Jaroslav Heyrovský, 1890-1967

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Early education in Prague and London

JAROSLAV HEYROVSKÝ was born in Prague (in the Old Town, Křižovnická 14) on 20 December, 1890. He was the fifth child of Klára (born Hanlová) and JUDr. Leopold Heyrovský (1852-1924). His father was Professor of Roman Law of the University, which was at that time called the Czech Charles-Ferdinand University. His textbook The history and system of Roman law, went through five editions. He was a free thinker and advocate of Czech autonomy, a friend of T. G. Masaryk. His great-grandfather JUDr. Ferdinand Heyrovský (1769-1839) was Mayor of Rokycany in South-West Bohemia.

After attending the primary school Jareoslav went in 1901 for eight years to a secondary school, called the Akademické Gymnázium. Even though the main stress in education at that time was on Latin and Greek, young Heyrovský showed a keen interest in the natural sciences. Mathematics and physics were his favourite subjects. In 1909 he passed his final examination (maturity examination) and matriculated in the Philosophical Faculty of the Czech University in Prague. In his first year he took courses in chemistry, physics and mathematics and was most deeply impressed by the lectures of B. Brauner on inorganic chemistry, as well as those of F. Záviška and B. Kučera on physics. He admired British natural scientists and in particular the recent achievements of Sir William Ramsay aroused his interest. He was therefore thankful when his severe father (who was a Rector, i.e. Vice-Chancellor, of the University at that time and was rather feared as examiner by the students) gave him permission to continue his studies in London. In 1910 he matriculated at University College, London. There he followed with great attention the lectures of Sir William Ramsay, and William C. McC. Lewis on general and physical chemistry, of F. T. Trouton and A. Porter in physics and L. N. G. Filon in mathematics. In 1913 he received the B.Sc. degree of the University of London. In that year Sir William Ramsay retired and was succeeded by F. G. Donnan. It was due to this eminent physical chemist that Heyrovský’s interest was turned to electrochemistry. He was appointed demonstrator for the session 1913-1914 and started experimental research work under Professor Donnan, who suggested for young Heyrovský a theme which undoubtedly determined
his later career, viz. to determine the electrode potential of aluminium. Oxidation and other passivity effects at the surface of metallic aluminium rendered this work difficult. Moreover, the evolution of hydrogen caused fluctuations of potential. Professor Donnan therefore advised Heyrovský to use a dilute aluminium amalgam and suggested that he might let the amalgam flow slowly out of a glass capillary. The continuous renewal of the surface would then prevent passivation phenomena. This was a device similar to that used by Donnan in his study of membrane equilibria. In these studies Donnan determined the activity of sodium ions by means of a dilute sodium amalgam, slowly flowing out of a thick-walled capillary tube. In this way Heyrovský experienced the advantages of liquid metallic electrodes, in particular their having always a freshly renewed surface, and he learned to use capillary electrodes. These experiences had a profound effect on Heyrovský's later investigations.

War and postgraduate activities

Heyrovský was only able to pursue his experimental work at the University College London for one year, because of the outbreak of war in the summer of 1914. At this time he had liked England so much he decided to stay and become naturalized in the course of time. He went so far as furnishing a couple of rooms in the house of the family where he had been lodging. However, he was visiting his parents when the war broke out and was unable to return. He then became associated with the University of Prague, where Professor J. S. Štěrba-Böhm made facilities available for him to continue his research at the Chemical Institute. In January 1915 he was called up for military service in the Austro-Hungarian Army, but because of his weak physical constitution he was soon posted to a military hospital for service and remained there as dispensing chemist and roentgenologist until the end of the war. This fact was fortunate for the progress of his studies, as his duties left him with enough time to evaluate his experimental material and to prepare his thesis. He submitted it under a title ‘The electro-affinity of aluminium’ to the Philosophical Faculty of the Czech University in Prague where he passed his final examinations and on 26 September 1918 was awarded the degree of Ph.D.

