Личности и настани

The Nobel Chemistry Prize Winners through Hundred Years

(On the occasion of the centennial of the Nobel Prize in Chemistry)

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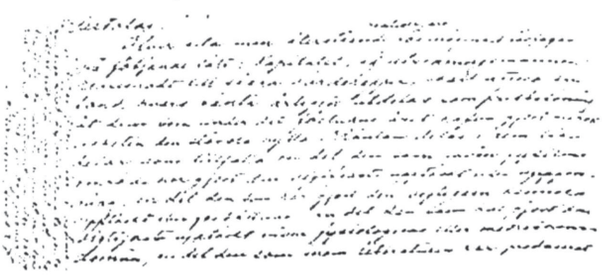
On the occasion of the centennial of the Nobel Prize in Chemistry (1901–2000) a short history of the Nobel Prize establishment is given (a copy of the excerpt from the original Nobel's will is included also). A brief analysis of the countries the Nobel laureates in chemistry are coming from including the number of the laureates from each country as well as the areas in chemistry for which the Nobel Prize has been awarded was done. In addition, the age of the scientists at the moment of the scientific achievement and also the age of the laureates when they were rewarded the chemistry Nobel Prize as well as their family background was analyzed. The cases when the Nobel Prize in chemistry was awarded to the physicists, mathematicians or biologists as well as the names of the scientists who had studied chemistry, chemistry and physics or chemistry, physics and mathematics but were awarded the Nobel Prize in physics and physiology or medicine were also analyzed. The data are summarized in 2 figures and 5 tables and followed by short comments concerning some curiosities. The complete List of the Nobel Prize laureates in chemistry from 1901 to 2000 together with the field of the achievement of the laureates is given as an Appendix of the paper.

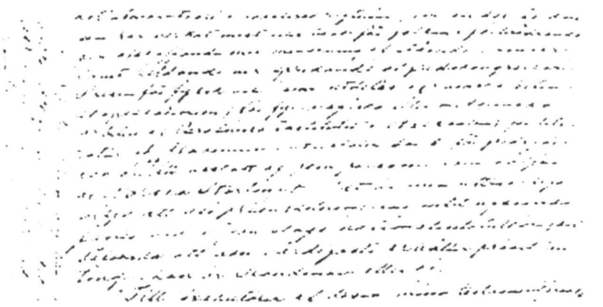
Key words: Nobel Prize; chemistry; hundred years

1997 marked 100 years of opening the will of the famous inventor of dynamite, the Swedish chemist and industrialist Alfred Bernhard Nobel, the 2000 marked 100 years of formation of the Nobel Foundation, whereas the running 2001 marks centennial of the Nobel prize in chemistry, physics, physiology or medicine, literature and peace. During his lifetime Nobel managed to make as many as 355 discoveries, all officially authorized. Nobel's last wish was written in Swedish in Paris on 27th November 1895. To follow this text you will find a facsimile of a part of his original will (taken from the Internet) which concerns the prizes.

Excerpt from the Will of Alfred Nobel



"The whole of my remaining realizable estate shall be dealt with in the following way: the capital, invested in safe securities by my executors, shall constitute a fund, the interest on which shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit on mankind. The said interest shall be divided into five equal parts, which shall be apportioned as follows: one part to the person who shall have made the most important discovery or invention within the field of physics; one part to the person who shall have made the most important chemical discovery or improvement; one part to the person who shall have made the most important discovery within the domain of physiology or medicine; one part to the person who shall have produced in the field of literature the most outstanding work of an idealistic tendency; and one part to the person who shall have done the most or the best work for fraternity between nations, for the abolition or reduction of standing armies and for the holding and promotion of peace congresses. The prizes for physics and chemistry shall be awarded by the Swedish Academy of Sciences; that for physiology or medical works by the Karolinska Institute in Stockholm; that for literature by the Academy in Stockholm, and that for champions of peace by a committee of five persons to be elected by the Norwegian Storting. It is my express wish that in awarding the prizes no consideration be given to the nationality of the candidates, but that the most worthy shall receive the prize, whether he be Scandinavian or not."



However, awarding the Nobel Prizes determined in the will, did not begin until 1901. It took a period of about three years to solve all the problems conected with reclaiming of Nobel's entire property (which, by the way, was spread over eight European countries) and to complete the reference documentation. This period was used to deal with issues regarding the ability and competence of the institutions which were to accomplish such a responsible assignment and to determine the manner of selecting nominees and making decisions as to the persons to be awarded the Nobel Prize.

It was on June 29th 1900 that eventually the **King of Sweden** signed the document which officialized the **Nobel Foundation.** The first prizes were rewarded in 1901. Nobel's property at the time was estimated to 33,000,000 Swedish crowns. As the time went by the fund grew by continual donations and increase of interest which enormously enlarged the total budget of the Nobel Foundation. Today **each Nobel Prize** amounts up to almost **one million dollars**. In other words, the **sum of the Nobel Prizes** (Physics, Chemistry, Physiology or Medicine, Literature, Peace and Economic Sciences) is close to **six million dollars**. In addition, the Foundation makes about four million dollars available to the prize-awarding institutions for tasks related to assessing candidates for the Nobel Prizes.

