

## Different sides of the Jabłoński Diagram on its 75<sup>th</sup> anniversary

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The list of *Named Concepts in Chemistry* presented by John Andraos in the Internet (<http://www.chem.yorku.ca/NAMED/>) contains the names of the scientists who have made outstanding contributions to science. With special pride and pleasure I found there the name of the author of the famous diagram Aleksander Jabłoński, which is presented with the following information:

<p style="text-align: center;"><b><u>Aleksander Jablonski</u></b></p> <p style="text-align: center;">1898 – 1980 Polish, <b>b. ?</b></p> <p style="text-align: center;"><b>Jablonski diagram</b></p> <p>Jablonski, A., Z. Physik <b>1931</b>, <u>73</u>, 460 Jablonski, A., Z. Physik <b>1931</b>, <u>70</u>, <del>53</del>-723 Jablonski, A., Z. Physik <b>1935</b>, <u>95</u>, <del>460</del>-53 Jablonski, A., Z. Physik <b>1931</b><del>5</del>, <u>94</u>, 38 Jablonski, A., Acta Phys. Pol. <b>1954</b>, <u>13</u>, 175</p>
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My roots, in fact both personal and professional, make me obligated to fill in the empty spaces in the above table, correct the references to Jabłoński's work; and by providing some data from his biography, to remove the question mark from above.

As a native of Toruń, Poland, I started my academic career there in 1966 as a first year student in the Physics Department of Nicolaus Copernicus University. Professor Aleksander Jabłoński at that time led the Department. He retired two years later but for more than ten years, following his retirement, he was present as a scientist, authority, advisor, and important persona. He was important also for us, the youngest undergraduates and later on, young scientists, who were watching him and his students, our teachers. Although Professor Jabłoński did not teach me, I was raised in the atmosphere of his scientific fame and charisma.

### Scientific side of the Jabłoński diagram

Professor Jabłoński published 101 scientific papers<sup>1</sup>, which catalogue 54 years of his active life. When asked in 1976 about his greatest scientific achievement, he humbly replied in two sentences<sup>2</sup>:

*The most important is the publication concerning the mechanism of fluorescence and phosphorescence – this one well known. Then I was*

<sup>1</sup> Complete list is presented by J. Szudy at the address: <http://www.fizyka.umk.pl/~lum98/papers.html>.

<sup>2</sup> Postępy Fizyki (Magazine of the Polish Physical Society) v. 33, issue (1-2), 1982; interview from 1976.

*interested in the pressure effects upon the broadening of the spectral lines.*

During the same interview he was asked also how has it happened that he created the diagram explaining the luminescence; he honestly replied:

*Some time ago Professor Förster, who came to Toruń for a visit just a few weeks before his death [1974], asked me what was my inspiration for the scheme of levels; that time I answered that I do not remember. Later on, while thinking I believed that possibly it was connected with the fact that at the beginning I worked on the fluorescence of the cadmium vapors...*

When the „Jablonski Diagram” is Googled, within fractions of a second more than there are 6000 hits. The diagram is indeed very well known. It has been applied over the years to explain different luminescence processes in various materials. It was modified, extended, generalized and adopted to specific problems, but in essence still remaining the Jablonski diagram. One of the more interesting versions can be found at the address: <http://www.innssi.com/Chapter1.htm>, where it is employed to explain pressure sensitive paint measurements, used by “NASA ARCs, ONERA in France, DLR in Germany, NAL of Japan, TsAGI in Russia, automobile industry Ford, Peugeot, full scale aircraft tests, numerous university wind tunnels” as described in this material.

## Back to the origin

The original diagram of the energy levels was published in a short paper in Nature in 1933 (copy of the title and the original diagram below, reprinted by permission from Macmillan Publishers Ltd: Nature **131**, page 839, copyright (1933)).

