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George Gamow: World line 1904 – 1933†
(On the ninetieth anniversary of G A Gamow's birth)

V Ya Frenkel'

Abstract. One of his articles written with a co-author Gamow called "My half-article". Here his 'half-biography' is presented. It covers the first very important part of his life, starting from his youth in Odessa, his student years in Petrograd – Leningrad and several of his visits to Germany, Denmark, and England in connection with his scientific work. Special attention is devoted to his first scientific researches (1926 – 1928) at the Leningrad State University and to his relations with fellow students — M P Bronshtein, D D Ivanenko, and L D Landau. His research into α-decay — its genesis and subsequent fate — is analysed. This article is in many respects based on new archive material.

The title of the present article, the publication of which is timed to coincide with the 90th anniversary of the birth of Georgii [George] Antonovich Gamow (1904 – 1968), is related to the title of his autobiography [5]. Gamow began to work on his book *My World Line. An Informal Autobiography* shortly before his death and was unable to see it published. The existence of Gamow's *My World Line* (which will be published this year in Russian) paradoxically hinders the work of his potential biographers. It is awkward to repeat what he has described 'in his own words' — also because Gamow's language is rich, exact, picturesque, and colourful. His autobiography resembles superior examples of Russian literature as regards not only genre but also literary skill. Here one may refer to Gor'ky's trilogy and even more legitimately, and with greater justification, to *My Reminiscences* by Academician A N Krylov (he, incidentally, knew Gamow well, having been Director of the Physicomathematical Institute of the Academy of Sciences in which Gamow worked). Unfortunately we do not have Gor'ky's complete biography and the books about Krylov do not withstand comparison with his own reminiscences.

Naturally, in working on Gamow's biography one can attempt to improve its accuracy — one can expose his lapses of memory or those cases where the information he used was erroneous.

V Ya Frenkel' Ioffe Physicotechnical Institute,
Russian Academy of Sciences, Politekhnicheskaya ul. 26,
194021 St Petersburg, Russian Federation. Tel. (7-812) 247 99 06

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A description of Gamow's circle as well as the pre- and post-history of his works with reference to archives (documents) associated with him and to his letters which he himself might have forgotten — all these are factors which create a certain 'freedom of manoeuvre' and justify the work of his future biographers. The study of these sources alters significantly the assessment of his human qualities which was based on legend or on the partisan tales of his contemporaries. I believe that the outcome of all the 'for' and 'against' arguments undoubtedly gives rise to a positive balance: he was a good man and, of course, a brilliant scientist! Gamow more than deserves a detailed biography. Within the framework of a short journal article, only its outline will be drawn.

George Gamow was born on 4th March 1904 in Odessa to a family of teachers. Having noted with bitterness in his book the early death of his mother, Aleksandra Arsen'evna Lebedintseva, he writes in fair detail about his father, Anton Mikhailovich Gamow, who played a major role in the establishment of his interests in literature and music and encouraged his occupation with physics, biology, and astronomy (the latter was expressed by the purchase of a micro-scope and a telescope for the boy; Gamow described, with a liveliness characteristic of his book, entertaining episodes of his work with them).

One of Anton Gamow's pupils at the Zhukovskii Secondary School (Gymnasium) was Lev Trotsky. Gamow [senior] valued the undoubted talent of this secondary school student and preserved the compositions which he had written. George Gamow recalls his father's story how he met Trotsky (Bronstein at that time) in the port of Odessa and asked him what was his occupation. "I work there" replied the young man somewhat sadly. A M Gamow did not suspect the real nature of Trotsky's work and thought bitterly how sad was the fate of this talented young man. While in exile, Trotsky wrote a two-volume autobiography in which he expressed himself with reserve about his teacher of litera-ture [7]. George Gamow commented on this probably with a [wry] smile.

† Until the end of the 1980s, G A Gamow's name was encountered in our country only in specialist scientific literature. Yu I Lisnevskii [1] was the first to break the imposed silence on this topic. This was followed by the publication of two comparatively large communications about Gamow [2, 3]; a collected volume [4] includes an excerpt from his autobiography [5]. Its abbreviated version has been published in a journal [6].

This is what Gamow writes about the spelling of his name: "...If I had come from Russia straight to England or to the United States I would have spelled my name in English with a *v* at the end. The *w*, confusing the issue, originated from the fact that I first spelled my name in the Latin alphabet for a publication in German, where *v* is pronounced like the English *f*, and *w* like English *v* ([5], p. 8).

Gamow inherited from his parents an interest in history and this manifested itself in a considerable interest in his pedigree. On the side of the Lebedintsev family, Gamow was able to trace it as far back as the XVIIIth century. Most of the Lebedintsevs were clergymen and this tradition originates from one of Gamow's 'great-granddaddies' who carried God's Word to the restless members of Zaporozhian host — it is not for nothing that Gamow's book is decorated by a reproduction of I E Repin's famous painting. On his father's side, his ancestors were mainly soldiers and one of them was sent by Catherine II to subdue the Cossacks of Zaporozhian host. Thus, notes Gamow, the world line of his ancestors on his father's and mother's sides might have intersected in the lower reaches of the Dnieper and the result of this encounter would probably have been extremely unfriendly.

Having mentioned that his grandfather on his father's side was Commander of Kishinev, Gamow speaks with great relish about the Lebedintsevs. His grandfather, Arsenii Lebedintsev, was a priest in Sevastopol, who distinguished himself during the Crimean Campaign and attained very high ranks in the Church. Listing them in his book, Gamow encountered a certain difficulty: how to select in English the equivalent of the title which Arsenii Lebedintsev possessed towards the end of his years. There was a similar difficulty in the back translation from English to Russian. As a result, in conformity with what is stated in the English – Russian dictionary, Gamow's grandfather was credited with the title of Metropolitan and Dean of the Odessa Cathedral Church [3]. This drew the attention of M A Podurets, who pointed out the inaccuracy of the translation in his letter to Frenkel' and Chernin and referred them to the journal 'Niva', which was perhaps the most popular pre-revolutionary periodical. A fairly detailed obituary of Arsenii Lebedintsev was published in one of its issues.

It turned out that he was Chairman of the Kherson Ecclesiastical Consistory and the Odessa Cathedral Archpriest. His services to Russia and the Russian Church were greatly valued; from the obituary, it was possible to trace in all its details the Lebedintsev family and even to construct its family tree. The Lebedintsevs belonged to a well known, especially in Little Russia, large family of clergymen, who frequently published their researches into the history of the Church in Russia as well as extensive autobiographical articles. There is an entry about them in the Brokgauz [Brockhaus] and Efron encyclopaedia and there are quite a few references to their works in the Index of the Library of the Russian Academy of Sciences in St Petersburg. In the XXth century, the Church tradition was broken by the Lebedintsevs. Thus K F Lebedintsev became a mathematician. His textbooks and exercises on algebra were repeatedly published and republished in Russia [8], and were recommended by various Ministries, in the first place naturally by the Ministry of National Education and also as the main teaching manuals and aids for Secondary Schools. The first editions of K F Lebedintsev's books appeared in 1910 – 1916, so that it is quite possible that George Gamow might have learned algebra from the textbook written by his relative.

Gamow does not mention this particular Lebedintsev but writes in fair detail about another kinsman — his first cousin Vsevolod, the son of Vladimir Arsen'evich who was the Chairman of the Odessa Court (and the grandson of the Cathedral Archpriest). His mother was Italian and this was apparently the reason why the young man, attracted to astronomy, was sent by his parents to Italy to study this science under the supervision of the renowned astronomer Giovanni Schiaparelli of the canals on Mars fame). In Gamow's words, Vsevolod Lebedintsev was attracted by the ideas of Italian 'nihilists' and joined their movement, which was close in spirit to our own National Will. After his return to the fatherland, he joined the most radical wing of this movement. Together with his comrades he planned an attempt on the life of P A Stolypin (this is what Gamow has written), but the entire group was betrayed by Azef shortly before the date earmarked for the attempt. Its members were arrested and executed.

Vsevolod Lebedintsev and his friends in misfortune became prototypes of the famous 'Tale of the Seven Hanged Men' by Leonid Andreev, which George Gamow did not fail to mention. Andreev's work has been thoroughly investigated (and is being investigated) by historians of the literature and there was no special difficulty in establishing the circumstances of the life and death of the prototypes of Andreev's tale. What Gamow has written has been confirmed, apart from a small although a significant detail. The subject chosen for the assassination attempt by Lebedintsev's group (Lebedintsev was its leader) was not Stolypin but I G Shcheglovitov, the Minister of Justice at the time, a character who was more than negative and even sinister. As regards Vsevolod Lebedintsev, introduced by Andreev under the name of Verner, he is represented in the story as a steadfast and clever man — no doubt in full conformity with what he had really been.

The military line was also broken in the Gamow family; the representatives of this fairly ancient family (in the encyclopaedia it is traced back to the XVIIth century) included in more recent times also mathematicians. One may therefore take it that both on his mother's and on his father's sides the corresponding talents were encoded in the Gamow genes (here we may add that towards the end of his life Gamow unravelled the puzzle of the hereditary code).