The selection of the nominees for undoubtedly the most prestigious prize in the world is done on the basis of previously written recommendations submitted by qualified and competent individuals and institutions from respective regions. Concerning chemistry, for instance, the right to submit recommendations for nominees is preserved for the members of the Swedish Academy of Science, the members of the Nobel Committee of Chemistry, the Nobel laureates in chemistry, chemistry professors at the universities and institutes of technology in Sweden, Denmark, Finland, Norway and Iceland and the Karolinska Institute, as well as for professors at respective university departments of at least six universities and colleges selected by the Academy of Science in order to ensure a favorable distribution among the countries of the world. Other scientists, which the Academy may find competent enough, are also invited to submit recommendations.

The **final decision** as to the Nobel Prize winners is made by the **Royal Swedish Academy of Science** in full session after the Nobel Committee for Chemistry (a body within the Academy) has prepared the matter. It is worth mentioning that professor T. Svedberg from Uppsala University has continuously been the member of the Chemistry Nobel Prize Committee for 40 years (1925-1964). It is also interesting to emphasize that from 1901 to 1910 the decisions for the Nobel awards were not made public until the presentation of the prizes at a special ceremony in Stockholm held on December 10, the anniversary of Nobel's death. After 1910 the Academy has changed this impractical arrangement announcing its prize decisions short time after reaching them. At the Prize Award Ceremony in Stockholm, His Majesty the King of Sweden hands each laureate a diploma and a medal. During the awarding ceremony the Nobel laureates usually present a lecture concerning their work.

The chemistry Nobel Prize was awarded **92 times** to **134 scientists** in the period from 1901 to 2000 (see Appendix).

The Prize was not awarded in 1916, 1917, 1919, 1924, 1933, 1940, 1941 and 1942. It is notable that a **single** person with exceptional contribution to the development of chemical science at universal level had the honor of being laureate as many as **61** times. The chemistry Nobel Prize was shared **20 times** by **two** scientists and **11 times** by **three** scientists. There is a tendency of **increase of sharing** of the Prize going **from the past to nowadays**. For instance, during the last 20 years the Prize was 7 times shared by three and 5 times by two scientists.

Of course, there are a lot of curiosities concerning the chemistry Nobel Prize winners, some of which are to be mentioned in the context of this paper. It is interesting, for instance, to point out that the winner in chemistry in 1920, Walther Nernst, had been continuously nominated for the Prize for 15 years (from 1906 to 1920) prior to actually receiving it. On the other hand, Henry Le Châtelier had been nominated for the chemistry Prize 20 times (discontinuously from 1905 to 1935), while Georges Urbain even 22 times (also discontinuously from 1912 to 1936), but they never became the Nobel laureates in chemistry. Another peculiarity is related to the self-nomination of some scientists (e.g. W. Mixter, 1912; G. Oddo, 1921; J. Houben, 1929). It is interesting to mention that the winner in 1904, W. Ramsay, had been nominated by even 23 nominators (among them: A. von Baeyer, E. Fischer, H. Goldschmidt, K. Hoffmann, F. Kohlrausch, J. H. Van't Hoff etc.). There are cases when some of the candidates have died before February 1st of the year of nomination (e.g. F. Osmond, 1913; E. Bourquelot, 1921).

It is also notable that the 134 chemistry Nobel Prize winners come from only **22 countries** listed in Table 1.

Table 1 clearly points to the fact that **two thirds** of the Prize winners (90) have come from only three countries (**U.S.A., Germany** and **U.K.**) where undoubtedly **the highest scientific potential** is concentrated, at least concerning chemistry.

The other "Prize winning countries" worth mentioning are France, Canada, Switzerland, Sweden, Austria, Netherlands, Japan and Norway, which, we may say, keep pace with the three undisputed scientific giants in the field of chemistry. It is also interesting to compare the number of European Prize winners with those from the rest of the world. Despite being seriously jeopardized lately, the "Old Lady" does not give up. Namely, about **60% of Nobel Prize laureates in chemistry** come from **Europe**.

