanned by all the nuclear coordinates of the species involved and determined by the electronic energy of the constituent atoms. This was exemplified by a very simple reaction, the exchange of a hydrogen atom with one bound in a hydrogen molecule. For this purpose a potential energy surface was used that had been calculated by Fritz London (an assistant of Erwin Schrödinger's, who had become Max Planck's successor in the chair of theoretical physics at the Berlin University) on the basis of the recently developed quantum theory. To commemorate the 50th anniversary of the historic Eyring and Polanyi paper, a symposium was held at the Fritz Haber Institute in October 1981. Among the participants, see Figure 1, were no less than five future Nobel Prize winners (D. Herschbach, M. Karplus, Y. Lee, J. Polanyi, and G. Ertl).

After returning to the U.S., Eyring developed this concept further into the so-called activated complex theory, which has so far provided the most successful description of the rates of chemical reactions. People often express surprise about why this concept had not been honored with a Nobel Prize, with only Eyring mentioned as a possible recipient. But awarding the prize solely to Eyring would, in my opinion, not had been justified: It was Polanyi's idea from which Eyring's work unfolded. Polanyi had worked already earlier, together with his former student Eugene Wigner, on related problems and the latter pursued these studies further. (One of my highly respected colleagues uses in his papers for monomolecular surface reactions not the term transition state theory, but Polanyi-Wigner theory). As Eyring himself admits, the Eyring-Polanyi paper had to be written by Polanyi, since Eyring left Berlin at the end of 1930 and, moreover, was not familiar enough with the German language. I think Polanyi was a man full of curiosity and whenever he thought he had understood a problem he left its further exploration to others and became involved in solving new problems.

I have never met Polanyi, but I had once a chance to see Eyring when I was an undergraduate student. In around 1960, I was at the Technische Universität Stuttgart in the laboratory with several other students when the door opened and our instructor

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[1] The symposium was announced in Bunsen Magazin 5/2016, p. 201, which also carried a historical article about Michael Polanyi, pp. 160 – 167.

[2] Prof. Dr. Gerhard Ertl, Fritz-Haber-Institut der Max-Planck-Gesellschaft Berlin. Recipient of the 2007 Nobel Prize in Chemistry, "for his studies of chemical processes on solid surfaces."

Fig. 1: Group photo of the participants at the symposium "50 Years of Dynamics of Chemical Reactions," held at the Fritz Haber Institute of the Max Planck Society on October 12-15, 1981 and organized by J.P. Toennies (chair), A. Ding, H. Gerischer, A. Henglein, and G.L. Hofacker.

entered the room, introducing a distinguished gentleman on his side with the words: "This is Professor Eyring, and I want to leave him alone with you for a minute." We knew of course this name and wondered whether this famous man would like to learn something about our work. But instead he asked: "What do you think about the present situation in the world?" This was at the peak of the cold war and we were all very much concerned about the danger of a nuclear war. We told Eyring as much, but his reply was: "If necessary we should use the bomb." We were really shocked and muttered in disbelief: "But that would kill us all." Eyring was an active member of the Mormon Church, which may explain his reply: "Oh, then we would be closer to heaven!"

Polanyi had certainly quite a different personality and was in my opinion not only an outstanding scientist but also a man of great humanity.

JOSHUA JORTNER[3]

Michael Polanyi is one of my heroes. He stood for remarkable science and the highest human and social values. I was first exposed to his legacy when, as a graduate student at the Hebrew University of Jerusalem, I read the article that Polanyi contributed to the 1950 Memorial Volume for Ladislaus Farkas, the founder of physical chemistry in Israel. In his article, Polanyi alluded to the legacy of John Dalton, whose chair at the University of Manchester Polanyi occupied after the dissolution of Fritz Haber's Kaiser Wilhelm Institute (KWI) for Physical Chemistry and Electrochemistry in Berlin by the Nazi Government in 1933 and his subsequent forced emigration from Germany. Farkas, who too held a position at Haber's KWI, was also forced to emigrate from Germany and settled in Palestine, then under the British Mandate. There he established and directed the Department of Physical Chemistry of the Hebrew University of Jerusalem. In addition to their fate as Jewish Hungarian émigré scientists, there is a deep intellectual connection between Polanyi and Farkas, through their scientific contributions to chemical dynamics.

Polanyi joined first the KWI for Fiber Chemistry in 1920, working, among other topics, on cellulose structure, while Farkas arrived in Berlin in 1924 and first worked with Leo Szilard on condensation of supersaturated vapor at the Technische Hochschule (today the Technische Universität) Berlin. This is where Farkas also conducted research, in 1927–28, for his dissertation under Karl Friedrich Bonhoeffer, another Fritz Haber affiliate, on the quantum mechanical implications of the photochemistry of hydrogen iodide (not a bad choice of subject for 1927!). Polanyi completed his Habilitation in 1923 and was appointed Extraordinarius at the TH in 1926, where he taught between 1925 and 1932. I have not been able to find out whether Polanyi, who was more senior, knew Farkas from the TH. The scientific relations between the two developed at Haber's KWI, where since 1923 Polanyi headed the Department of Physical Chemistry (Chemical Kinetics and Quantum Mechanics) and which Farkas joined in 1928 as an assistant to Fritz Haber. A major work conducted by Ladislaus Farkas, together with Bonhoeffer, Paul Harteck and his brother Adalbert Farkas, focused on ortho- to para-hydrogen conversion. A strong scientific interaction between Polanyi and Farkas came about when in 1931 Polanyi and Eyring conducted their seminal theoretical work on the activation energy of the $H+H_2$ bimolecular chemical reaction, which relied on the 1928 experimental work of the Farkas brothers. Chemical dynamics came about during 1925-1935 through the pioneering theoretical work of Michael Polanyi in conjunction with the experimental work of Ladislaus Farkas and of their collaborators.