Gamow does not write about any external stimuli which determined his interest in natural sciences and mathematics (apart from the telescope and microscope already mentioned). However, it is thought that a factor which played a by no means minor role was the existence in Odessa of the 'Matezis' Publishing House, which was well known in pre-revolutionary Russia and which published books and brochures on natural sciences. Gamow states that he read with interest the brochures which began to appear on the theory of relativity; there is no doubt that he did not overlook H Lorentz's textbook of physics which was translated into Russian and published by 'Matezis'. Gamow recalls that at the time of the civil war he was sitting at the window of his room and reading a book on Euclidean geometry while the reality of the XXth century was making itself known by breaking glass owing to an explosion outside. Thus the shock wave, which Gamow investigated during the Second World War in the USA at the request of the U.S. Navy, entered his life much earlier!

For Gamow, who graduated from the school in which his father taught in 1921, there was no question concerning the choice of a career: the university (called at the time the Novorossiisk University which afterwards became the Odessa University in view of its location) and the Mathematical Division of the Physicomathematical Faculty. He joined it in the same year of 1921. Outstanding physicists lived in Odessa at that time — L I Mandel'shtam and N D Papaleksi, as well as I E Tamm who was embarking on his scientific and teaching career. However, they all worked at the Polytechnic Institute. Physics was represented at the University by Prof. N P Kasterin, a pupil of A G Stoletov. He was known through his studies on molecular physics and acoustics (and also, alas, through his rejection of the theory of relativity). Gamow writes kindly about Kasterin, emphasising — what is a characteristic feature of his book — entertaining incidents associated with the professor†. Brought up in the classical spirit, Kasterin could not imagine lectures on a general course of physics without the corresponding lecture demonstrations. However, it was simply impossible to organise such demonstrations at the University, which had not yet been set to rights after the devastation. Kasterin then categorically refused to deliver the course of lectures, remarking that he did not propose to engage in 'melodeclamation'. To the Russian ear, an apt pun is readily perceived in this instance: to give a recitation with the aid of chalk [deklamirovat' = recite, mel = chalk] instead of using demonstration instruments. Gamow expended much effort to make his anglophone readers appreciate the wit of this pun, which naturally loses its sharpness in detailed linguistic explanations. A general characteristic feature of Gamow's autobiographical book is an endeavour to convey to his readers the picturesqueness of Russian speech, ranging from the classical poetry of Pushkin, Blok, and Voloshin to a children's song about 'chizhik-pyzhik' [siskin-young deer].

Gamow established good relations with the University mathematicians, in the first place with Prof. V F Kagan (he, incidentally, directed the Natural Science–Mathematics Department of the 'Matezis' Publishing House), who delivered a course of lectures on multidimensional geometry, and Prof. S I Shatunovskii (Higher Algebra). Gamow notes that under their supervision he himself studied and dealt with problems of the theory of sets and the foundations of geometry. With evident satisfaction, he relates the story of how Shatunovskii was caught out in an arithmetical error by a student, which arose in the mental multiplication of two-digit numbers. Without denying his mistake, Shatunovskii snapped at his young critic: "It is not the job of mathematicians to do correct arithemetical operations. It is the job of bank accountants".

Commenting on this statement by the famous mathematician, Gamow writes: "I am not ashamed if in multiplying 7×8, I get 45." "Fairy tale — falsehood", as Pushkin used to say, "but it contains a hint of the truth: a good lesson for a fine young man". Gamow mentions his troubles with mathematics more than once. This claim conflicts with the high assessment of his mathematical abilities by Prof. G M Fikhtengol'ts, who subsequently became the author of one of the best Russian textbooks on analysis. (G M Fikhtengol'ts, a Leningrad mathematician, was born in Odessa where he taught mathematics for several years. It is not clear whether he knew at the time any of the Gamows or whether he became acquainted with Gamow during the test examinations when the latter joined the Petrograd University.)

At that time, the news of the vigorous development of physics in Petrograd reached Odessa and George Gamow decided, with the blessing of his father Anton Mikhailovich, to join the Physicomathematical Faculty of the Petrograd University. He travelled to the city on the Neva armed with a letter of recommendation to V N Obolenskii, a professor at the Forestry Academy (with whom Anton Milhailovich Gamow was acquainted in Odessa) and also with a certain sum of money gained from the sale of family silver.

Thus the most important, decisive stage in George Gamow's life began in 1922. In the curriculum vitae written on the 2nd October 1925 when he began work in the Computational Subdivision of the Theoretical Division of the Physicotechnical Institute (PTI), Gamow wrote the following statement — apparently the most detailed and accurate information about his places of employment:

1. On the staff of the Computational Bureau of the Astronomical Observatory in Odessa in 1921.
2. On the staff of the Meteorological Station of the State Forestry University in Leningrad from July 1922 to September 1923.
3. In charge of the Field Meteorological Observatory at the 1st Artillery School in Leningrad from September 1923 to October 1924.
4. A nonstaff employee at the State Optical Institute (SOI) in Leningrad from October 1924 to April 1925.

The following comments have been made concerning the places of employment of George Gamow in Petrograd–Leningrad (apparently in 1925 the people of the above city already became rapidly accustomed to its new name so that Gamow, speaking of his work in 1922 and 1923, forgets to mention that this was still the 'Petrograd' period').

Before the revolution, the State Forestry University was called the Forestry Institute (incidentally, Ya I Perel'man, who shared with the 'later' Gamow the renown of a brilliant populariser, graduated from this Institute). In the 1930s the same educational establishment was called the Kirov Forestry Technical Academy. It was there in fact that Gamow began to work for Prof. Obolenskii. His duties were not onerous and occupied him altogether for one hour per day. However, this hour comprised three '20 minute periods', each of which began daily on weekdays and holidays, at 6 in the morning, at 12 noon, and at 6 in the evening. Gamow recorded the readings of instruments measuring the temperature, atmospheric pressure, and wind velocity (and direction), mounted on a hill in the picturesque park of the Forestry Technical Academy (we shall refer to it by its modern name). Gamow wrote: "I still remember climbing on my knees (with a flashlight before sunrise and after sunset during the winter months) with snow falling on my head" ([6] p. 152). However, for the rest of the time he was free and managed to work in the libraries and to attend lectures. Obolenskii grew to like the diligent and sensible young man and suggested to him that he should become a meteorologist and was deeply offended when Gamow refused. Nevertheless, it is interesting to note that during this brief stage in Gamow's life his profession was the same as that of his university profes-

† Gamow recounts that he was well acquainted with Kasterin's daughter Tatiana, who was a student in his class. "Tanya and I became very good friends", he adds, "and could have become husband and wife had I not been so shy. But I was shy, so nothing came of it" ([5] p.27)." This is an interesting self-assessment by young Gamow, which has little in common with his usual personality!

sor — Alexander Friedmann, and it cannot be ruled out that it was in this connection that they first became acquainted. His work as an observer provided Gamow with means for subsistence.

Gamow devotes a fairly large amount of space in his book to his work at the 1st Artillery School which at the time underwent a change from its previous name 'The Grand Duke Konstantin Artillery School' to the 'The Red October Artillery School'. In addition to his management of the observatory, the 20 year old Gamow was asked to deliver lectures on physics — he deputised for a lecturer who had taken sabbatical leave. The lecturer had to have the *ex officio* rank of colonel and indeed Gamow became a colonel, recieved the appropriate ammunition, a budyonovka (a conical hat, referred to by the wits of the time as 'umoo-trod' — mind shunt), and four rectangles (Gamow refers to 'squares' having forgotten that a colonel had 'rectangles' and not 'squares' placed on his collar).

With his characteristic humour, Gamow described his adventures in field practice, which he performed with students reading the course, frequently mounting his 'personal horse' with the nickname Voron (Raven), etc. (He mentions the panic which his report that he had been a colonel in the Red Army caused among the officials testing the political loyalty of the physicists called upon to work at Los Alamos in the late 1940s in connection with the development of the hydrogen bomb project.) His work at the Artillery School strengthened Gamow's financial position and it may be that he acquired his lecturing skills there.

Gamow also comments in detail on his collaboration with the State Optical Institute to which he was brought by Dmitrii Sergeevich Rozhdestvenskii and again largely emphasises the entertaining incidents concerning the work in the experimental laboratory of this Institute. To start with, Gamow was given the task of developing a method (and of testing its effectiveness) for the quality control of the optical glass prepared at the Institute. This work was comparatively new — previously such glass was supplied to Russia by Germany. The 1914 war naturally interrupted these supplies and the need for optical glass for defence purposes naturally increased. I V Obreimov put forward a fundamental although simple idea for the quality control. The test specimen is placed in a liquid the refractive index of which may be regulated. When it becomes equal to that of the piece of glass investigated, the specimen becomes invisible except for the inhomogeneities present in the glass — the so called schlieren. These were in fact the observations on which Gamow was engaged. Subsequently Rozhdestvenskii asked him to study anomalous dispersion (in potassium vapour) — these investigations were his hobby. Gamow worked without much enthusiasm and, in his own words, soon abandoned the experiments which did not work satisfactorily and decided to select a theoretical study as his diploma subject. He claimed that he was subsequently very surprised to find that the results of his optical topic were published. This happened in 1927 in the German journal *Zeitschrift fur Physik*, popular among the physicists throughout the world during those years [9]. The paper "Anomalous dispersion of the lines in the potassium main series" was published under the names of G A Gamow and V K Prokof'ev (W Prokefev), who continued, now without Gamow's participation, the experiments on the anomalous scattering. However, Prokof'ev writes in his reminescences about

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D S Rozhdestvenskii that Gamow's role in the research was large, consisting in the theoretical interpretation of their results. According to Prokof'ev's statement, P S Ehrenfest became interested in this investigation.