JUNE 10, 1933

NATURE

839

### Efficiency of Anti-Stokes Fluorescence in Dyes

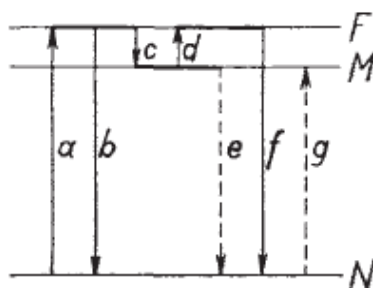


FIG. 1.—Energy levels in a phosphorescent molecule. *a*-absorption, *b*-fluorescence, *c*-transition to metastable level, *d*-thermal excitation, *e* and *f*-phosphorescence, *g*-absorption of very small transition probability.

Using the words of the author, the process of luminescence was explained in the following way:

*...We can assume therefore that in such molecules there must be at least one metastable energy level M, situated lower than the level F reached immediately after absorption. From the state F the molecules can pass either to a normal state N, emitting the band F-N (fluorescence), or to the metastable state M. The probability of the transition M-N is very small. Therefore when the temperature is sufficiently high, a great majority of molecules will be raised thermally from the level M to F and will be able to emit the band F-N (phosphorescence at room temperature). At low temperatures, direct transitions M-N take place.*

In 1941 (when Poland was under Nazi occupation, and the author of the diagram suffered its consequences, as described below) G. N. Lewis, *et al* wrote in their paper<sup>3</sup>:

*This simple scheme of Jablonski has been criticized on several grounds by Pringsheim and Vogels<sup>4</sup>. [...] It seems to us that the scheme of Jablonski is sufficiently flexible to take care of such complexities as they arise.*

The evidence, how right Lewis and his collaborators were may be found in all the modifications of the original diagram that have been introduced in the literature. A special place on the list of all these publications is reserved for a paper by Lewis and Kasha<sup>5</sup> from 1945, since it implemented the Jabłoński diagram introducing the realization of the metastable state of the original diagram by the triplet state; in this very paper also the term *inter-system crossing* was introduced (see also review articles by M. Kasha<sup>6</sup>).

The metamorphosis of the Jabłoński diagram observed over the years and its flexibility, as described by Lewis, are illustrated in the article *A generalization of the Jablonski diagram to account for polarization and anisotropy effects in time-resolved experiments*, by J. Zimmermann, A. Zeug and B. Röder (Phys. Chem. Chem. Phys., **5**, 2964 (2003)). In this paper the authors are writing:

*...the idea to model the process of rotational diffusion by a series of arbitrary jumps between discrete states fits nicely into the concept of the Jablonski diagram. In this paper, we present a generalization of the Jablonski diagram to account for rotational diffusion using a DDA like method [discontinuous distribution approach], which we call the polarization sensitive Jablonski diagram (PSJD). The main advantage of this model is its easy customization to special requirements, as the Jablonski diagram itself can be easily extended to any possible electronic states and transitions in (supra-) molecular systems.*

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<sup>3</sup> G. N. Lewis, D. Lipkin and T. T. Magel, J. Am. Chem. Soc., **63**, 3005 (1941).

<sup>4</sup> Pringsheim and Vogels, J. chim. Phys., **38**, 345 (1936).

<sup>5</sup> G. N. Lewis and M. Kasha, J. Am. Chem. Soc., **66**, 2100 (1945).

<sup>6</sup> M. Kasha, J. Chem. Educ., **61**, 204 (1984) and Acta Phys. Pol., **A71**, 661 (1987).

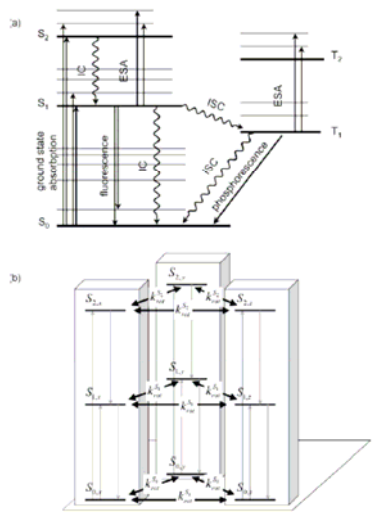


Fig. 1 (a) Jablonski diagram of organic dyes IC—internal conversion, ESA—excited state absorption, ISC—intersystem crossing, (b) Polarization sensitive Jablonski diagram for a spherical rotor: the three sublevels of each electronic states are connected by “rotational” transitions (only the singlet system from Fig. 1a is shown).