The examination in physics was another of these occasions which strongly affected Heyrovský’s scientific career. His teacher, B. Kučera, Professor of Experimental Physics, gave him a question on the electrocapillarity of mercury. He was already so far experienced that he knew that examiners often give questions that have some relation to their own work. He knew that Professor Kučera had developed a new experimental technique for the measurement of electrocapillary curves, namely, weighing the mercury drops that have fallen out of a dropping mercury electrode, rather than by the capillary electrometer used previously. The discussion went on smoothly and during this confrontation, Professor Kučera described to the candidate...
some results that he had discovered recently. In the presence of atmospheric oxygen, some of the electrocapillary curves recorded with the dropping mercury electrode showed maxima that were not observed in the electrocapillary curves recorded in the same solution using the capillary electrometer. Professor Kučera expressed a view that these deviations could be explained only by a physical chemist and proposed to the surprised candidate that he should continue the researches on the surface tension of mercury electrodes, to which a voltage has been applied.

Professor B. Kučera invited Heyrovský to visit him the following day and showed him how to construct the dropping mercury electrode using a glass capillary, connected to a mercury reservoir, so that from the orifice of the capillary a drop of mercury would fall every few seconds. He also gave Heyrovský reprints of his papers on the anomalous maximum* and advised him to cooperate on the tedious weighing of mercury drops with Dr R. Šimůnek, who was at that time a lecturer in experimental physics. For nearly two years the young scientists spent their free hours in collecting mercury drops at various voltages, weighing them accurately and plotting the weight as a function of the applied voltage. The work proceeded slowly, since, in January 1919, Heyrovský was appointed lecturer in the Department of Inorganic and Analytical Chemistry. The head of this department was Professor B. Brauner, a former intimate friend of D. I. Mendeleev and R. Abegg, who directed Heyrovský’s attention to the problems of chemical affinity and valency. The work on aluminic acid, the structure of aluminates and amphotericity, which reflects the influence of the environment in Professor Brauner’s laboratories, was submitted as a ‘Habilitation Thesis’. Based on this work Heyrovský was appointed on 2 August 1920 as a first Reader (Docent) in Physical Chemistry at the Czech University in Prague, henceforth called Charles University. Heyrovský applied for the Fellowship of the Chemical Society (London) in 1914, but World War I broke off his contacts. In 1919 he regained his Fellowship and published his studies on aluminium in the Transactions of the Chemical Society (130) to (132).†

He also submitted his three joint papers as a thesis for the D.Sc. to the University of London, which conferred the degree upon him in 1921.

Discovery of polarography

From that time Heyrovský was able to devote himself more intensively to the study and interpretation of electrocapillary curves. An important step forward was made when his electrochemical interest induced him to determine the decomposition voltages of some metal ions (Zn²⁺, Cd²⁺, Mn²⁺, Ba²⁺) using the drop-weight measurement. Heyrovský reported

* Although the observation of this maximum in electrocapillary curves was one of the starting points in the discovery of polarography, its exact origin is still a puzzle. Many factors governing its height are understood, but attempts of rigorous mathematical treatment failed.

† Numbers in parentheses refer to the numbered entries in the Bibliography at the end of this Memoir.
on these experiments at a meeting of the Czech Mathematical and Physical Society in the presence of Professor B. Kučera, who unfortunately did not live to see the successes of his pupil, for he died in 1921.

Heyrovský was not content with the accuracy and reproducibility of the ‘decomposition voltage’, obtained from measurements of indentations on electrocapillary curves. He decided to measure the current flowing through a solution into which a dropping mercury electrode is immersed. Because the limited funds of the Chemistry Department did not allow him to purchase a galvanometer, he contacted his former teacher, Professor F. Záviška, who lent him a galvanometer and potentiometer. Whereas his electrocapillary measurements were carried out in the Department of Physics, he was now able to continue the experimental work in the laboratories of the Chemical Institute. He placed a dropping mercury electrode in the solution under investigation, added some mercury to form the mercury pool electrode and started to measure the current flowing between the two electrodes at various voltages. The first current voltage curves, obtained with the dropping mercury electrode formed the basis of the new polarographic method. Thanks to his electrochemical education Heyrovský quickly recognized the advantages of electrolysis with the dropping mercury electrode in the study of electrochemical and analytical problems. The problem of the anomalies on the electrocapillary curves was put aside and all Heyrovský’s attention, energy and knowledge was now devoted to the development of the new method. In this way polarography was born.