Nevertheless, Gamow's main activity in 1922–1928 involved study and postgraduate work at the University. On 1st September 1922, he joined the Physical Division of the Physicomathematical Faculty. In a brief document written personally by Gamow as a student, which is kept in the Archive of the St Petersburg University, there is a list of examinations which he passed in the course of his study. We find outstanding Petrograd (Leningrad) physicists and mathematicians among his examiners. These were in the first instance O D Khvol'son (General Physics Course), V K Freederiksz (Optics), M M Glagolev (Electricity), A I Tudorovskii (Theoretical Mechanics), Yu A Krutkov (Mechanics), and V I Smirnov (Mathematics). Gamow was examined in practical physics by Prof. V I Pavlov (the son of the great physiologist) and by K K Baumgart and again by Yu A Krutkov in the knowledge gained from the lectures delivered in seminars by the examiners.

While acknowledging the undoubted importance of the studies carried out by Gamow at the State Optical Institute and of the physics and mathematics courses which he read and passed, we may venture to express the view that the nonobligatory lessons in physics were even more important for him. Here we have in mind his participation in the University physics seminars, his socialising with older members of the Physical Faculty, professors, and lec-

'The whole Jazz Band'. From left to right: A I Ansel'm (Aldi), G A Gamow (Johnny), D D Ivanenko (Dymus), and V A Kravtsov (Bobby). Below: Part of the reverse side of the photograph. The following words are written in Gamow's hand: The epoch of the box N 13′—a room in the building of the Physical Institute in Leningrad State University where the theoreticians met.

turers. Thus Gamow recalls the strong impression made on him by the lectures of A Friedmann—at the time when Gamow arrived in Petrograd Friedmann was already the author of the theory of the expanding universe. This theory, which refutes Einstein's cosmological ideas based on his general theory of relativity, was initially criticised by Einstein and then adopted by him. It made a profound impression on Gamow. He wrote that he decided to specialise in this field of physics or, at least and as a beginning, to select this topic for his diploma work. A Friedmann accepted the proposition that he should supervise it. Cooperation between the very young student and the young professor with world renown thus began. In one of his autobiographies Gamow refers to Friedmann directly as his teacher and writes with sorrow about Friedmann's premature death (1925), which interfered with his plans.

Gamow's contacts with the theoretical physicists Yu A Krutkov and V A Fok and the mathematician V I Smirnov were also fruitful. His friendship (and later also collaboration) with his comrades at the Physico-mathematical Division were no less important for Gamow. This association was called by its members 'The Jazz Band' (subsequently 'Jazz Band' and 'Joe Band'; in the latter case, the name Joe or Johnny is one his friends used to address George Gamow). A V Kravtsov provided me with the photograph published here of G A Gamov, D D Ivanenko, A I Ansel'm, and V A Kravtsov, dated 22nd February 1926 (the photograph was taken in the photographic studio of the celebrated Leningrad photographer Napel'baum). At the back of the photograph there is an inscription in Gamow's hand: 'The whole Jazz Band' this means that it began with four young people appearing under the nicknames of Joe, Dymus, Aldi, and Bobby respectively. The circle of friends then expanded and included L D Landau (Dau), M P Bronstein (Abbat, Abbatik) and V A Ambartsumyan (Ambarchik). The core of the circle undoubtedly consisted of Gamow, Ivanenko, Landau, and Bronstein (who joined them a little later, towards the end of 1926).

They called themselves the musketeers after the heroes of the famous novel by A Dumas (however, it is impossible to compare the four physicists with the four king's musketeers).

This splendid quartet also had a circle of friends and kindred spirits who occupied, as it were, second rank positions. Apart from the students already listed, one should add to them F F Vol'kenshtein (Fefu). The female sex was also quite well represented in the company of the musketeers. There is no doubt that the sisters Evgeniya and Nina Kanegiesser (a physicist and a biologist) and Irina Sokol'skaya (a physicist and subsequently a university professor) were stars of the first magnitude. Without risk of giving offence to the memory of Nina Nikolaevna and Irina Leonidovna, priority among the fair sex must be given to Evgeniya Nikolaevna, later Lady Peierls. After graduating from the university, Evgeniya Nikolaevna became a good physicist, but was later remembered as a person with remarkable literary gifts and entered as such into the annals of the history of Russian physics in the 1920s. She had an excellent knowledge of Russian and German (and later also English) poetry and herself wrote poems—both humorous and serious. The former became the property of a wide circle of Leningrad and not only Leningrad physicists. About the latter—her lyric verses—much less is known. In 1956, during their holiday in Europe, Gamow wrote a cordial, friendly letter to Evgeniya Nikolaevna and enclosed as an appendix her most successful verses, which he reproduced from memory.

Naturally Bronshtein, Gamow, Ivanenko, and Landau were mainly united by physics, a science which they loved devotedly and this was reciprocated. This reciprocal loving relationship is also revealed by the facts in their biographies. An early success was characteristic of all four physicists (this is, incidentally, a characteristic feature of theoreticians). We produce here their names followed by the years of their first scientific publications in well known journals: Bronstein (1906–1938)—1925; Gamow—1926; Ivanenko (born in 1904)—1926, and Landau (1908–1968)—1926. There are also interesting comparisons: Bronstein and Gamow are famous not only because of their theoretical studies but also because of their activities as popularisers of science. Their books are still being reprinted. Yet another aspect involves textbooks for higher educational establishments. Here there is no doubt that priority goes to Landau—his textbook (written together with E M Lifshitz as a coauthor) is known throughout the world. But, Gamow also wrote a series of books for higher educational establishments, which have enjoyed a major and deserved success. Ivanenko (jointly with A A Sokolov) published a two volume textbook on the classical and quantum field theory. Only Bronstein, whose life was prematurely and tragically terminated, did not leave behind this kind of 'university' textbook, although Ya A Smorodinskii kept three notebooks on each of which the following words were written: ''M P Bronstein and L Landau. Statistical Physics (synopsis of manuscript)'' ([10], p. 206).

An unfortunate circumstance which all four had in common was conflict with authority. Bronstein's fate is well known: he was arrested in August 1937 and shot in February 1938. Ivanenko was tried in March 1935 and, after spending five years in a concentration camp, was sent into exile in Tomsk. Landau was arrested in 1938 and only thanks to the exceptional boldness of P L Kapitza, who interceded on his behalf, was he freed from prison after spending a year in it. Only Gamow escaped this fate having left the USSR forever in 1933 — is it not likely that the appreciation of the potentially tragic development of events was one of the reasons for his departure abroad?

However, in the middle and the second half of the 1920s, the life of the quartet was without a cloud on the horizon. It spread before Gamow in its splendid present and in the beckoning future. A new physics — quantum mechanics — was born before his very eyes. About its first steps and its dizzy advances, he learned from current issues of physical journals and from the words of those of his teachers and senior colleagues who became rapidly involved in this activity — they were already lucky enough to spend some time in European scientific centres where the founders of the new science worked together with their schools. In Germany this was Gottingen with Max Born and his young assistants (W Heisenberg, P Jordan, and F Hund); in England this was Cambridge with the great theoreticians R Fowler, C Darwin, and a rising star in theoretical physics — P A M Dirac; while in Holland such a centre was Leiden with P S Ehrenfest and his students H Kramers, S Goudsmit, and D Uhlenbeck (the first Soviet physicist who visited Bohr in Copenhagen in 1928 was Gamow himself). Among those theoreticians whom Gamow got to know at the univerity, the State Optical Institute, and the Physicotechnical Institute, and who succeeded in working in the above centres were V R Bursian, Yu A Krutkov, I E Tamm, V A Fok, V K Freederiksz, Ya I Frenkel', and A Friedmann.

Fairly democratic rules reigned at the University, the attendance of lectures not being obligatory. Thus Gamow contrived not to attend even one lecture by Khvol'son! What guided him in this is not clear. It may be that he was convinced that Khvol'son lagged hopelessly behind modern physics. But, this was not so. Despite his catastrophically failing sight, the 75 year old professor was well informed about current physical novelties and, furthermore, responded to them in print (this included his papers and brochures on the theory of relativity and the book *The Physics of Our Day* [11], which was published a little later than the time under consideration — 1930 — and in which the results obtained by Gamow two years earlier are described more than routinely! ([11], pp. 326, 344).