The fact, however, that so far only **eight Scandinavians** have been awarded the Prize points out that the body in charge of deciding on the chemistry Nobel Prize winners, The Royal Swedish Academy of Science, operates strictly in line with the part of Nobel's will stating: *"It is my express wish that in awarding the prizes no consideration be given to the nationality of the candidates, but that the most worthy shall receive the prize, whether he be Scandinavian or not."*

Table 1

The countries from which Nobel laureates in chemistry are coming from including the number of the laureates from each country

Country	Number of Prize winners
U.S.A.	43
Germany	26
U.K.	23
France	7
Canada	5
Switzerland	5
Sweden	4
Austria	3
Netherlands	3
Japan	2
Norway	2
Argentina	1
Australia	1
Belgium	1
Czechoslovakia (The Czech Republic)	1
Denmark	1
Finland	1
Hungary	1
Italy	1
South-African Republic	1
Taiwan	1
U.S.S.R. (Russia)	1

Regarding the "Prize winning countries" it is surprising that Japan has only two, whereas U.S.S.R. (Russia) for instance, only one chemistry Nobel Prize winner. It is also notable that the most populous country in the world, China, does not have a Prize winner for chemistry, whereas the countries of the former so called Eastern Block can only boast with two, Nikolay Semënov from U.S.S.R. (Russia) (1956) and Jaroslav Heyrovský from the Czechoslovakia (Czech Republic) (1959).

While we are talking about curiosities, it is interesting to point out that the genius discoverer of the periodic law of the elements **D. I. Mendeleyev, is not** among the Nobel Prize winners, while at the same time the Prize was awarded to scientists who isolated one element of the periodic system or discovered an isotope of an element (for instance, **Henry Moissan** in 1906 *for his investigation and isolation of the element fluorine and for ... the electric furnace (The Moissan furnace) named after him* or **Harold Urey** in 1934 for *discovering the heavy hydrogen).* Mendeleyev was nominated and almost received the Nobel Prize in chemistry in 1906. Nevertheless, the Prize was awarded to Henry Moissan by one vote. One should have in mind, however, that several generations of chemists, among these Lavoisier, Davy and Faraday, had failed in the attempts to isolate fluorine. On the other hand, the discovery of deuterium and, afterwards, heavy water led to scientific investigations in various areas of chemistry (e.g. mechanisms of chemical reactions, biochemical processes, spectroscopy etc.). Urey's experience in isotope separation put him on the list as a member of Manhattan Project for production of nuclear weapons (along with Edwin McMillan, Glenn Seaborg, Melvin Calvin, Robert Mulliken, Herbert Charles Brown, Jerome Karle). Later, together with other Nobel laureates led by Linus Pauling, through a campaign, they worked hard to stop the nuclear weapons tests. Also, there is a number of famous chemists who have not became Nobel Prize winners. Among them are M. Berthelot, S. Cannizzaro, H. Le Châtelier, J. W. Gibbs, V. M. Goldschmidt, C. Neuberg etc.

It is also interesting to mention the story concerning the Nobel Prize awarded to **Richard Kuhn** in 1938 *for his work on carotenoids and vitamins.* Namely, angered by the presentation of the 1935 peace Nobel Prize to the political dissident Carl von Ossietzky, who was imprisoned in a German concentration camp, Hitler forbade Germans to accept Nobel Prizes. Nevertheless, Kuhn received his gold medal and the diploma **11 years later** (in 1949).

The number of scientists originating from one country who made their scientific achievements in the countries of their emigration is notable and is presented in Table 2.

Table 2

The number of scientists originating from one country who made their scientific achievements in the countries of their emigration

Origin	Number of winners (in other countries)
Poland	4
U.K.	3
U.S.S.R. (Russia)	3
France	2
Germany	2
New Zealand	2
Austria	1
Bosnia and Herzegovina	1
Canada	1
Croatia	1
Egypt	1
Hungary	1
Latvia	1
Lithuania	1
Luxemburg	1
Mexico	1
Slovenia	1
South Korea	1
Ukraine	1

Considering the 1901–2000 group of Nobel laureates in chemistry as a whole, it is evident that, in general, almost all of them have shown interest in natural sciences and their curiosities during their school years, some of them (about 15) being able to do experimental work in their childhood home laboratories.

One of the curiosities concerning the Nobel Prize winners is related to laureates Arne Tiselius and Roald Hoffmann. Namely, **Tiselius's manuscript** referred to the separation of horse blood serum (with a new instrument for separating proteins electrically built by himself) **had been rejected** by a biochemical journal for being too physical. The manuscript was later published in the *Transactions of the Faraday Society* (1937). In 1948 Tiselius received the Nobel Prize in chemistry "for his work on electrophoresis and adsorption analysis and especially for his discovery of the complex nature of the proteins occuring in blood serum". Similarly, the *Journal of the American Chemical Society* **declined to publish Hoffmann's manuscript** entitled "The Bonding Capabilities of Transition Metal Carbonyl Fragments" on account of its lengthiness. The manuscript was later published in *Inorganic Chemistry* (1975). Hoffmann's work in this area in 1982 has been recognized by the Inorganic Chemistry Award of the American Chemical Society.

It is undoubtedly of interest to see for which fields of research the chemistry Nobel Prize is awarded for (see Table 3).