**Principles of polarography**

Before following the further development of polarography and its connexion with the life of J. Heyrovský, we may state briefly its principles and characteristic features. The solution to be investigated is brought into contact with two electrodes, the dropping mercury electrode and a reference electrode. The dropping mercury is realized by a glass capillary of an inner diameter of 0.1 to 0.05 mm, connected by a rubber or plastic tubing to a mercury reservoir (see figure 1). From the orifice of the glass capillary immersed in the studied solution droplets of mercury regularly fall off. The electrode is formed by the growing mercury drop hanging at the orifice of the capillary. For reference electrodes an electrode is chosen, the potential of which does not change with applied voltage. Curves showing the dependence of current on the potential of the dropping electrode are called polarographic curves. When substances are present in the solution that can undergo reduction or oxidation* at the surface of the dropping mercury electrode in the available potential range, an increase of current is observed and so-called polarographic waves are formed on the polarographic curves. These are S-shaped curves, reaching at sufficiently negative

* Some other processes like catalysis or mercury compound formation can be involved in special cases.
or positive potentials limiting values, where current does not change with the change in potential. Such waves may be characterized by two quantities. First, the potential at the point on the polarographic curve, where the current reaches half the limiting value (half-wave potential). This is characteristic qualitatively of the electrolyzed substance and its measurement makes it possible to detect substances present in the solution, e.g. a half-wave potential of $-0.6\, \text{V}$ may correspond to cadmium ions, and a half-wave potential of $-1.2\, \text{V}$ to zinc ions.

![Image](http://rsbm.royalsocietypublishing.org/)

**Figure 1.** Heyrovský's original drawing of the dropping mercury electrode as given in the *Transactions of the Faraday Society*, 19, 692 (1924).

Secondly, the height of the polarographic wave, when the current has reached its limiting value, is usually proportional to the concentration of the electrolyzed substance. By measuring this height it is thus possible to determine the concentration of the compound present. This provides a method of quantitative analysis of considerable practical value.

Attempts to study intensity-potential curves by means of solid electrodes had been made before Heyrovský's approach. The surface of such electrodes changes during the electrolysis; and the current-voltage curves obtained were little reproducible and ill-suited for theoretical treatment.

The introduction of the dropping mercury electrode for the study of electrolysis enabled Heyrovský to eliminate or diminish these serious disadvantages. In the case of the dropping mercury electrode a fresh and
clean mercury surface is maintained. The electrolytic process that takes place during the life of one drop is in most cases practically unaffected by the process which terminated at the dropping off of the previous drop. Numerous researchers considered the steady fluctuation of the current intensity, caused by the periodical change in the surface of the electrode, an unsurmountable obstacle to the measurement of the current-voltage curves. Heyrovský was not deterred by this detail because he had the rare ability to see and solve the problem in its simplest and essential features. He used for the recording of polarographic curves a suitably damped galvanometer that made it possible to measure only the mean current value. It was proved later that this approach is also theoretically fully justified. He also recognized at an early stage other advantages of the mercury electrode, in particular the high hydrogen over-voltage of dropping mercury electrodes which enables the study of electrolysis to be extended into the region of negative potentials, which is not accessible with most of the solid electrodes.

**Further development of the polarographic method**

The first account of the use of dropping mercury electrode for the study of electrolytic processes was published by Heyrovský in 1922 in Czech (44) and in 1923 in English (45). The first discussion abroad on the phenomena displayed in electrolysis with the dropping mercury electrode took place at the 1923 meeting of the Faraday Society held in London on 26 November. Heyrovský contributed two papers to the General Discussion on Electrode Reactions and Equilibria (47, 48). Another paper at this meeting was delivered by a young Japanese co-worker of Heyrovský, Masuzo Shikata, which dealt with the electro-reduction of nitrobenzene at the dropping mercury electrode. Heyrovský with his young co-workers tried to extend the study of current-voltage curves to many other solutions. But the point-by-point measurement and plotting was tedious and time-consuming. It was thus of particular importance for the development and dissemination of the polarographic method that Heyrovský, with M. Shikata, only a short time after the discovery of the new technique, constructed an apparatus which registered automatically well-reproducible current-voltage curves. The new instrument recorded such a curve photographically in several minutes, whereas an hour was required to obtain a curve manually. At the present time, when numerous laboratory methods are carried out automatically, an automatic record of current-voltage curves is not surprising, but in the early twenties an automatic instrument of this type was a really advanced apparatus.