Gamow was a diligent student and later a diligent scientific worker. His reviews and books (the first edition of the book on the atomic nucleus was published in 1930 when its author was only 26 years old [12]) indicate the acquisition of an enormous amount of data, which were digested and arranged systematically. However, he himself and his fellow students were able, and liked, to relax well, which is of course quite natural. As is frequently the case with young and talented students and scientists embarking on their career, they liked to pretend that they were engaged in science 'among other things', that they leared and remembered everything, as it were, 'in flight', and that in general science to them was a joyous game. A sharp wit, a happy prank or a practical joke, and pre-eminence in intellectual or sporting games were valued no less than success in science. The success of the entire quartet during student years, although not overwhelming, was quite substantial. An overwhelming success awaited Gamow in the fairly near future.

Khvol'son's opinion about Gamow was based on the impression gained from the examination which Gamow had taken on the general physics course (however, much he might have wished it, Gamow could no longer stay away from him), on the reading of Gamow's first papers, and on the views of other university professors. Perhaps it is now appropriate to summarise briefly Gamow's publications.

Chronologically the first work by Gamow which appeared in print, published jointly with Ivanenko, was ''The wave mechanics of matter''. It was printed in *Zs. Phys.* [13], a fifth to a quarter of the papers in each issue of which were by Soviet physicists. Carried out under the undoubted influence of V A Fok, this study demonstrated that the young people were able to operate freely with the concepts of quantum mechanics newly born and attempted to use five-dimensional geometry for the solution of the Schrodinger equation, having selected the ψ-function as the fifth coordinate. Gamow mentions this work only very briefly.

He speaks at significantly greater length about the paper based on his diploma work [14]. Yu A Krutkov, a pupil of P S Ehrenfest, was Gamow's supervisor in his diploma work. As Ehrenfest's pupil, Krutkov began his scientific career with studies on adiabatic invariants, taking over from his teacher. Gamow wrote that he occupied himself with his diploma work without special enthusiasm and did not bother to complete it. The reason for this procrastination was that the formulation of the relevant study was somewhat obsolete. Quantum mechanics was already around by that time but Gamow had to deal with the old quantum theory, although he was here concerned with fine points of the latter. His task included the examination of the transition of the motion of the Rayleigh pendulum (a pendulum with a slowly varying length) from vibrational to rotational motion, i.e. from an oscillator to a rotator. The adiabatic invariant of the Rayleigh pendulum is E/ν — the ratio of the energy of its vibrations to their frequency. Ehrenfest demonstrated in his time that the adiabatic invariants are in fact quantisable in the quantum theory. However, he noted that in the above transition (from an oscillator to a rotator) the adiabatic invariant is not preserved. This paradox was later emphasised in a joint study by Ehrenfest and his American student G Breit. Gamow demonstrated that the paradox can be accounted for by the fact that, at the point corresponding to the transition from the vibrational to the rotational motion, the adiabatic condition (slow change of the parameters of the system — say the length of the pendulum or, as happens in the case considered by Gamow, the change in the acceleration due to gravity) does not hold, which in fact leads to the resolution of the Ehrenfest–Breit paradox.

Gamow's paper [14] was not outstanding among the series of good quality papers which appeared in the pages of the physics section of *Zhurnal Russkogo Fiziko-Khimicheskogo Obschchestva* [Journal of the Russian Physico-chemical Society] in 1926 but it undoubtedly played a decisive role in Gamow's subsequent fate. One can hardly doubt that its preprint was sent to Ehrenfest in Leiden — either by Gamow himself or by Krutkov. Ehrenfest might have recalled the very young man who spoke two years earlier, in 1924, at the IVth Congress of Russian Physicists in Leningrad — a Congress in which Ehrenfest participated.

In publishing the biographical article on Gamow in the pages of *Uspekhi*, it is gratifying to note that chronologically his next article appeared in this. This was a tiny review, or a large abstract, headed "The principle of fundamental observability in modern physics" [15]. Gamow wrote copiously about the advances in quantum mechanics and in the statistical interpretation of the wave function and about the actual equivalence of the two approaches (Heisenberg's and Schrodinger's). Attention is concentrated in the review on the development of Heisenberg's ideas about the necessity of dealing with quantities which are observable in principle, i.e. quantities for which a method of their direct determination may be indicated. Such quantities should in fact be employed in constructing a physical theory. With the aid of the analysis of the Compton effect, Gamow achieved a very elegant derivation of Heisenberg's uncertainty relation. If one were to select an example of Gamow's skill as a populariser of science (for example, one to be placed in an appendix to a complete biography), then perhaps the article from *Uspekhi* would be the best choice, which would compete successfully with excerpts from his numerous science fiction books (for example, about the adventures of Mr Tompkins, which have finally seen the light of day in Gamow's fatherland [16]).

We shall omit here the experimental 'half-paper' (this is what Gamow called it, bearing in mind his coauthor V K Prokof'ev) about anomalous dispersion (which was mentioned above) and shall proceed to his last paper prior to his departure [17]. It was published in *Zhurnal Russkogo Fiziko-Khimicheskogo Obschchestva* under three names: Gamow, Ivanenko, and Landau. Gamow does not mention it in his book; it was not included in the two-volume collection of Landau's work. What a pity! In recent years, this paper, written by the three musketeers (their combined age at the time of the publication of the paper was 65 years, which does not greatly exceed the average age of Full Members of the present Russian Academy of Sciences) has attracted the attention of investigators (see the papers by L B Okun' in *Uspekhi* [18] and the special paragraph devoted to it by G E Gorelik in the book about M P Bronstein written jointly with the present author [10]).

The subject of the communication indicates the interest of the young theoreticians in fundamental problems of physics: The title of the paper is "World constants and the limiting transition". The choice of such constants as key quantities permitted conclusions about the limits of the applicability of particular theories, atomicity ('granularity' — similar to the granularity of the electric charge), time, and length. The Planck constant h, the velocity of light in vacuo c, and the world-wide gravitational constant G were chosen as such world constants [17] (12 years later the Latin letters designating these constants were chosen by Gamow as the initials of his hero, expanded in the English manner, who was presented to the readers as C G H Tompkins). In the above paper [17], the authors develop with the aid of the aforementioned world constants and their combinations a kind of hierarchy of physical theories — in terms of the extent to which they are fundamental. Here the transition from one to another is achieved by means of the limiting transition — the tendency of the corresponding constants h, $1/c$, and G towards zero.

In the stated hierarchy of theories (or fields of physics) associated, say, with Planck's constant h, Newtonian mechanics — classical in relation to h — occupies the lowest step. Quantum mechanics — in the above paper [17] it was called 'limiting' in relation to h — is reduced to Newtonian mechanics by means of the limiting transition $h \to 0$. On the other hand, Bohr's quantum theory of the atom (second, intermediate step), 'with its h derived ad hoc' — in the words of Gamow, Ivanenko, and Landau — 'can be called vulgar'. The three musketeers, who were soon due to become acquainted with Bohr, were hardly likely to tell the latter about this not very flattering epithet, which they applied to the old quantum theory, the importance of which in the development of physics cannot be overestimated!

In relation to the constant $1/c$ (the authors regard the reciprocal of the velocity of light as the 'true' constant in contrast to c itself), relativistic mechanics is placed on the highest step of limiting science. Newtonian mechanics (as well as nonrelativistic quantum mechanics) occupies the first step and is classical in relation to $1/c$, whereas the role of the vulgar theories is assigned to prerelativistic electrodynamic sciences. The paper ends with the consideration — in line with the tradition already established at that time — of combinations of world constants, defining in terms of dimensionality the quantities most important for the theory of the electron — its charge and mass. Analysis of these quantities enables the authors to reach a conclusion about the ways in which the theory of the electron may be constructed in terms of the general theory of relativity: according to the authors [17], such attempts are doomed to failure.

In his various questionnaires, Gamow gave different dates of his graduation from the university. In the first place, he states that he completed a 'course of sciences' in three years (instead of four), i.e. in 1924. On the other hand, when he departed for Germany in the summer of 1928, he still counted as a student, although by that time he had defended a diploma work. It may be that this time discrepancy is in fact associated with the very concept of graduation from the university and Gamow sometimes includes and sometimes excludes his postgraduate years.

Archive data [1] indicate that as early as the end of 1926 O D Khvol'son recommended Gamow as a candidate for posting to a summer term in Germany in 1927 at the expense of Narkompros [The People's Commissariat of Education]. However, nothing changed until May 1928 (!): events then began to develop at a proper rate or at what could even be described as breakneck speed from the standpoint of people who have become used to the tortoise-like rate of movement of official papers in our sticking bureaucratic machine.