Figure reproduced from the article by J. Zimmermann, A. Zeug and B. Röder in *Phys. Chem. Chem. Phys.*, **5**, 2964 (2003) (by permission of the Royal Society of Chemistry).

## Human side of the Jabłoński diagram



A. Jabłoński  
/Prof. Aleksander Jabłoński/

(photograph from private album of E. Walentyńowicz)

Professor Aleksander Jabłoński was born on February 26, 1898 in Voskresenovka, Ukraine (that time part of Poland) in a very patriotic, Polish family. He died on September 9, 1980 in Warsaw survived by his two

daughters and their families; his beloved wife, Wiktoria, neé Gutowska, his best life companion, confidant, advisor and pianist, who also played in his string quartet, passed away in 1970. His life spanned a very difficult period of history in Europe, in general, and Poland in particular. He served his country in both the First and Second World Wars and suffered all their consequences; yet he was an outstanding scientist, talented musician, warm family man, skillful organizer and simply a nice person emanating tender attitude toward all those around him. At the same time however, he was serious, always defending the moral and ethical rules and searching for the truth, also in science. Demanding much from all those working with him and for him, expecting honest and truthful performance from all sharing life with him, he drew by his own devotion, determination and hard work a clear picture for others to follow.

The First World War interrupted his study of physics at the University in Kharkov. He continued his education at Warsaw University in 1918, when Poland regained its independence,

and completed it under the supervision of Professor Stefan Pieńkowski. After obtaining his PhD in 1930, he spent two years working for Professor Peter Pringsheim in Berlin, while maintaining a scientific collaboration with Otto Stern in Hamburg. His time spent at University of Warsaw after returning from the stay abroad was very fruitful, and it culminated in his publishing in 1933 in *Nature* the diagram that brought him international fame. This time was also a good time from a personal point of view, as recollected by Jabłoński's daughter Danuta. Indeed, married in 1922 to the accomplished pianist Wiktoria Gutowska, he started his family life in Warsaw; and his two daughters were born there, Halina in 1923 and Danuta in 1925.

While studying physics he was simultaneously a student of music under the guidance of famous violinist Stanisław Barcewicz, who studied music composition under Piotr Tchaikovsky (the same who composed the Fourth Symphony and the opera *Eugene Onegin*). In fact for some years, between 1921 and 1926, Jabłoński played violin in the orchestra of the Teatr Wielki - Polish National Opera (founded in 1778) with Emil Młynarski as conductor. This was a real dilemma for a talented violinist and, at the same time, talented physicist, which profession to choose for the future. With the serious voice of his wife's advice, physics won, and the main stream of Jabłoński's life was devoted to research and teaching. However, during his whole life he was also a devoted musician organizing at his own home string quartets, in every city he lived to the end of his life. As his daughter Danuta recalled<sup>7</sup>, her parents were playing music every evening, mother on piano, father the violin. Sometimes father was also improvising on the piano, but early in the morning he was practicing on the violin silently, with no sound of music.

In 1938 he accepted an academic position of docent at the Stefan Batory University in Vilnius, Lithuania, (that time part of Poland) to establish an independent and his own research group on a new ground. Unfortunately the war that broke out on September 1, 1939, which again ruined the normal life of the Jabłońskis, with the worst to come in July 1940. After the fiasco of the defense of the mother country at the German front, recovering from the wounds from the battle, he stayed at home being completely suspended between the military and civil life styles, and crushed by the internal conflict between his feelings of patriotic obligation and the helpless and hopeless situation. In order to survive hunger his wife cooked candies, and the daughters bartered them in the neighborhood for food, but docent Jabłoński, as a Polish Officer, could not accept an offer from his German colleagues to work on scientific Abstracts to earn money. As reminisces his daughter Danuta,<sup>8</sup> he argued that *Poland and Germany are in war, therefore I cannot accept such an offer*, agreeing at the same time with his wife that he should be indeed moved by this gesture of his colleagues.