In their joint paper Heyrovský & Shikata (53) suggested for the instrument the name polarograph and for researches in this field of electrochemistry the term polarography. The description of the first polarograph was published (53) in the Brauner’s Jubilee Volume of the Recueil de Travaux
Chimique de Pays Bas together with several other papers on polarography, so that it became the first collection of papers on this technique. These publications reflect Heyrovský’s early recognition of the duty of a creative scientist to give his work to the scientific community. In accordance with his belief a printed inscription of Faraday’s words ‘Work, finish, publish’ was found on the walls of laboratories in which he worked and followed him wherever he moved.*

Appointments and honours

The extraordinary success of Heyrovský’s work was early reflected in his scientific career. In 1922 he was appointed Assistant Professor and in 1926 Ordinarius Professor of Physical Chemistry at the Charles University of Prague. In 1922 he became also Director of the newly established Department of Physical Chemistry at the Charles University, which soon became a centre of polarographic research.

The thriving research spirit in this Department was broken up by the closing of the Charles University by the Nazi German occupants of Czechoslovakia in 1939. Thanks to friendly efforts of Heyrovský’s colleague, the German anti-Nazi Professor J. Böhm, his laboratory remained at his disposal during the World War II. He could carry on his experiments, even though without students and co-workers. Fortunately enough, some of his closest co-workers also found it possible during the German occupation to continue polarographic researches in laboratories in hospitals, in the pharmaceutical industry and in the chemical industry. Heyrovský was able during this period to finish his large textbook on polarography (8) and started oscillographic investigations of processes (105, 107) which take place at the dropping or streaming mercury electrode during very short periods of electrolysis.

At the end of World War II the Department of Physical Chemistry of Charles University soon became again a centre of the polarographic research. The difficult task of the new organization, of teaching and re-equipment of the Department which had been closed down for five years was undertaken by two of Heyrovský’s prominent co-workers, Professors R. Brdička and M. Kalousek. After the war the friendly help of Professor J. Böhm was for a time misunderstood by some of Heyrovský’s colleagues, yet a thorough rehabilitation followed and Heyrovský’s attitude was fully justified. Delicate health due to the privations suffered during World War II forced Professor Heyrovský to limit his lecturing to lectures on polarography. He nevertheless took part actively in seminars and in supervising the work of postgraduate students.

Because of the scientific and practical importance of polarography, the Centre for Research and Technological Development founded, in

* It is not known where Heyrovský found this. We have learnt from the Royal Institution that the following, written by W. (later Sir William) Crookes, has been found in an obituary notice of Faraday in the Chemical News, dated 20 August 1868: ‘certainly, no more golden words were ever uttered than those in which he delivered to a young enquirer the secret of his uniform success; “The secret”, said he, “is comprised in three words—Work, Finish, Publish”.'
May 1950, a Central Polarographic Institute. It was one of the first seven institutes founded as a kernel for the development of the re-organized Czechoslovak Academy of Sciences. Heyrovsky became the first Director of this Institute. He remained an Honorary Professor of Charles University and for more than a decade delivered lectures on polarography and organized practical courses in this technique.

Professor Heyrovsky was accompanied in his shift to the Polarographic Institute by twelve of his students who had just finished their theses. They were soon joined by some of his older pupils. In this way one of his ambitions became fulfilled, namely, that his co-workers whom he taught and interested in polarography should carry on the research in this and related fields of electrochemistry.

In 1952 the reorganization of the Czechoslovak Academy of Sciences was realized and the Institute became the Polarographic Institute of the Czechoslovak Academy of Sciences. As the number of the research associates in the Institute increased, new laboratories were established so that after 1963 the Institute was located in four separate buildings in various, rather distant parts of Prague. Heyrovsky relinquished his post as the head of the Institute in 1963 and was temporarily succeeded by Professor R. Brdička, head of the Institute of Physical Chemistry of the Czechoslovak Academy of Sciences. Since 1964 the Institute was renamed the J. Heyrovsky Institute of Polarography, Czechoslovak Academy of Sciences. In 1965 one of Professor Heyrovsky's pupils, Dr A. A. Vlček was appointed Director of the Institute. In 1962 Heyrovsky became seriously ill, but recovered and even after his retirement came regularly every day to the Institute and took an active part in its life. In particular he joined the lectures and seminars and when one or another of his co-workers returned from a trip abroad he was especially interested in hearing their impressions. In fact, his health seemed steadily improving and he came regularly to his Institute, which became the pivotal point of his life, until a few days before his rather sudden death.