As a result, young Gamow, accompanied by his friends, arrived in the Leningrad seaport before 10 June 1928. At that time there was a regular steamer service to Germany — to Stettin and Swinemunde. The sea journey was both cheaper and simpler: there was no need to obtain transit visas through 'intervening' countries on the way to Germany (the Baltic States and Poland). Having reached Swinemunde and having changed to a train, Gamow appeared in Gottingen on 11th June. He gives a hilarious account of his first evening and night spent in this quiet small university town. On the following day, Gamow took furnished rooms which were rented to visiting foreigners by the widow of one of the Gottingen professors. Gamow describes both the hospitable old woman and the room given to him in the flat on the fourth floor of a house on Herzenberger-Landstrasse. Apparently this was Frau Wende, well known among Leningrad physicists visiting Gottingen. Quite a few Leningrad physicists assembled in Gottingen at the time, including N E Kochin (subsequently an Academician), Yu A Krutkov, and V A Fok, who knew Gamow well. They introduced Gamow to Max Born, who headed the Institute of Theoretical Physics at the University and who conducted a famous seminar on theoretical physics. During one of the first if not the first 'working days', Gamow spent some time in the university library in order to become acquainted with current journals. In his words, he did not endeavour to become involved in the development and application of the general principles of quantum mechanics to specific problems. In his view, this would have meant (at the given stage) becoming immersed in the mathematical treatment of the corresponding (no longer fundamental) theories. (Surveying, from the standpoint of the 1990s, all that has been achieved in this field during the more than 60 years which have elapsed, we surely cannot agree with Gamow!) He sought new fields untouched by the 'sharp minds' of theoreticians. His first visit to the library already revealed to him such a field. This was nuclear physics. Incidentally, it is likely that Gamow began to think about nuclear topics already in Leningrad: the participants of the theoretical seminar at the Physicotechnical Institute state that problems of the theory of the nucleus and in particular of nuclear forces were already discussed at these meetings.

This is why it was not fortuitous that an issue of the *Philosophical Magazine* attracted Gamow's attention, especially since Rutherford's paper 'The structure of radioactive atoms and the origin of α-rays' was published in it [19].

The paper deals with the nuclear reaction arising when uranium is bombarded by fast α-particles from natural radioactive sources. Rutherford was concerned with the question why these particles, having an energy approximately twice as great as the α-particles emitted on disintegration of uranium, cannot penetrate the nucleus. After all, the same barrier does not prevent the escape of α-particles from uranium. Gamow states that, as a classical physicist, Sir Ernest proposed the following explanation to account for this paradox. A neutral helium atom is emitted from the nucleus — Coulombic forces do not hinder it! After this, two electrons are abstracted from the helium atom via some kind of unknown mechanism, are attracted to the nucleus, and return to it (we may recall that the neutron had not been discovered at the time and it was assumed that, within a nucleus with an atomic mass A and an atomic number Z, there are $A-Z$ electrons compensating for the charge on some of the protons), whereas the α-particle formed continues its motion outside the nucleus. Rutherford explained this by an analogy. Imagine, he said, that an enormous steamer is towed out of the harbour by two tugs, which return on reaching the open sea. Rutherford's analogy appeared to Gamow as no more than entertaining. Having thought about it, he understood what was happening: namely that the wave function describing the α-particle penetrates and 'seeps through' into the region beyond the barrier and emerges from this region. This means that the probability of observing an α-particle outside the limits of the nucleus is different from zero. He returned home and, in his own words, on the following day his paper was ready as regards the underlying ideas. It was immediately supported by E Wigner and F Houtermans in Gottingen (the latter subsequently became Gamow's coauthor). L Rosenfeld, subsequently Bohr's assistant and closest collaborator, also worked in Gottingen at the time. He recalls that Gamow successfully reported his work at Max Born's famous seminar and that this report caused a 'literal sensation'.

On 29th July, Gamow sent his paper to *Zs. Phys.* [20]. It described a detailed theory of α-decay on the basis of the concept of the sub-barrier 'escape' (i.e. the tunnelling effect — this term came into use later) of the α-particle from the nucleus. It is shown by the direct solution of the Schrodinger equation for a potential barrier of special form that, although the energy of the α-particle is in fact lower than the height of the Coulombic barrier surrounding the nucleus, there is a finite probability of observing it outside the confines of the barrier.

After a few preliminary remarks, we shall turn directly to Gamow's paper on α-decay. We may point out in the first place that the history of the writing of this paper, the prehistory of the problem (a large review of the development of nuclear physics up to 1928), and analysis of the paper itself are given in an excellent work by R Stuewer [21]. Experimental studies on the scattering of high-energy α-particles over a period of many years, initiated by Rutherford, led him in 1911 to the construction of a nuclear model of the atom. By 1928, the data accumulated during almost two decades, referring to the phenomenon of α-radioactivity, made it possible to obtain fairly accurate characteristics of this process. The half-lives of the α-radioactive nuclei (according to current data, they cover an unusually wide time range — from 3×10^{-7} to 5×10^{26} s), the energies of the α-particles emitted by the nuclei (from 4 to 9 MeV), their discrete spectrum, line widths, etc. were known.

These data made it possible to estimate the radius of the atomic nucleus, which proved to be $\sim10^{-13}$ cm, i.e. smaller by 5 orders of magnitude than the atomic radius. Rutherford's coworkers H Geiger, and J M Nuttall (1911–1912) made the important discovery of an experimental relation between the half-life of a α-radioactive nucleus τ and the path traversed by the emitted α-particle R_α, which is involved in a one-to-one relation with the velocity v (and the energy E) of the α-particle. It was found that, when plotted in the ($\ln\lambda$, $\ln v$)-scale, the corresponding relations can be represented by straight lines for the three radioactive series (Fig. 1); we recall that $\lambda=\ln2/\tau$ is the so-called decay constant.

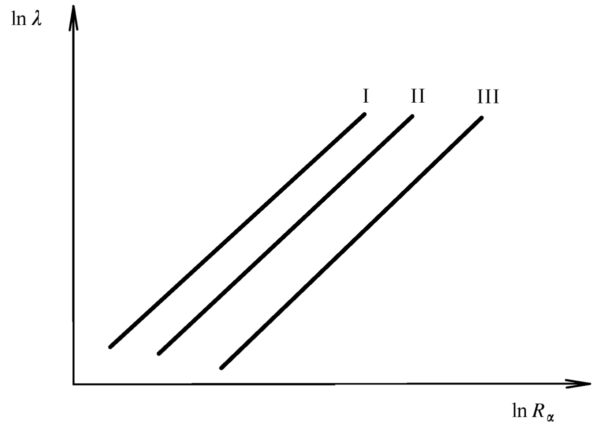

Figure 1. Schematic illustration of the Geiger–Nuttall law. $\lambda = (0.7/\tau)$ $(1/c)$ is the decay constant and R_α the length of the path traversed by α-particles in air (determined from their energies). Series: (I) uranium; (II) thorium; (III) actinium.

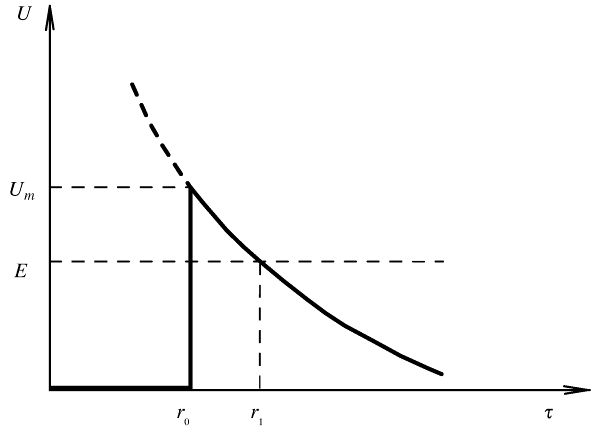

Figure 2. Coulombic potential barrier surrounding a spherically symmetrical nucleus with radius r_0. U_m = height of the barrier. The curve (continuous and dashed) is described by the Coulombic formula. The region $0 < r < r_0$ is the region where nuclear forces operate.

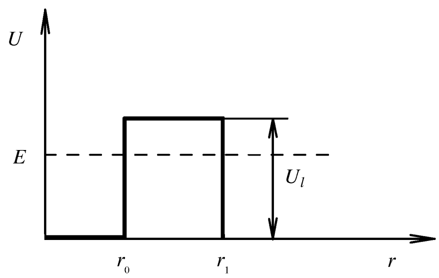

Figure 3. A rectangular potential barrier with a width $l = r_1 - r_0$ surrounding a nucleus with a radius r_0.

The relative stability of radioactive elements with their positively charged nuclei (and especially the stability of the atoms of nonradioactive elements) implied that the charged particles forming part of the nucleus are bound over short distances by short-range cohesive forces. According to the ideas at the end of the 1920s, a nucleus with an atomic mass A and an atomic number Z consisted of N_α α-particles (an 'α-conglomerate' according to Gamow) and N_p protons as well as $A - Z$ intranuclear electrons compensating for the positive charge on the nucleus: $A = 4N_\alpha + N_p$, where $N_p = 0$, 2, and 3 respectively for the radioactive thorium, uranium, and actinium series†. According to modern ideas, it is believed that the nucleus consists of nucleons—Z protons and $A - Z$ neutrons—linked to one another by charge-independent (i.e. identical for the p–p, p–n and n–n pairs) nuclear attraction forces.

Another experimental fact already known in the 1920s was the impermeability of nuclei to the α-particles of radioactive elements with an energy exceeding by a factor of 2 the energy of the α-particles emitted by these nuclei (the findings of which Rutherford spoke). This indicates the presence of a barrier preventing such penetration. This barrier is due to the Coulombic repulsion forces. The potential energy curve for an α-particle in the nucleus and in its vicinity, expressed as a function of the distance r, therefore has the form presented schematically in Fig. 2. Its profile can be made even more 'schematic' by adopting the model illustrated in Fig. 3 ('rectangular barrier').