In July 1940 the war for Jabłońskis turned into a new chapter. In the middle of the night Jabłoński was arrested, not by the obvious enemy, the Germans; but by new ones, the Russians, who in 1939 had joined the German side<sup>9</sup>. Only later it was learned that he was taken together with other Polish officers to Kozielsk, a camp in Russia, to occupy the vacant places created by the massive murder of Polish officers and intelligentsia in the spring of that year. In fact, at that time nobody knew that a few months earlier, in April, Professor Jabłoński's brother Feliks, the judge, had been killed in Katyń<sup>9</sup>. It is scary to repeat after Danuta Jabłońska, that her father, while

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<sup>7</sup> Danuta Jabłońska-Fraćkowiak, *Na Uniwersytecie Mikołaja Kopernika w latach 1946-1966. Wspomnienia fizyka* (in Polish), Wydawnictwo UMK, Toruń, 2006.

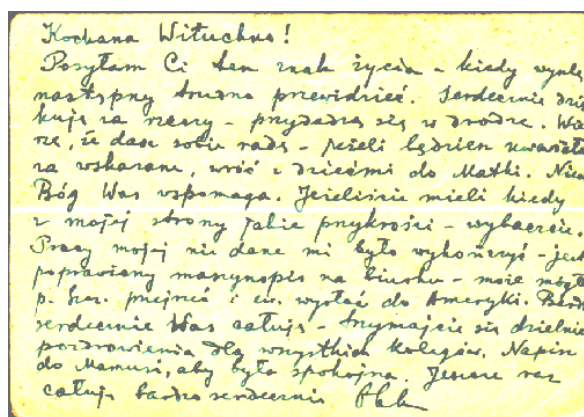
<sup>8</sup> Danuta Jabłońska-Fraćkowiak, *Pomruki wojny* (memoir in Polish), Tow. Miłośników Wilna i Ziemi Wileńskiej, Bydgoszcz, 2004.

<sup>9</sup> As a result of the Ribbentrop-Molotov Pact, on September 17, 1939, Poland was invaded by the Soviet Army, and several thousand of officers of the Polish Army, policemen and civilians were arrested. There were three NKVD camps: Kozielsk, Ostashkov and Starobielsk; in the spring of 1940 thousands of prisoners were executed and the most known execution place was Katyń Forest.

in captivity, found the name of his brother engraved on the wooden bunk bed! That time he naively assumed that, since the brother was not present, this had to be vivid evidence that he had been previously transported to another camp. I have to confess that this story is very emotional for me, since in the same place, in Katyń, and at the same time as Professor Jabłoński's brother, my father's brother was killed (on April 10, 1940). For the reader not familiar with the achievements of the political changes of 1989 in Central and Eastern Europe, I have to add that for all the years prior to these changes, the Russian camps existed only in the tragic stories whispered among the family members in the privacy of home; they had been removed from the official history books and from the official version of the Second World War. Only in the last 19 years did the scale of this crime come to the surface, and its victims have been openly mourned. However still not all the documents filed in the Russian archives are open for public eyes and souls.

Jabłoński survived the captivity in the Russian camp, but it sounds like a paradox that it happened thanks to the war against Hitler. In a real war zone it was indeed possible, and in this particular case the actions of war took a reverse order. Russians, on being attacked by the Germans on June 22, 1941, realized the danger of the situation and suddenly changed their colors and side. They became the allies of the Poles, unified in the fight against a common invader.