Table 3

The fields of research for which the chemistry Nobel Prize is awarded for and the number of the Prize winners

	Field of research	Number of Prize winners
1.	Physical chemistry	41
2.	Biochemistry	34
3.	Organic chemistry (synthesis)	29
4.	Radioactivity and isotopes	11
5.	Physico-chemical methods	9
6.	Analytical chemistry	7
7.	Inorganic chemistry (synthesis)	3

It is obvious that nearly **every fourth** Prize concerns high scientific achievements in the fields of **physical chemistry, biochemistry** or **organic chemistry** (mostly synthesis), which jointly com pose about three fourths of the total awarded Prizes. The second field characterized by a slightly lower "rewarding frequency" includes radioactivity and isotopes, physico-chemical methods, analytical chemistry and inorganic chemistry (synthesis).

Fig. 1 shows the distribution of the Nobel Prize winners in the above mentioned seven fields of research by two decade intervals. The histogram shows that during the **first two decades** (1901-1920) the Prize has been **rather equally distributed** among all seven fields of research. On the other hand, the period of the **last 40 years** (1960-2000) is characterized by **domination** of the awards in **physical chemistry, biochemistry** and **organic chemistry**. Namely, from the total of 68 Prize winners in the period from 1960 to 2000, even 60 (88%) are from these three dominant fields of chemistry. The maximum dominance of the Prize winners in the field of physical chemistry, biochemistry and organic chemistry is achieved in the 1960-1980 period, when even 30 Prizes (out of 31) have been awarded to the scientists working in the mentioned three fields. The tendency of dominance in the field of physical chemistry for the last two decades is even more expressed. Their evident dominance is influenced by the increasing interest in studying the complex properties of various biomolecules at the same time being supported by the respective development of the appropriate experimental techniques during the last four decades.

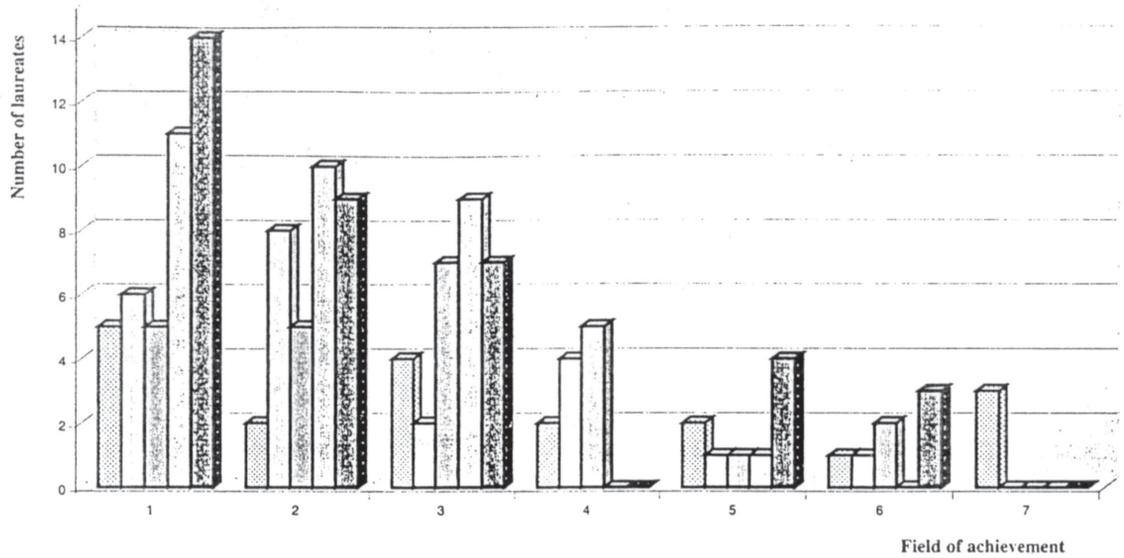


Fig. 1. The two decade intervals distribution (from left to the right) of the Nobel Prize winners in the field of: physical chemistry (1); biochemistry (2); organic chemistry (synthesis) (3); radioactivity and isotopes (4); physico-chemical methods (5); analytical chemistry (6); inorganic chemistry (synthesis) (7)

In general, the Nobel Prize is awarded either for a lifetime contribution to a particular area of chemistry or for a single breakthrough achievement.

The readers of this text will surely be interested in the age of the Nobel Prize winners. Table 4 displays the age of the laureates when they were rewarded the chemistry Nobel Prize.

Table 4

The age of the laureates when they were rewarded the chemistry Nobel Prize

Age	Number of Prize winners
30–40	10
40–50	37
50–60	46
60–70	33
70–80	6
80–90	2

However, if we judge from the figures of chemistry Nobel Prize winners presented in decades in Table 4, we may come to the conclusion that the age of highest achievement is between 50 and 60. We should still have in mind that considerable time passes between the year (years) of the scientific achievement and the year of being awarded a Nobel Prize. Therefore the age of the scientists at the moment of the scientific achievement for the period from 1901 to 2000 has also been analyzed. The analysis has shown that the **average age** of the scientists at the moment of **scientific achievement is 36** compared to the **average age** of the laureates when they **have been awarded** the Nobel Prize, which is **55**. Otherwise, the more detailed analysis **of the age** of the laureates when they **have been awarded** the Nobel Prize has shown that there is a **tendency** of its **moderate increase** going **from the past to nowadays** (Fig. 2).