The effect involving the passage of an α-particle with an energy E through the barriers illustrated in Figs 2 and 3 (the barrier heights are U_m and U_l, respectively) appears incomprehensible from the classical point of view when the energy E already present in the nucleus of the α-particle is less than U_m or U_1 respectively. Here one must stipulate that the emission of an α-particle from the nucleus does not imply that it had been present in the nucleus up to that moment—just as the emission of an electron from a β-radioactive nucleus by no means constitutes evidence in support of the existence of 'intranuclear' electrons—the idea of their existence had already been abandoned in 1932 after the discovery of neutrons‡. At the same time, since the α-particle is the stable $^4_2$He nucleus, it can also form part of the [atomic] nucleus as a kind of 'cluster', apart from the hypothesis that it arises at the instant of α-decay, i.e.in statum nascendi.

There is a familiar relation between the potential energy of the α-particle U, its kinetic energy T, and the total energy E: $E = T + U$. This means that, since $E < U$, it follows that $T = \frac{1}{2}mv^2 < 0$, i.e. the velocity of the particle in this region acquires an imaginary value. Nowadays it is known from many textbooks on nuclear physics (or quantum mechanics) that the application of simple methods of quantum-mechanical analysis together with Heisenberg's uncertainty principle demonstrates that the observation of an α-particle in the r_0, r_1 region of the barrier is possible although it involves an additional energy being imparted to the α-particle, the magnitude of which eliminates the paradox of its imaginary velocity. These considerations were probably known to Gamow, although neither in the series of his papers in 1928 nor in later publications, in particular in books on the structure of the nucleus and radioactivity (published in the USSR in 1930 and 1932), does he describe them, confining himself to the remark that the phenomenon

‡ Here is a similar example as an illustration (due to Ya I Frenkel'). The presence of sodium chloride molecules evaporating from the surface of a NaCl crystal by no means implies that they had been present 'in a finished form' in the ionic lattice of the crystal.

of the penetration of particles into the region with $E < U$ is analogous to the well-known phenomenon of total internal reflec-tion. In his paper in *Zs. Phys.* [20], Gamow solved the quantum-mechanical problem of the motion of a particle in the field presented in Fig. 2 and showed directly that, when $E < U$, there is a nonzero probability of its permeation through this region (the reflection of a particle from the barrier subject to the condition $E < U$ is just as quantum-mechanical but has no classical analogue).

As a result of his calculations, Gamow obtained a formula for the coefficient of the transparency of the barrier D in Fig. 2 and the decay constant λ, which includes the principal characteristics of the α-decay process: the charge on the nucleus (formed after the decay) Ze; the charge and mass of the α-particle, $2e$ and m; the height u and the width $l = r_1 - r_0$ of the potential barrier through which the particles permeated and finally the velocity of the emerging particle v.

This relation, written in terms of the rotation adopted since then, has the folowing form:

$$\lambda = \frac{v}{2r_0} D_0 \exp\left\{-\frac{2}{\hbar}\int_{r_0}^{r_1} \sqrt{2m[U(r)-E]}\,\mathrm{d}r\right\};$$

It is seen from Fig. 2 that $2Ze^2/r_1 = E$, i.e. $r_1 = 2Ze^2/E = 4Ze^2/(mv^2)$.

After substituting here the 'Coulombic' energy U, integrating, and taking logarithms of the resulting expression, we obtain

$$\ln\lambda = -\frac{4\pi e^2 Z}{\hbar v} + \frac{4e\sqrt{m}}{\hbar}\sqrt{Zr_0} + \ln\frac{\hbar D_0}{2mr_0^2},$$

i.e. an 'easily legible' (theoretical!) formula, from which follows the Geiger–Nuttall law relating $\lambda \sim 1/\tau$ to the velocity of the α-particle v (D_0 is a multiplier of the order of magnitude of unity). The formula also demonstrates a weak dependence of λ on Z and r_0 — the radius of the nucleus†.

Next Gamow proceeded as follows with the formula which he had obtained. Knowing Z and v and having selected a value (one) for the nuclear radius r_0 (he assumed in this case that $r_0 = 8 \times 10^{-12}$ cm), he calculated λ and obtained a satisfactory agreement with his experimental values for different α-radioactive nuclei. On the other hand, using the experimental data for λ and v (naturally knowing also Z and D_0), he obtained a specific value of r_0 for each element in the three radioactive series, diminishing on moving in succession from heavier to lighter nuclei. He found a value of r_0 in the range $(6.6 - 8.9) \times 10^{-13}$ cm for the thorium series, $(6.3-9.5)\times 10^{-13}$ cm for the uranium series, and finally $(6.9-8.3) \times 10^{-13}$ for the actinium series.

Summarising, we may say that the triumphal success of Gamow's study consisted in the fact that he not only explained the 'quantum physics' of α-decay by introducing the concept of the tunnelling mechanism of this phenomenon (we shall show below that very slightly earlier the same had been done by the Englishman R W Gurney and the American E U Condon in their joint investigation) but also calculated from his formulae the radius of the nucleus and obtained a formula which confirmed theoretically the empirical Geiger–Nuttall law. In modern sporting parlance, he raised to an unusual level the fence height which he overcame successfully in the obstacle race with which the difficult pursuit of scientific truth may be metaphorically compared. Did young Gamow think that this significant result might prove to be the greatest achievement in the series of his investigations including those in the future? The history of science shows that it frequently happens that the first outstanding study by a scientist proves at the same time to be also his last major achievement, the level of which he is unable to attain throughout the rest of his life! (This is often true also of the achievements in the arts.) Did he assume that his future work would enable him to equal (if not surpass) the superlative results he obtained already at the age of 24?

Examination of Gamow's paper in *Zs. Phys.* [20] shows that in its concluding part (the section where the authors usually express their acknowledgements) the name Kochin appears. He writes that ''in conclusion I should like to express my sincere gratitude to my friend N Kochin for a friendly discussion of mathematical problems''. In 1968, Gamow stated that Kochin simply showed him how to derive a simple integral encountered in the course of calculations (''I am not good in mathematics'', he explained in the same year to the historian of science, C Weiner, who interviewed him‡). When Kochin's colleagues asked him (already in Leningrad) in what way he had assisted Gamow (his article was apparently known to everyone!) and he stated that it was an integral of the type $\int\sqrt{(1-a/r}\,\mathrm{d}r$§, they all had a friendly laugh at Gamow, while in 1968 he himself joined in their laughter!

It happens in the history of science, and more frequently the closer we are to the present days, that communications about the results obtained by different investigators on the same important problem appear in print almost simultaneously — within several days, weeks, or months. This also happened with the quantum-mechanical theory of α-decay.

Only two months elapsed since the day when Gamow completed his calculations, whereupon, on opening a fresh issue of the English journal *Nature*, he discovered that the idea of the tunnelling mechanism of α-decay was the basis of a qualitative theory of this phenomenon in the paper by R W Gurney and E U Condon [22]. They completed their communication on 30th July, i.e. a day later than Gamow. One cannot fail to recall Pushkin's inspired phrase ''strange coincidences happen!''.

The paper of Gurney and Condon appeared in the issue of 22 September 1929. We indicate all these dates because, in view of the importance of studies on the theory of α-decay, questions concerning priority have occupied both historians of science and the authors of the papers under discussion.

It is interesting that the possibility that the passage of a particle under a potential barrier is considered in Gurney and Condon's paper as something self-evident — without

†The expression for λ presented here is not formulated in Gamow's notation because there is an abundance of misprints in the corresponding formulae in his various publications — this applies both to papers and to books.

‡We have already stated above that, while he formulated his final result correctly, Gamow arrived at it through a fairly complex obstacle field of errors (or misprints).

§In the formula presented above, this is

$$\int_{r_0}^{r_1}\left[2m\left(\frac{2Ze^2}{r}-E\right)\right]^{1/2}\mathrm{d}r.$$

references to the Moscow physicists (Leontovich and Mandel'shtam) or any other sources. Incidentally, these workers referred to the paper by R H Fowler and L Nordheim published in the May issue of the English journal *Nature*. However, we may refer to the later more detailed communication [23] (received by the editors on 31st March 1928 — how rapid was publication at that time!). In their communication, the same idea of 'sub-barrier permeation' was used to account for autoelectron emission.

Here we have again an entertaining feature. In the article commemorating Gamow, Rosenfeld states that, in the discussion of the report on the quantum-mechanical theory of α-decay in Gottingen, Max Born presented an example in which the tunnelling effect 'operates': cold emission of electrons in strong fields. Rosenfeld wrote (in 1972**!**) literally as if this idea had only just entered Born's head directly at the seminar. It may be that this was so and possibly Born recalled a paper by Fowler and Nordheim, a German physicist visiting England, which he had read. At that time, the number of physics journals was small and their inspection was not all that difficult.