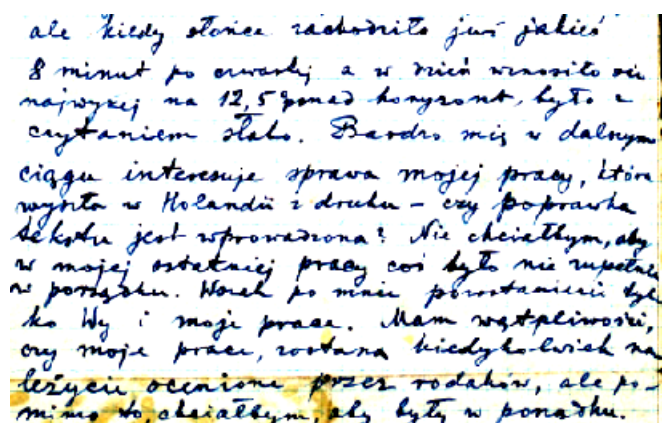
Below is a copy of the first card written on August 23, 1940 by Professor Jabłoński to his wife and daughters. It was written during his travel across Lithuania in an unknown direction; it reads (my translation of a fragment from the original correspondence donated by Danuta Jabłońska-Fraćkowiak to the Archives of Nicolaus Copernicus University in Toruń, cat. num. AUMKW-24/3;):



Dear Wituchna<sup>10</sup>,  
 I am sending you this sign of life, it is difficult to predict when it will be possible to send another one. Thank you cordially for all the clothes you gave me – they will be useful during the way. I believe you will be able to survive; if you think it would be better, move with children to Mother. Let God take care of you. Please forgive me if I have caused you any sorrow. I was not given a chance to complete my work - there is a corrected manuscript on the desk, maybe Prof. Sz. would be willing to check it and eventually mail it to America.

<sup>10</sup> Nickname of Wiktoria, wife of Professor Jabłoński

Nobody knew where he was kept in captivity, and only from a message written in one of his letters where the time of the sun rise and its position were mentioned, it was possible to deduce that it is indeed the camp in Kozielsk (copy below)



ale kiedy słońce zachodziło już jakieś  
8 minut po ciemności, a w dzień wznosiło się  
najwyżej na 12,5° ponad horyzont, było z  
czytaniem słabo. Bardzo mi w dalszym  
ciągu interesuje sprawa mojej pracy, która  
wygłoszona w Holandii z druku – czy poprawka  
do której jest wprowadzona? Nie chciałbym, aby  
w mojej ostatniej pracy coś było nie zupełnie  
w porządku. Wszak po moim przywróceniu był  
to Wy i moja praca. Mam wątpliwości,  
czy moje prace, zostana kiedykolwiek na  
leżycie ocenione przez rodaków, ale po-  
mimo to, chciałbym, aby były w porządku.

Copy of a fragment of the letter written on February 26, 1941  
(in the second line from the top: sun set at around 8 minutes  
after 4, and during the day it was 12.5° above the horizon; the  
rest of this letter is translated below (courtesy of the UMK  
Archives, AUMK W-24/3)

In the same letter (presented above), which in fact has been written on February 26, 1941, Professor Jabłoński's birthday, he wrote (from the memoir of Danuta Frąckowiak-Jabłońska<sup>11</sup>):

*I am most interested in my work, which was printed in Holland; was the correction introduced? I would not want there to be something wrong in my last paper. You know, only you and my papers will be left after me.*

On March 23, 1941 the following report has been written to his wife and daughters:

*I have not been ill, not even with flu, my teeth are strong (I was given a gift of a small piece of onion and garlic which is supposed to preserve teeth). I try and keep fit by studying physics and reading English books...*

and continuing (my translation from the Polish original):

*I am very happy that my last paper was found interesting, the external conditions are rather inappropriate. But unfortunately still I do not know whether my erratum was taken into account and the error is corrected. Are there in Vilnius copies of my paper available? I am unable to have contact neither with Fokker (the editor of Physica) nor with Opechowski, his assistant<sup>12</sup>.*

In the last letter dated on April 30, 1941 he wrote<sup>11</sup>:

<sup>11</sup> *Born 100 Years Ago: Aleksander Jabłoński (1909-1980)*; ed. J. Szudy, Wydawnictwo UMK, Toruń, 1998.

<sup>12</sup> The paper mentioned in these letters, entitled: *Pressure Broadening of Spectral Lines*, was published in *Physica*, **6**, 541-550 (1940).

*Lately I have started to play the violin, built with the aid of a penknife and piece of glass; the bow has thread instead of horse hairs.*

Family, physics, music... these were the main sources of strength for Jabłoński to survive the extreme conditions.