During his life, Heyrovsky's scientific merits were recognized by bestowing upon him honorary memberships of the American Academy of Arts and Sciences, Boston; of the Hungarian Academy of Science, of the Indian Academy of Science, Bangalore, of the Czechoslovak Chemical Society, of the Polish Chemical Society, of the Verein Österreichischer Chemiker, of the Chemical Society (London), of the Societies for Analytical Chemistry (London and India) and of the Polarographic Societies (London, Japan, Australia) and of the International Society for Research on Nutrition and Vital Substances. He was a Member of the Czechoslovak Academy of Sciences, of the Deutsche Akademie der Wissenschaften (Berlin), of the Deutsche Akademie der Naturforscher, Leopoldina-Halle/Saale, of the Polish Academy of Sciences, the Danish Academy of Sciences and the Academy of Sciences of the U.S.S.R. Heyrovsky was also Fellow of the University College London, Founding Member of the University of Peace, Huy (Belgium) and was elected Foreign Member of the Royal Society.
(London) in 1965. He was further the bearer of the Czechoslovak State Prize 1st grade (1951) and of the Order of the Czechoslovak Republic (1955, 1960). He received honorary doctorates from the universities in Warsaw, Prague, Dresden, Aix, Marseille, Paris, Vienna and Frankfurt-am-Main. Due to ill health Professor Heyrovský was unable to go to Frankfurt to receive his degree, but the dignitaries of the Frankfurt University came to Prague and the ceremony took place in 1966 in Prague.

In 1959 the Nobel Prize in Chemistry was awarded to him for his discovery of polarography and for his role in the development of this technique.

**Heyrovský and publications**

In accordance with his favourite quotation, from Faraday, 'Work, finish, publish', Heyrovský was greatly interested in the means of printed dissemination of scientific ideas and findings, and realized the necessity in the present age not only of the original scientific papers, but of reviews and summarizing articles of which he contributed a considerable number (39 to 43, 150 to 193). He also devoted considerable time to writing textbooks and monographs on his subject (2, 3, 8, 11, 14, 20, 29, 30, 34) which undoubtedly did much to popularize the polarographic method.

Of primary importance for the extension of understanding of the polarographic method was his article on polarographic analysis in Böttger's *Physikalische Methoden der analytischen Chemie* (39). Perhaps of even greater scientific influence was the large textbook (8) and his introduction to theoretical polarography written with J. Kúta (34) that has been recently made accessible to English-speaking chemists. A Russian translation (2) of the Czech book on polarography by Heyrovský's pupil E. Varasova helped to spread the knowledge of polarography in the U.S.S.R. He never forgot that advances in any area of science depended not only on the experienced scientists, but also on the suitable introduction of beginners into that area. Consequently, he wrote a detailed elementary laboratory manual on polarography (11) which has been since revised in co-operation with P. Zuman (14) and published in eight languages.

Laboratory experiments described in this manual have been used for two decades, under the supervision of Professor Heyrovský and his assistants, in the Department of Physical Chemistry at Charles University for training of students and participants in International Polarographic Courses in handling of polarographs and evaluation of polarographic curves. In co-operation with J. Forejt (20) and R. Kalvoda (30) he produced monographs on oscillographic polarography, which since the early fifties had been his favourite subject.

Long before the establishment of international journals Heyrovský recognized the need for a suitable publication medium for the work of Czech and Slovak chemists. In 1928, with his friend E. Votoček, Professor of Organic Chemistry, he founded an Anglo-French journal, called *Collection*
of Czechoslovak Chemical Communications. The journal is now printing papers in English, German, French and Russian and publishes original contributions from Czechoslovakia to the extent of some 4000 pages yearly. Until 1947, Heyrovský and Votoček were not only the editors of the journal, but also publishers and often the translators of its papers. The journal is now published by Academia, the Publishing House of the Czechoslovak Academy of Science.

Heyrovský also recognized the importance of systematic documentation long before the present era of numerous review journals. He started at an early date to collect and publish periodically bibliographies on polarography (4, 5, 6, 9, 10, 12, 13, 15-19, 21-28, 31-33, 35-38), in which he was aided by J. Klumpar (4) and O. H. Müller (10, 12, 13, 15, 17-19, 21); in recent years there has been an unnamed co-author, his wife. These lists were first published in monographs (8, 40), in an independent publication (16), and periodically in the journal Collection of Czechoslovak Chemical Communications. Since 1951 the 'Bibliography of Publications Dealing with the Polarographic Method' has appeared annually as a supplement to this journal. Recently, also, a subject index has been published (26, 33). Thanks to these bibliographies and similar efforts in Italy and U.S.A., documentation in polarography is more easily accessible than in most other branches of chemistry.