A month elapsed and Gamow's note appeared in the same journal *Nature* on 24 November 1928 [24]—naturally without a detailed quantum-mechanical calculation (the solution of the one-dimensional Schrodinger equation with a specified potential relief) but with a presentation of calculated curves describing satisfactorily the characteristics of the decay discovered in the experiments of Rutherford and other investigators. In this communication, Gamow naturally notes the validity of the qualitative findings of his Anglo-American colleagues. Furthermore, speaking of his quantitative theory, he not only refers to its forthcoming publication in *Zs. Phys.* [20], but actually states the number of the page (p. 204 in the 3rd issue of the journal in 1928) on which it appears: this means that its page proofs were 'already in his hands'.

The above communication [21] was concerned also with questions of priority. According to this paper [21], by 1928 the problem of the passage of particles through a potential barrier appeared not only self-evident to leading theoreticians, but the concept was also applied by them to specific tasks. Thus F Hund took this possibility into account in 1927 in considering the behaviour of a diatomic molecule and the corresponding numerical calculation was stated [25] to have been carried out by O Bourraud in the same year. Nordheim did the same in considering the emission of thermal electrons in 1927 [26] and, jointly with R H Fowler, in relation to autoelectron emission in March 1928. In the interview granted by Nordheim to the American historian of science D Heilbron, he recalled that Gamow (according to the latter's own statement) knew about this study even before departing for Germany and was 'inspired' by it. Gurney and Condon referred to these investigations and to Oppenheimer's study (1927) in their communication. To this, we may add the important study by M A Leontovich and L I Mandel'shtam [27], which appeared in 1928 (it dealt with the general problem and its possible applications to specific phenomena were not indicated).

It is somewhat surprising that while it is formally recognised that Gurney and Condon on the one hand, and Gamow on the other, devised the quantum-mechanical theory of α-decay independently, some preference is usually given to Gamow in describing the corresponding investigations. Gamow himself always accurately noted the major role of the study by Gurney and Condon (with whom he had good relations after he became a resident of the USA). The reason for this apparently arises from two factors. The first, already mentioned, is that Gamow was able to confirm by direct calculations, by means of the formulae which he obtained, the validity of the law of Geiger and Nuttall which had been puzzling for many years. The second factor is that he reported his investigation, published it, and subsequently developed it vigorously in Europe, in what was at that time the centre for research into nuclear physics and not only nuclear physics, whereas the USA was then somewhat on the margin of such research. One may apply to Gamow the popular English saying 'the right man in the right place'.

Stuewer begins his article superbly [21]: "George Gamow burst into the European community of physicists like a meteor from outer space". This phrase might be selected as an epigraph to the brief but very fruitful Gottingen period of Gamow's life, with an added modification: this meteor occupied a stable 'planetary' orbit on the horizon of European and World physics! Gamow's stay in Gottingen did not involve solely the preparation and publication of his first communication on the theory of α-decay. During his $2^1/_2$ months stay, he succeeded in writing yet another communication in which a more correct form was given compared to the results obtained previously [20]. This was done together with F Houtermans as the coauthor [28].

The latter must be mentioned especially among the friends whom Gamow acquired in Gottingen. In terms of character and scientific interest, Fritz Houtermans resembled Gamow in many respects. The same fascination with physics and liking for jokes and games (after Houtermans's death, his co-workers, students and friends published a small booklet in which apt examples of Houtermans' wit, funny stories which he told, and amusing incidents which happened to him or which he 'organised' were collected — a similar booklet could be published also about Gamow!). As a scientist, Houtermans was remarkable because he combined the skill of an experimenter with the outstanding ability of a theoretician. After the study on α-decay published jointly with Gamow, Houtermans carried out a brilliant investigation into astrophysics together with the Englishman R Atkinson who was in Gottingen at the time. Starting with the idea of quantum-mechanical tunnelling, Houtermans and Atkinson developed a theory of thermonuclear synthesis. After the studies by Gamow and by Gurney and Condon, it became clear that, in order to achieve the fusion of hydrogen nuclei to form the helium nucleus — a reaction accompanied by the evolution of a large amount of energy — there is no need whatsoever for the hydrogen nuclei to 'scramble' on to the top of the Coulombic barrier. They can fuse in the presence of much smaller energies by permeating through the barrier. Houtermans and Atkinson suggested that this reaction actually occurs within the stars (and the sun), maintaining their high temperature and ensuring their powerful radiation into the surrounding space. Need one say that there is an accurate reference to Gamow in this communication? Gamow told Houtermans a lot about his country and about the vigorous development of physics in Leningrad. There is no doubt that it was on his 'suggestion' that Houtermans was invited in the Summer of 1930 to the 1st All-Union Congress of Physicists in Odessa. This visit was followed, at one year intervals, by trips to Kharkov and Leningrad, and in 1935 Houtermans became a permanent collaborator of the Ukrainian Physicotechnical Institute in Kharkov.

Gamow became acquainted with M Delbrück, E Wigner, and L Rosenfeld, let alone Max Born and Wolfgang Pauli. However, in August 1928 Gamow's visit to Gottingen came to an end when the fully law abiding Gamow set out on his journey to Leningrad via Denmark. He arrived in Copenhagen with 10 dollars in his pocket — this amount of money was sufficient to enable him to spend one day in a cheap hotel. The morning following his arrival, he set out for Blegdamsvej 15, which was then the only building in Bohr's Institute of Theoretical Physics. Bohr's secretary, Mrs Betty Schultz, arranged a meeting between Gamow (having been moved by his poor circumstances) and Bohr. The encounter took place in the library of the Institute. Bohr asked him what Gamow was engaged in at the time. "My secretary told me that you have only enough money to stay here for a day. If I arrange for you a Carlsberg Fellowship at the Royal Danish Academy of Sciences, would you stay here for one year?" — this is how Gamow describes the end of his conversation with Bohr ([5] p. 64). Gamow immediately agreed — here is an instance of how quickly most important matters are settled.

Here we are able to correct somewhat Gamow's account. It follows from documentary data that, whilst getting ready for his voyage, he requested A F Ioffe to write for him something in the way of a letter of recommendation to Bohr whom Ioffe knew fairly well by then. Thus the trip to Denmark had been planned already in Leningrad. Bohr's decision was also evidently thought out beforehand, on the basis of this letter and the news about Gamow's work in Gottingen: the relation between the two European centres of theoretical physics was at the time very lively. Naturally, their personal encounter and the impression which Gamow made played a major role in Bohr's decision.

We emphasise yet another factor concerning the contact between Gamow and the Physicotechnical Institute. The support which he received from A F Ioffe shows that, even during the period when he worked in the State Optical Institute–Leningrad State University setup, he was quite firmly associated with another setup — the Physicotechnical Institute (PTI) – Leningrad Polytechnic Institute (LPI) (Fizmekh).

Letters sent by Gamow from Gottingen to Bohr were received by the latter in good time. In the article mentioned above [21], R Stuewer refers to them. Here we publish only a letter by Gamow and Bohr's reply to Ioffe's letter (as well as an excerpt from his next letter to Ioffe).

Dear Professor

One of the main aims of my trip abroad, was to visit your Institute and to have the opportunity to spend several weeks in Copenhagen. Professor Ioffe gave me reason to hope that you might permit this visit and gave me the enclosed letter addressed to you.

While in Leningrad, I secured a Danish visa which would enable me to arrive in Denmark before the 27th July. However, I learned in Gottingen that your Institute is closed until 1st September for vacations. I therefore do not intend to arrive in Denmark until the end of August and in view of this must renew my Danish visa, which will involve certain difficulties. I therefore take the liberty to ask you if you would be willing to write to me that you have no objection to my arrival in Copenhagen?†

A letter of this kind from you would help me greatly in prolonging my visa.

With deep respect, sincerely yours

G Gamow
Assistant at Leningrad University.

21st June 1928
Gottingen. Herzenberger-Landstrasse, c-I.

Letter from Bohr to Ioffe:

25th October 1928

Dear Professor Ioffe,

I should have written to you long ago to thank you for the kind letter conveyed to me by Dr Gamow whose visit here has given us all much satisfaction. You will learn from the latter about his successful tackling of the problem of radioactive nuclei and their structure during his stay in Gottingen and here. These studies open up new horizons for fruitful theoretical studies and I am bound to state directly that, despite his youth, Dr Gamow has demonstrated that he possesses gifts which justify the highest expectations from his future work. As he told you, I secured a grant for him, which enables him to work in Copenhagen for half a year and to continue his intercourse and discussions with the scientists present here, which in my view will be useful to him too. This state of affairs is a matter of great satisfaction also for me and I hope that it will not create inconvenience, from the standpoint of the plans of Leningrad University, although I quite understand that you wish him to return soon and to resume his work at home.

Here is an excerpt from the next letter by Bohr, sent towards the end of December 1928:

Dear Professor Ioffe,

I thank you for your kind letter and enclose in this envelope my previous letter to you [evidently from 25th October 1928 — V F], which you did not receive. As regards Gamow, I might add that the grant for his half a year stay in Copenhagen has been given to him. Wishing to make this time as fruitful as possible, he intends to pay a visit to Cambridge during the Christmas holidays, which are just beginning here, in order to discuss there the problems of radioactivity with the physicists from the Cavendish Laboratory. I await with interest his comments on his return to Copenhagen.

Having accepted Bohr's flattering proposition, Gamow spent about nine months abroad, mainly in England and Denmark (but also with trips to Germany and Austria).