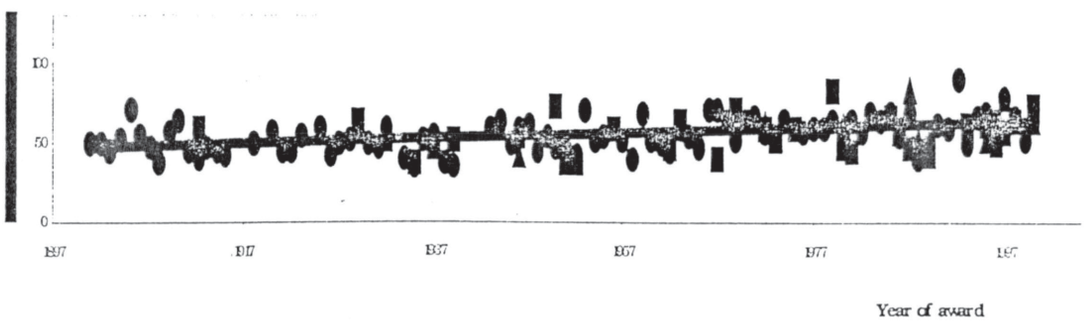


Fig. 2. The age of the laureates when they vere been awarded the Nobel Prize for the period from 1901 to 2000. The circle (for the corresponding year) is used in the cases when single persons had the honor of being laureate, the circle and square correspond to the cases when the chemistry Nobel Prize was shared by two scientists, while the circle, square and triangle are used in the cases when the Prize was shared by three scientists.

The **youngest** ever Prize winner in chemistry was **Frédéric Joliot** – at the age of **35**, and the **oldest Charles Pedersen** at the age of **83**. Taking into account all research fields, the absolute youngest Prize winner at the moment of receiving the Prize was William Lawrence Bragg (physics), **25**, and the oldest were Payton Rous (physiology or medicine), Carl von Frisch (physiology or medicine) and Joseph Rotblatt (peace), all at the age of **87**. William Lawrence Bragg's age (25) is the one when students would still not have graduated, and even if they had, they would in many countries be looking for employment.

It might be interesting to emphasize here that **Frederick Sanger** received the Nobel Prize **twice** (in 1958 and 1980), whereas **Marie Curie-Sklodowska**, in addition to the Prize in **chemistry** (1911) has also been awarded the prize in **physics** (1903). **Linus Pauling**, besides the Prize in **chemistry** (1954), has also been awarded a Prize for **peace** (1964). There are cases when the **Nobel Prize in chemistry** was awarded to a **mathematician** (e.g. Herbert Hauptman in 1985; John A. Pople in 1998), **physicist** (e.g. Ernest Rutherford in 1908; Marie Curie-Sklodowska in 1911; Irene Joliot-Curie and Frederic Joliot in 1935; Peter Debye in 1936; Edwin McMillan in 1951; Gerhard Herzberg in 1971; Aaron Klug in 1982; Johann Deisenhofer in 1988; Walter Kohn in 1998; Alan J. Heeger in 2000) or to a **biologist** (e.g. Walter Gilbert in 1980).

There are cases, however, when the scientists who had studied **chemistry**, **chemistry** and **physics**, or **chemistry, physics** and **mathematics** were awarded the **Nobel Prize in physics** (e.g. Marie Curie-Sklodowska in 1903; Max von Laue in 1914; James Franck in 1925; Jean Perrin in 1926; Isidor Rabi in 1944; Fritz Zernike in 1953; Willis Lamb in 1955; Lev Landau in 1962; Eugene Wigner and Hans Jensen in 1963; James Rainwater in 1975; Kai Siegbahn in 1981; Jack Steinberger and Leon Lederman in 1988), whereas the number of **chemists** (mostly biochemists) who were awarded a **Prize in physiology or medicine** is as high as **42**.

At the end, in Table 5 we present the family background (occupation of father) of the Nobel Prize laureates in chemistry.

The survey points out that the **vast majority** of the Nobel Prize winners in chemistry belonged to **well-off families** of university professors, traders, factory or farm owners, engineers, judges and lawyers, doctors, clerks etc., while only about **11%** of the winners come from **workers' families**.

It is also important to note the fact that out of the 134 Nobel Prize winners in chemistry **only three** are **women** (Marie Curie-Sklodowska, her daughter Irène Joliot-Curie and Dorothy Hodgkin).