In the early development of polarography many important contributions came from Czechoslovakia and even now Czech and Slovak authors contribute some 10 per cent of the approximately 1000 papers on polarography published yearly.

Contacts with the world

In 1926 Heyrovský was given a Rockefeller Fellowship which enabled him to stay for six months in the laboratory of Professor G. Urbain in the Sorbonne, Paris. In the twenties and early thirties polarography was studied, with few exceptions, almost solely by his direct pupils. It was a combination of a lecture trip and a book that helped a wider dissemination of polarography in both the Western and Eastern world.

In 1933 Heyrovský was appointed Carnegie Visiting Professorship and lectured on polarography for six months at the University of California at Berkeley. He also visited Stanford University and the California Institute of Technology, besides making a number of visits to various universities in the central and eastern United States. After this journey and the publication of Heyrovský's contribution in Böttger's volume (39), a considerable increase in the number of polarographic papers published in English and German was observed.

Similarly, in the Soviet Russia it was the translation of Heyrovský's book (2) and his lecture in Leningrad in 1934 on the occasion of the Mendeleev centenary celebration that resulted in an increase of polarographic activity in Soviet literature.
After World War II he made numerous lecture tours in various countries. In 1947 he visited England as the guest of the British Council, and took part in the Centenary Celebration of the Chemical Society in London, 1947, and in the same year made a two-month lecture tour to Sweden and Denmark. He often spoke about his two-month visit to China in 1958, because, inspired by a book by two monks, which he had read in his childhood, he was always interested in this country and the trip was a fulfilment of one of his dreams. Finally in the sixties he twice visited Egypt, where he sought shelter from cold in the winter months.

Another possibility of contact with those interested in polarography was made possible by international congresses devoted to this field. The First and Fourth International Congresses of Polarography were held in Prague in 1951 and 1966, the Second in Cambridge (1959) and Third in Southampton (1964). Of other international meetings on polarography he also took an active part in those in Warsaw (1956), Dresden (1957), Veszprém (1955) and Prague (1958), Smolenice (1954, 1961, 1963).

Additional stimulus to the growth of polarography was provided by visits of students and guests from abroad who started to flow to Heyrovsky’s laboratory early after the invention of polarography: infected by his enthusiasm they helped to spread the knowledge of polarography throughout the world. Many started active centres of polarographic research in their home countries, e.g. M. Shikata in Japan, W. Kemula in Poland, B. Breyer in Australia, K. Wiesner in New Brunswick, O. H. Müller in the U.S.A., E. T. Verdier in France and G. Semerano in Italy, where a Polarographic Institute was already founded in Padua in the thirties. Many of those who played an important role in the development of polarography were inspired at least during a visit to Heyrovsky’s laboratories, as was the case with I. M. Kolthoff who greatly influenced the growth of polarography in the U.S.A.

**Heyrovsky the teacher**

It was both the possibility of working in a promising and developing new field and the personality of Professor Heyrovsky that attracted so many students and co-workers to him. His devotion and enthusiasm, his modest and polite behaviour, his efforts and patience made him an outstanding practical example for young people. He did not belong to the ivory tower type of scientist, guarding his field of interest. On the contrary, he was always ready to offer his ideas on unsolved problems, his thoughts and suggestions and, in his kind manner, he always tried to help anybody interested in polarography. Nevertheless he was able to reject tersely those who were insincere or greedy of personal gains. He followed the problems of his pupils and co-workers just as eagerly as his own, but, when it came to publication, his name rarely appeared on the paper. When it did, it can be taken for granted that more than half of the work had been carried out by him. Most of his co-workers were allowed to choose their own problems.
and from this they developed as specialists in certain aspects of polarography and electrochemistry. At seminars in the Institute problems were discussed rather fiercely and young people were encouraged to express their opinions and, with the exception of some few 'taboo' concepts, it was possible to air opinions even when they were in disagreement with those of the Director. As a result, his pupils and co-workers were devoted to him, a devotion of which he was justly proud. All this also explains why he was able to build up such a large and coherent scientific school.