The next episodes of the life of Jabłoński sound very straightforward in comparison to the trauma of the war: the Polish Army organized on the Soviet territory, transit through the Middle East and the final destination in Edinburgh, Scotland, where he taught at the Polish School of Medicine<sup>13</sup>. In November 1945 his advisor from Warsaw, Professor Pieńkowski, arrived in Edinburgh to convince him to return to Poland, since, as he said, young people in liberated Poland want to study; and they are awaiting teachers! Professor Jabłoński indeed returned to Poland out of his deep patriotism, dedication to family and to his mission as scientist and teacher.

Although he had the opportunity to stay at Warsaw University, again the chance of creating his own research group on a new territory was the reason that he accepted a position at as yet a non-existing university, which was just in the process of being established in Toruń, in the northern part of Poland. In 1946 Jabłoński, a scientist already recognized in the world in spite of a break of five years in his scientific activity caused by the war, faced a new challenge. His task was to create the Physics Department, including research and teaching. Nothing was available at that time – equipment for laboratories, buildings, people...



Professor Jabłoński at his desk looks with smile at the results of a new experiment presented by his students (from the left): Emanuel Walentynowicz, Kazimierz Antonowicz (first PhD student in Toruń), Edmund Lisicki, Henryk Łożykowski i Stanisław Łęgowski (private collection of Emanuel Walentynowicz).

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<sup>13</sup> In fact it was a long, tragic and painful way. The treaty between the Soviet government and the Polish government in exile was signed in London on July 30, 1941. On August 14, 1941 there was a military agreement signed in Moscow giving permission to organize the Polish Army on Soviet territory. General Władysław Anders became its chief; it was a voluntary army established for the Polish men on Soviet territory. However nobody knew how many of them had been living there and how many were kept there, not voluntarily of course. Only after the amnesty, when Polish prisoners were freed, thousands of them joined the army, and in February 1942 there were 75 thousand soldiers. Nobody knew at that time why the Polish officers were not joining the army; nobody knew, until 1943, that they had been killed in Katyń. Stalin did not fulfill his promise to provide military equipment and food for the army; there was hunger, death, misery and no arms with which to fight. With the approval of Stalin, the Polish Army was evacuated in the spring of 1942 and in September of that year General Anders in Iraq started the formation of a Polish Army in the East.

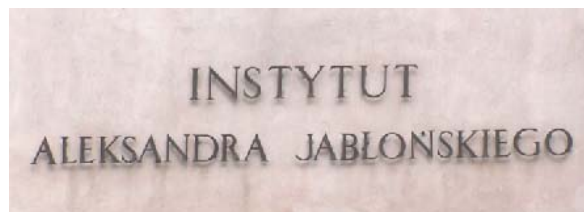


Professor Jabłoński dedicated his life to the Institute of Physics of Nicolaus Copernicus University, he created the Toruń School of Physics, and he built its home, which is now the Institute of Aleksander Jabłoński (picture below).



Professor Jabłoński (in the first row in a light jacket, next to him is Professor Roman Stanisław Ingarden, who succeeded Jabłoński as Director of the Institute) in the front of the Physics Institute with some of the faculty members, May 27, 1972.

...and everything has happened in my hometown Toruń, a small town established 755 years ago, the same where in 1473 Nicolaus Copernicus was born...



Aleksander Jabłoński's Institute, the home of the Physics Department of Nicolaus Copernicus University, Toruń, Poland (photographed by Dawid Piątkowski, a graduate student of physics, 2008).

## **Acknowledgement**

I wish to express my gratitude to Danuta Jabłońska-Fraćkowiak, Professor of Physics, for sharing with me over the phone her personal reminiscences, for her wonderful books with her own memories and memoirs of her famous father; for her moral support, extreme amount of optimism, pleasure provided during multiple conversations, and for her patience in answering my questions. I thank Emanuel Walentynowicz, one of the students of Professor Jabłoński, for the photographs from his private album presented here. I acknowledge also the very prompt and useful help I received from the Archives of Nicolaus Copernicus University in Toruń.

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