Table 5

The family background of the Nobel Prize laureates in chemistry

Family background (Occupation of father)	Number of Prize winners
Professors	22
Traders	14
Factory/farm owners	13
Workers	12
Engineers	9
Judges and lawyers	7
Doctors	5
Office clerks	5
Pharmacists	3
Schoolteachers	3
Artists	3
Military officers	2
Clergymen	1
Miscellaneous (unknown)	35

At the end of this short analysis of the Nobel laureates in chemistry it could be concluded that, although the number of the scientists who have had a significant contribution to the progress in the field of chemistry after 1900 is undoubtedly many times greater than 134, it is evident that the **Nobel laureates in chemistry** have created the **modern chemical science**. At the same time they have given considerable contribution to the development of the chemical education process. Namely, **127 chemistry Nobel laureates** (95%) have been or are **university professors**. They have educated thousands of young enthusiasts in chemistry and other natural sciences. The books written by the chemistry Nobel Prize winners as well as their published papers in various leading scientific journals are among the most influential chemical texts of the twentieth century.

It could be also concluded that although the scientific achievements of all chemistry Nobel Prize winners may not be of equal importance, there is no doubt that **all rewarded achievements** have **„passed the test of time"** giving exceptional contribution to the development of the chemical science. Nevertheless, it is interesting to point out that about half of the interviewed laureates have been convinced that it has not been their best work. The comments of two laureates are chosen as examples:

„The experimental work cited in the Prize award was ... not necessarily the work I'm most

proud of. There were other things that didn't get the notoriety that ... were better done or more inspired"

„It was good work. I wouldn't say the best work".

There is an enormous literature on the background of the Nobel Prizes where an in-depth analysis from various aspects has been done. One of the best among them is the book entitled: ***Scientific Elite - Nobel Laureates in the United States*** written by Harriet Zuckerman (see Literature cited) from which, at the end of this paper, I cite the following:

„Although nearly all the laureates who were interviewed expressed the belief that had deserved their prizes, most were ambivalent about it for one reason or another. One source of ambivalence was the conviction that the research cited for their award was not the best they had done. Another was the conviction that other scientists who had not been so honored were just as deserving. A third reason, for some, was the lateness of the prize. Last and most important of all, many laureates concluded that having won the prize had thoroughly and unalterably disrupted their lives and their work".

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Р е з и м е

НОБЕЛОВЦИТЕ ПО ХЕМИЈА НИЗ СТО ГОДИНИ
(По повод стогодишнината од Нобеловата награда по хемија)

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Клучни зборови: Нобелова награда; хемија; сто години

По повод стогодишнината од Нобеловата награда по хемија (1901–2000), на почетокот на текстот е дадена куса историја на нејзиното установување, при што е приложен извадок од оригиналот на Нобеловиот тестамент. Потоа е направена анализа на земјите од коишто доаѓаат нобеловците по хемија, вклучувајќи го и бројот на лауреатите од секоја земја, како и анализа на научниците кои потекнуваат од одредена земја, а резултатите ги постигнале во земјата во која емигрирале. Анализирани се и подрачјата од кои е доделена Нобеловата награда по хемија. Покрај тоа, анализирана е возраста на научниците во моментот на научното достигнување, како и нивната возраст во моментот кога ја добиле наградата. Проучувано е и семејното потекло на лауреатите. Предмет на анализа се и случаите кога Нобеловата награда по хемија е доделена на физичари, математичари или биолози, но и имињата на научниците што студирале хемија, хемија и физика или хемија, физика и математика, а добиле Нобелова награда по физика или по физиологија, односно медицина. Сумираните податоци, презентирани во 2 слики и 5 табели, се проследени со кратки коментари врзани за одредени куриозитети. На крајот (како прилог кон текстот) е дадена комплетна листа на добитниците на Нобеловата награда по хемија за периодот од 1901 до 2000 година, проследена со подрачјето од кое е доделена наградата.