[3] Prof. Dr. Joshua Jortner, Tel Aviv University.

During the genesis of Chemical Dynamics in 1925 – 1935, Polanyi and Farkas made major contributions to intramolecular dynamics and to the dynamics of bimolecular chemical reactions. The three cornerstones of their accomplishments were:

Heisenberg's Uncertainty Principle in Chemical Dynamics. In their theory of bimolecular reactions Polanyi and Wigner established in 1925 that a collision of molecules to trigger chemical reactions can be described in terms of two-body capture and its inverse, the one-body decay. The dynamics corresponds to a resonance which can be described in terms of the Heisenberg time-energy uncertainty relation $\Delta E \Delta t \sim \hbar$, thus providing the first quantum mechanical dynamical relation for bimolecular reactions. In the experimental exploration of intramolecular dynamics, Bonhoeffer and Farkas observed in 1927, prior to Farkas's PhD thesis, that the predissociation of the electronically excited ammonia molecule is manifested by spectral line broadening, providing experimental verification of the Heisenberg time-energy uncertainty relation and establishing a central spectroscopic-dynamical relationship for resonances in intramolecular dynamics.

Bimolecular Chemical Reaction Dynamics. In their 1931 landmark paper on the Dynamics of Gas Phase Reactions, Henry Eyring and Polanyi relied on the experimental work of the Farkas brothers on the "simplest" chemical exchange reaction $H+H_2$, which provided the presumed mechanism for the ortho-para hydrogen conversion. This joint theoretical and experimental work established the quantum-mechanical foundation for the description of making and breaking of chemical bonds.

Novel Concepts in Chemical Dynamics and Photochemistry. In 1935 Polanyi, together with Meredith Evans, developed in Manchester the transition state theory of chemical reactions. In 1937 Farkas pioneered in Jerusalem the experimental field of photoselective chemistry using just a mercury lamp and without lasers!

Michael Polanyi and Ladislaus Farkas were two outstanding members of the "Society of Explorers" (which is how Polanyi described the scientific community), who laid the foundations of modern chemical sciences. While both of them integrated experiment and theory, as was common in physical chemistry at the time, Farkas was an outstanding experimentalist with a strong theoretical background, while Polanyi, beyond pioneering experiments and ideas, was a founder of the theory of chemical dynamics. Their approach to the experiment-theory interrelation, or "experimental proof of tacit knowledge" (in Polanyi's words) was vastly different. While Farkas believed and practiced theory based on and supported by experimental reality, Polanyi believed that great scientific theories, like Einstein's special relativity theory, are based on rational intuition that precedes confrontation with experimental reality.

While making use of different methods in science, Polanyi and Farkas adopted a remarkably similar approach to science as a socially based enterprise. Polanyi considered science to rely on behavioral norms and personal commitments. This attitude was reflected in Michael Polanyi's refusal in 1932 to leave Berlin and accept an attractive position at the University of Manchester, with his reluctance originating from his loyalty to Weimar Germany during its hard times. Concurrently with providing leadership at the Hebrew University of Jerusalem, Farkas made major contributions to the development of R&D for Israel's chemical industry. During WWII, he made lasting contributions to the defense R&D of Great Britain and later of Israel during Israel's War of Independence. Farkas's approach to public-scientific service manifested a deep obligation to his newly founded country, which provided shelter to him and to his family during the most difficult of times. The attitude of both Polanyi in Weimar Germany and of Farkas in Israel – admittedly under vastly different conditions – reflected the social obligations of two outstanding scientists, whose shared scientific legacy became a cornerstone of chemical sciences.

JOHN POLANYI[4]

I am moved that you remember my father. You honor an individual, but also a city. My father was welcomed to Berlin almost a century ago, following a stint as a medical officer in the Hungarian army. He was burning with desire to participate in the scientific renaissance taking place in Berlin.

Remarkably, he had some success. He exhibited an ability to see ahead down the twisting path of science. Still more, he is remembered as among the most reflective of scientists. He rejoiced in the community of science, which was taking a leading part in mankind's quest for truth. From that flowed public respect for the truth-seeker. And from that, shared humility in the face of the vast unknown.

But these values were soon threatened by an opposing tide, marked by arrogance and disdain for human values. Incredibly, this too was trumpeted as being science. It comprised the pseudoscience of race- and class-purification, that in its blindness trampled on all who opposed it. Little wonder my father's interests began to shift to epistemology; the study of the way we distinguish truth from falsehood.

Notwithstanding these trials, the greatest tests of humanity surely still lie ahead. How are we to fashion a world sufficiently just that it can endure, and sufficiently wise that it refrains from creating hell in pursuit of heaven?

Today millions flee in search of a safe place, while at every compass bearing lie stocks of nuclear weapons. These weapons testify to the power of scientific thinking, but also to the risk of human folly. For it is folly to rely on this most terrible form of war, as offering the surest path to peace. As scientists we should warn of the dangers inherent in such a paradox.

It was good of you to invite my message. My scientific work may perhaps serve as a footnote to my father's. I cherish his memory, and am grateful to those who conceived this meeting. By remembering what is past, we illuminate the landscape of the future. I thank you, especially, for that.

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[4] Prof. Dr. John Polanyi, University of Toronto, Canada. Co-recipient, with Dudley Herschbach and Yuan Lee, of the 1986 Nobel Prize in Chemistry, "for their contributions concerning the dynamics of chemical elementary processes." John Polanyi is the son of Michael Polanyi.