Heyrovský's main interest was always in experiment. His strong point was his ability to find new phenomena and to design new experiments for the purpose of deciding between existing ideas and to distinguish the important from the unimportant. One of his collaborators compared him to a genial mushroom picker, who is able to find a mushroom even on a highway. He was often ingenious in the explanation of experimental facts and interpretation of the basic principles, but frequently left the more quantitative treatment of the problems to his co-workers. He rejected premature theorizing and was ready to accept a theory only when it had been verified by experiment. When he was the editor of Collection of Czecho- slovak Chemical Communications, the journal refused to publish purely theoretical papers without any experimental verification. But when Heyrovský became convinced that a theory was in accordance with experiment and explained important findings, he was ready to accept it. This was the case, for example, in the problem of chemical reactions accompanying the electrode process proper, elucidated by his close collaborators Professors R. Brdicka and K. Wiesner.

**Heyrovský the man**

Professor Heyrovský always worked very intensively. His working day in the laboratory always was from 8 a.m. to 7 p.m., followed in his younger years by the evening working at home. In his late years he allowed himself a short nap after lunch. He always adhered to the habit of spending week-ends in the laboratories, being an excellent example of another motto, found on the walls of the Institute: Newton's 'A man must resolve either to produce nothing new or to become a slave to defend it'. He of course insisted that week-ends were the only time when he could be certain not to be disturbed during work.

But he not only worked hard, he expected his co-workers to follow suit. At the University, discussion of research projects was sometimes arranged on Saturday afternoon; at the Institute he could be seen with his watch in hand, standing at a few minutes past eight on the staircase and watching the late-comers arrive! He had the feeling that the day-time in the laboratory is for experimental work and the evaluation and reading should be done in the evenings. He hated dust on the instruments ('you have to brush it every morning, like your teeth'), reading of newspapers in the laboratory and in particular smoking. The smokers in the Institute had to go out of the
building, into the garden, to smoke. Even then occasionally they had to hear some sarcastic remarks.

But while Professor Heyrovský expected some sacrifice from his co-workers, he was himself ready to give up most of his early interests for the major interest of his life, polarography. Once a pianist and a member of a student chamber orchestra, later he was only able to listen to music. He was fond of attending the opera and knew lengthy parts of many of the operas by heart. At one time a well-known reviewer of books, when he became enchanted with polarography he hardly found time to read novels. Only when he wished to brush-up his knowledge of languages, such as before a trip abroad, did he read crime stories. During the sixties he again found more time for reading and often returned to the books which impressed him in childhood. In his youth he had, with his father, made several unforgettable high mountain tours in the Alps. Always interested in sports, a soccer and tennis player, skier and swimmer, Heyrovský never missed making the kick-off at the traditional soccer matches between the Institute of Polarography and the Institute of Physical Chemistry (in the early days at the Charles University these matches took place between his students and those of Professor Dolejšek). In the garden of the Institute in Vlašská Street he rarely forgot to feed the squirrels.

He was fond of entertaining guests and his hospitality became proverbial. He also gave his collaborators an unforgettable example of how to treat Institute visitors, whether V.I.P. or unknown. He liked good jokes, red wine and good cooking. His pleasant sense of humour was most characteristically expressed during the annual Institute parties, where his speeches were spiced with good jokes. In the fifties he and Professor Brdička used to perform short improvised satirical plays based on scientific life. On these occasions, he showed his ability in make-up, usually involving long beards.

During his whole scientific career Heyrovský was steadily supported and encouraged by his devoted and charming wife Marie, born Kořánová, the daughter of a brewer and grand-daughter of a noted forester (her mother, born Heyrovská, was the daughter of a cousin of J. Heyrovský’s father). They married when Heyrovský was thirty-six and he tried to indicate to his young collaborators that this is the right age for a polarographer to marry. However, in this respect his precept was not usually followed. His daughter Jitka (Czech for Judith) is a biochemist in a research institute for food science. His son Michael, who received his Ph.D. in Cambridge in 1966, works on an electrochemical project in the Institute of Polarography.

Scientific contribution of J. Heyrovský and his school

Heyrovský was remarkable for his life-long devotion to the development of his early discovery of the polarographic phenomena. Although he followed other fields of physical chemistry with interest, his main work since the
early twenties was concentrated on polarography and its applications, and he sought to develop its possibilities to the full. During the next two decades the centre of gravity shifted to more theoretical aspects and especially the exact interpretation of polarographic curves. He distinguished (84, 93) the migration-governed component of the current from that controlled by diffusion and found conditions under which the limiting current is determined only by diffusion. In this way he laid down a reliable basis for analytical application of the method which paved the way for an exact interpretation of diffusion limiting currents by Ilkovič. Then it was possible to derive an equation for the whole current-voltage curve (89, 90), which indicated the physical meaning of the half-wave potential and its relation to the standard potential. The equation also demonstrated the shift of the half-wave potential of reversible oxidation-reduction systems, in which complex formation occurs. Capacity currents (Ilkovič), and catalytic hydrogen currents (74, 88, 98) were recognized. It was also ascertained how the various types of processes such as reduction, oxidation and mercury salt formation are manifested on polarographic curves.