APPENDIX

Year of Prize	Winner(s)	Achievement
1901	Jacobus van't Hoff	For the discovery of the laws of chemical dynamics and osmotic pressure in solutions.
1902	Emil Fischer	For his work on sugar and purine syntheses.
1903	Svante Arrhenius	For the services he has rendered to the advancement of chemistry by his electrolytic theory of dissociation.
1904	William Ramsay	For his discovery of the inert gaseous elements in air, and his determination of their place in the periodic system.
1905	Adolf von Baeyer	For his services in the advancement of organic chemistry and the chemical industry, through his work on organic dyes and hydroaromatic compounds.
1906	Henri Moissan	For his investigation and isolation of the element fluorine, and for the adoption in the service of science of the electric furnace called after him.
1907	Eduard Buchner	For his biochemical researches and his discovery of cell-free fermentation.
1908	Ernest Rutherford	For his investigations into the disintegration of the elements, and the chemistry of radioactive substances.
1909	Wilhelm Ostwald	For his work on catalysis, and for his investigations into the fundamental principles governing chemical equilibria and rates of reaction.
1910	Otto Wallach	For his services to organic chemistry and the chemical industry by his pioneer work in the field of alicyclic compounds.
1911	Marie Curie-Sklodowska	For her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature of compounds of this remarkable element.
1912	Victor Grignard	For the discovery of the Grignard reagent.
	Paul Sabatier	For his method of hydrogenating organic compounds in the presence of finely disintegrated metals whereby the progress of organic chemistry has been greatly advanced in recent years.
1913	Alfred Werner	For his work on the linkage of atoms in molecules by which he has thrown new light on earlier investigations and opened up new fields of research especially in inorganic chemistry.
1914	Theodore W. Richards	For his accurate determinations of the atomic weight of a large number of chemical elements.
1915	Richard M. Willstätter	For his researches on plant pigments, especially chlorophyll.
1918	Fritz Haber	For the synthesis of ammonia from its elements.
1920	Walther H. Nernst	In recognition of his work in thermochemistry.
1921	Frederick Soddy	For his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes.
1922	Francis W. Aston	For his discovery, by means of his mass spectrograph, of isotopes in a large number of non-radioactive elements, and for his enunciation of the whole-number rule.
1923	Fritz Pregl	For his invention of the method of microanalysis of organic substances.
1925	Richard Zsigmondy	For his demonstration of the heterogeneous nature of colloid solutions and for the methods he used, which have since become fundamental in modern colloid chemistry.
1926	Theodor Svedberg	For his work on disperse systems.
1927	Heinrich Wieland	For his investigations of the constitution of the bile acids and related substances.
1928	Adolf Windaus	For his researches into the constitution of the sterols and their connection with the vitamins.
1929	Hans von Euler-Chelpin, Arthur Harden	For their investigations on the fermentation of sugars and fermentative enzymes.
1930	Hans Fischer	For his researches into the constitution of haemin and chlorophyll and especially for his synthesis of haemin.
1931	Friedrich Bergius,	In recognition of their contributions to the invention and Carl Bosch and development of chemical high pressure methods.
1932	Irving Langmuir	For his discoveries and investigations in surface chemistry.
1934	Harold C. Urey	For his discovery of heavy hydrogen.
1935	Frédéric Joliot, Irène Joliot-Curie	In recognition of their synthesis of new radioactive elements.
1936	Peter Debye	For his contributions to our knowledge of molecular structure through his investigations on dipole moments and on the diffraction of X-rays and electrons in gases.
1937	Walter N. Haworth	For his investigations on carbohydrates and vitamin C.
	Paul Karrer	For his investigations of carotenoids, flavins and vitamins A and B_2.

1938	Richard Kuhn	For his work on carotenoids and vitamins.
1939	Adolf F. J. Butenandt	For his work on sex hormones.
	Leopold Ružička	For his work on polymethylenes and higher terpenes.
1943	George Hevesy	For his work on the use of isotopes as tracers in the study of chemical processes.
1944	Otto Hahn	For his discovery of the fission of heavy nuclei.
1945	Artturi J. Virtanen	For his research and inventions in agricultural and nutrition chemistry, especially for his fodder preservation method.
1946	James B. Sumner	For his discovery that enzymes can be crystallized.
	John H. Northrop, Wendell M. Stanley	For their preparation of enzymes and virus proteins in a pure form.
1947	Robert Robinson	For his investigations on plant products of biological importance, especially the alkaloids.
1948	Arne W. K. Tiselius	For his research on electrophoresis and adsorption analysis, especially for his discoveries concerning the complex nature of the serum proteins.
1949	William F. Giauque	For his contributions in the field of chemical thermodynamics, particularly concerning the behaviour of substances at extremely low temperatures.
1950	Kurt Alder, Otto P. H. Diels	For their discovery and development of the diene synthesis.
1951	Edwin M. McMillan, Glenn T. Seaborg	For their discoveries in the chemistry of the transuranium elements.
1952	Archer J. P. Martin, Richard L. M. Synge	For their invention of the partition chromatography.
1953	Hermann Staudinger	For his discoveries in the field of macromolecular chemistry.
1954	Linus C. Pauling	For his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances.
1955	Vincent du Vigneaud	For his work on biochemically important sulphur compounds, especially for the first synthesis of a polypeptide hormone.
1956	Cyril N. Hinshelwood, Nikolay N. Semënov	For their researches into the mechanism of chemical reactions.
1957	Alexander R. Todd	For his work on nucleotides and nucleotide co-enzymes.
1958	Frederick Sanger	For his work on the structure of proteins, especially that of insulin.
1959	Jaroslav Heyrovský	For his discovery and development of the polarographic method of analysis.
1960	Willard F. Libby	For his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science.
1961	Melvin Calvin	For his research on the carbon dioxide assimilation in plants.
1962	John C. Kendrew, Max F. Perutz	For their studies of the structures of globular proteins.
1963	Giulio Natta, Karl Ziegler	For their discoveries in the field of the chemistry and technology of high polymers.
1964	Dorothy C. Hodgkin	For her determinations by X-ray techniques of the structures of important biochemical substances.
1965	Robert B. Woodward	For his outstanding achievements in the art of organic synthesis.
1966	Robert S. Mulliken	For his fundamental work concerning chemical bonds and the electronic structure of molecules by the molecular orbital method.
1967	Manfred Eigen, Ronald G. W. Norrish, George Porter	For their studies of extremely fast chemical reactions, effected by disturbing the equilibrium by means of very short pulses of energy.
1968	Lars Onsager	For the discovery of the reciprocity relations bearing his name, which are fundamental for the thermodynamics of irreversible prosesses.
1969	Derek H. R. Barton, Odd Hassel	For their contributions to the development of the concept of conformation and its application in chemistry.
1970	Luis Leloir	For his discovery of sugar nucleotides and their role in the biosynthesis of carbohydrates.
1971	Gerhard Herzberg	For his contributions to the knowledge of electronic structure and geometry of molecules, particularly free radicals.
1972	Christian B. Anfinsen	For his work on ribonuclease, especially concerning the connection between the amino acid sequence and the biologically active conformation.
	Stanford Moore, William H. Stein	For their contribution to the understanding of the connection between chemical structure and catalytic activity of the active centre of the ribonuclease molecule.

1973	Ernst Otto Fischer, Geoffrey Wilkinson	For their pioneering work, performed independently, on the chemistry of the organometallic so called sandwich compounds.
1974	Paul J. Flory	For his fundamental achievements, both theoretical and experimental, in the physical chemistry of macromolecules.
1975	John W. Cornforth	For his work on the stereochemistry of enzyme-catalyzed reactions.
	Vladimir Prelog	For his work on the stereochemistry of organic molecules and reactions.
1976	William N. Lipscomb, Jr.	For his studies on the structure of boranes illuminating problems of chemical bonding.
1977	Ilya Prigogine	For his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures.
1978	Peter Mitchell	For his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory.
1979	Herbert C. Brown, Georg Wittig	For their development of boron and phosphorus compounds, respectively, into important reagents in organic synthesis.
1980	Paul Berg	For his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant-DNA.
	Walter Gilbert, Frederick Sanger	For their contributions concerning the determination of base sequences in nucleic acids.
1981	Kenichi Fukui,	For their theories, developed independently, concerning
	Roald Hoffmann	the course of chemical reactions.
1982	Aaron Klug	For his development of crystallographic electron microscopy and his structural elucidation of biologically important nucleic acid-protein complexes.
1983	Henry Taube	For his work on the mechanisms of electron transfer reactions, especially in metal complexes.
1984	Robert Bruce Merrifield	For his development of methodology for chemical synthesis on a solid matrix.
1985	Herbert A. Hauptman, Jerome Karle	For their outstanding achievements in the development of direct methods for the determination of crystal struc-
1986	Dudley R. Herschbach, Yuan T. Lee, John C. Polanyi	For their contributions concerning the dynamics of chemical elementary processes.
1987	Donald J. Cram, Jean-Marie Lehn, Charles J. Pedersen	For their development and use of molecules with structure-specific interactions of high selectivity.
1988	Johann Deisenhofer, Robert Huber, Hartmut Michel	For the determination of the three-dimensional structure of a photosynthetic reaction centre.
1989	Sidney Altman, Thomas R. Cech	For their discovery of catalytic properties of RNA.
1990	Elias J. Corey	For his development of the theory and methodology of organic synthesis.
1991	Richard R. Ernst	For his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy.
1992	Rudolph A. Marcus	For his contributions to the theory of electron transfer reaction in chemical systems.
1993	Kary B. Mullis	For his invention of the polymerase chain reaction (PCR) method.
	Michael Smith	For his fundamental contributions to the establishment of oligonucleotide-based, site-directed mutagenesis and its development for protein studies.
1994	George A. Olach	For his contributions to carbocation chemistry.
1995	Paul Crutzen, Mario Molina, Sherwood Rowland	For their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.
1996	Robert F. Curl, Jr., Harold W. Kroto Richard E. Smalley	For their discovery of fullerenes.
1997	Paul D. Boyer, John E. Walker	For their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP).
	Jens C. Skou	For the first discovery of an ion-transporting enzyme, Na^+,K^+-ATPase.
1998	Walter Kohn	For his development of the density-functional theory.
	John A. Pople	For his development of computational methods in quantum chemistry.
1999	Ahmed H. Zewail	For his studies of the transition states of chemical reactions using femtosecond spectroscopy.
2000	Alan J. Heeger, Alan G. MacDiarmid, Hideki Shirakawa	For the discovery and development of conductive polymers.