Further attention was paid to processes accompanying the electrode process proper. The theory of currents governed by the rate of chemical reaction was developed by Brdička, Wiesner, Hanuš, Koutecký & Koryta. Absorption processes involving the electroactive species (Brdička) and added inhibitors (Kůta, Smoleř, Weber, Koutecký) were studied. The relations between the structure and polarographic behaviour were investigated and regularities found, which enable us to predict the behaviour of hitherto unstudied compounds and contribute to the elucidation of structure for inorganic complexes (Vlček) and organic compounds (Zuman). Electrode processes of some complicated systems were elucidated (Kůta, Mašek, Vlček, Volke, Manoušek, Zuman).

The present trend in polarography is on the one hand, in combination with the other electrochemical techniques, to contribute to further elucidation of electrode processes, on the other to contribute to the solution of some more general problems of inorganic and organic chemistry and biochemistry.

In 1925 Heyrovský devoted much time to the search for manganese homologues in manganese salts, using his sensitive polarographic method. The nobler metal impurities, which showed waves on polarographic curves, were concentrated and examined by his friend and co-worker Professor V. Dolejšek. They did not know that experiments with a similar objective were being pursued by J. G. F. Druce and F. H. Loring in London and were surprised by the announcement of the discovery of new elements by Noddacks. On the basis of the X-ray spectrum V. Dolejšek (who later died in a German concentration camp) and Heyrovský claimed to have detected traces of the element No. 75 in manganese salts (55-57). A series of polemical papers ensued (58-60) and an exhaustive examination of samples was then carried out by Heyrovský. The results, however, did not satisfy him as to the presence of the element No. 75 and he consequently renounced the
discovery (62) as far as the reliability of the polarographic proof was concerned. Since those years there has remained on the walls of Heyrovský's laboratories, Ramsay's consoling remark 'Progress is made by trial and failure'.

Heyrovský also gave considerable attention to the problem of hydrogen over-voltage. Based on polarographic studies he was able to approach the problem from new points of view. The mechanism he suggested became a part of several mechanisms put forward later and is an element of currently accepted views.

In 1940 he supplemented the original polarographic equipment by an oscilloscope, which he used successively in several circuits. The dropping electrode was in this case used for controlled current electrolysis and the method, called oscillographic polarography, provides information on electrolytic and adsorption processes taking place during the life of a single drop. The last experiments with the classical polarograph to be carried out by Heyrovský, who always worked experimentally alone, without technician or assistant, were done in the early fifties on the comparison of waves of glucose in aqueous solutions and solutions in deuterium oxide and on the reduction of carbon disulphide (unpublished). Since then he used oscillographic techniques, in particular showing the dependence of the function $\frac{dE}{dt}$ on potential $E$. He tried to explain differences in rates of electrode processes of various substances, to identify isomers and explain the effects of surface-active substances on electrode processes. For these purposes he introduced the mercury streaming electrode which found applications even in classical polarography. His enthusiasm for and fascination with oscillographic polarography were partly due to the short time needed for the experiments, partly due to his conviction that new method provided new information and offered possibilities of solving some of the old unsolved problems. The main idea stemming from his studies in oscillographic polarography was, that in the reduction of multivalent inorganic cations the electron transfer occurs in successive, one-electron steps. He also considered the possibility of mutual interaction of the intermediates.

**Conclusion**

Heyrovský's life was possibly unique in the single-minded devotion with which he pursued the basic principles of the method discovered in his first researches and later applied it to numerous problems in pure and applied chemistry. Although the method attracted the attention of a large number of workers in many countries, he remained the centre of these developments and continued to exert a profound influence on them, not only scientifically but by the force of his personality, which made an unforgettable impression on the many scientists who had the good fortune to be in contact or to work with him at some time in their careers.
We are grateful to Mrs. M. Heyrovská and Dr Michael Heyrovský for kindly supplying us some personal information.

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