†As can be seen from his note in a special guest book at the Institute, Gamow arrived in Copenhagen on 22nd August 1928. His arrival confirms that Bohr responded to his request. As regards the letter itself, its structure (and, as I have been told, its perfect German) show that Gamow was helped in writing it. It is difficult to say who the assistant was — either his senior colleagues from Leningrad [Krutkov or Fok (both had a perfect command of the German language)] or his newly acquired friends — Houtermans or Delbrück.

He went to England because Bohr sent him to Rutherford (it was in fact Bohr who recommended that Gamow send a resume of his work to *Nature* [24]). Sir Ernest naturally could not fail to be interested in the work of the young Soviet theoretician. The only request that Bohr made of Gamow was that, in discussing the theory of α-decay, he should try to make do with a minimum of mathematical formulae and quantum-mechanical considerations which tended to irritate Rutherford. This problem was solved successfully by Gamow on his arrival in Cambridge, where in his detailed discussions with Rutherford, Cockcroft, Walton and other physicists (including P L Kapitza)† he helped a lot in the preparation of studies on the fission of light elements by bombardment with artificially accelerated protons. After all, as a result of the possibility of the passage, by means of tunnelling, of the charged bombarding particles through the Coulombic barrier surrounding the target nucleus, the energies of these particles could be significantly less than the height of the barrier! It was only necessary to ensure a sufficiently intense source of protons at the Cavendish Laboratory. This was achieved in 1932 by J D Cockroft and E T S Walton in Cambridge and somewhat later by A K Val'ter, G T Latyshev, A I Leipunskii, and K D Sinel'nikov in Kharkov with the aid of artificially accelerated protons.

On the way from Copenhagen to Cambridge on 5th January 1929, Gamow spent several days in Leiden in order to discuss his studies with P S Ehrenfest. These discussions not only strengthened Gamow's confidence in the validity of the quantum-mechanical ideas about α-decay which he developed but also proved to have a bearing on yet another of his important studies on nuclear physics. This concerns the creation, in the course of discussions with Ehrenfest, of an outline of the liquid drop model of the nucleus — a concept which is firmly associated in our country with the names of N Bohr and A Wheeler, on the one hand, and Ya I Frenkel', on the other, bearing in mind their communications in 1939 on the physics of nuclear fission [29, 30].

We have already spoken of the short-range nuclear forces binding into one entity the positively charged particles in the nucleus. Their nature resembles that of the forces binding the molecules in a liquid. Here is what Gamow wrote about this in 1930: "An assembly of a finite number of particles will form something in the nature of a drop possessing a surface layer and corresponding surface tension. The existence of such a drop will be determined by the equilibrium between the surface tension force and the internal pressure within the drop (the zero point energy of the α-particles). Preliminary calculations for this model on the basis of wave mechanics yield the radius and energy of the nucleus–liquid drop, which agree fairly well with the experimentally found radii and energies of the real drops. The theory leads to the variation of the radius of the nucleus from element to element approximately in proportion to the cube root of the atomic weight (the 'density' of the nucleus must remain constant for different elements), which also agrees with experimental data."

The relation between the atomic mass of the element and the radius of its nucleus, mentioned by Gamow, has the well known form $r_0 = \mathrm{const} \times A^{1/3}$. Thus the surface energy

†At whose seminar Gamow delivered a report on his studies [see the 'Correspondence between G A Gamow and P L Kapitza' published in this issue (p. 879)].

The early 1930s. From left to right: G A Gamow, A F Ioffe, and R Peierls.

of the nuclear liquid should be included in the relation defining the energy of the nucleus, apart from the term taking into account 'the zero-point energy of the α-particles' (of which the nucleus is made up according to Gamow) and the energy of their Coulombic repulsion. This surface energy is proportional to the surface tension of this unusual liquid and also to the square root of the radius of the nucleus r_0, i.e. $A^{2/3}$ according to the relation presented above. The corresponding formula in which the total energy of the nucleus is represented as the sum of the above terms and is expressed as a function of the atomic mass A was first put forward and considered by von Weizsacker.

In his introductory article to the 9th volume of the collected works of Neils Bohr [31], R Peierls published a letter written by Gamow to the Danish physicist on 6th January 1929 from Leiden. Here we read: "Ehrenfest was very interested in the 'liquid drop model'. He thinks that it may also be possible to consider 'capillary oscillations' in order to account for γ-levels" ([31], p. 36). After a week, on 16th January, Ehrenfest wrote to Bohr on the same subject, pointing out that Gamow "...considers nuclei to resemble, as a rough approximation, liquid droplets with their characteristic capillary forces. I asked him — continues Ehrenfest — if one could not relate the γ-levels to the capillary oscillations of a liquid sphere in a less crude model (the formula for axially symmetrical oscillations in this case has been given by Lamb)" ([29], p. 129).

The contents of these two excerpts provide a fairly accurate date of the birth of the first approximation to the

The beginning of the 1930s in Copenhagen. In the seminar hall of the Niels Bohr Institute on Blegdamsvej 15. From left to right: G A Gamow, I Jakobsen, N Bohr, ?, C Raman.

drop model of the nucleus. The communication about the drop model (and the term itself) appeared for the first time in a periodical in the report of the 'Discussions on the Atomic Nucleus' which took place in Cambridge under the chairmanship of E Rutherford on 7th February 1929. In the discussions of his report, Gamow stated: "an assembly of α-particles, joined to one another by forces of attraction which diminish very rapidly with distance, may be treated to some extent as a tiny droplet of a liquid in which the particles are retained by surface tension". After 40 years, on 25th April 1968, whilst examining the reports of these discussions together with Dr C Weiner who interviewed Gamow on that day, the latter said, pointing to the phrase (quoted above) from his speech in the 'Discussions': "here is where I might have predicted fission if I had been cleverer".

In reply to Weiner's question why this idea was not duly developed in Gamow's subsequent studies, the latter gave no definite reply, noting, however that Ehrenfest insistently advised him to publish the relevant considerations. Gamow did this later, in particular in his books on the atomic nucleus and radioactivity. Admittedly, one should note that the possibility of the appearance of capillary oscillations, in particular oscillations in the shape of the nucleus-drop, was not discussed either by him or by Ehrenfest. These oscillations in fact ultimately lead to the phenomenon of nuclear fission — the process which has determined the very nature of our nuclear century.

In the Spring of 1929, Gamow returned to Leningrad as a well known scientist whose work had been well received by major European centres of theoretical physics. The stream of articles on the theory of α-decay increased at that time and calculations were made of the probability of the passage of charged particles through Coulombic barriers of different form. Gamow recalls ironically that a barrier form was frequently chosen not because it could claim to be similar to the true form but because it permitted the corresponding mathematical exposition. In this connection, Pauli paraphrased a statement used in weather forecasts "Es regnet wieder" i.e. "it is raining again". Having seen the next paper of this kind, he said "Es Gamowt weider", which can be rendered "it is Gamowing again". Since Gamow was called George abroad, one may also say "it is Georgeing again".

From the Autumn of 1929, Gamow was again abroad. This time he set out as a holder of a Fellowship from the Rockefeller Foundation. He was proposed for this Fellowship by A N Krylov and Yu A Krutkov and the proposal was supported by E Rutherford. This 26 year old young man was now recognised as one of the major specialists in the field of theoretical and nuclear physics. He published papers on the theory of the nucleus and wrote a series of reviews for *Uspekhi Fizicheskikh Nauk*, which served as a basis for the book, already mentioned, *Atomnoe Yadro i Radioaktivnost'* [English title *The Constitution of Atomic Nuclei and Radioactivity*], which appeared in 1930 in the series 'Latest Trends in Scientific Thought'. Its second Soviet edition appeared as early as 1932 and a year later the English translation was published by one of the most prestigious English publishing houses — the Clarendon Press in Oxford (soon afterwards this book was also published in Germany).

During his year as a Rockefeller grant holder, Gamow worked in England and Denmark and travelled much during the holidays (thus he went on a skiing trip to Norway together with Bohr). Gamow (Joe, Johnny, Geo), rapidly became a popular figure among theoreticians. Together with his books and papers, his wit and jokes became well known.

We shall quote here Gamow's characteristics attributed to him by various people on the basis of personal acquaintance with him during his three year stay abroad. Thus C Moller wrote: "Sometimes the impression was created that he [Gamow] actually expends all his time and energy on inventing jokes and coarse witticisms and that he actually believed that this was, as it were, his main task and that the important paper which he wrote at the time about α-decay and the properties of atomic nuclei were merely a side product of his activity" [35].

Delbrück recalls that during the Summer of 1928 he spent a fairly large amount of time at the 'Crown and Spear' cafe at the centre of Gottingen. One could settle there behind a table on the second floor and observe through a window what was going on outside. Someone pointed out to him a somewhat unusual figure: a Russian student, a theoretical physicist, who had only just arrived from Leningrad. This was something new because previously mature physicists, and not students, arrived in Gottingen from Russia. However, he had already written or was in the course of writing papers on α-decay. He was a remarkable figure: very thin and tall, apeparing even taller because of his upright bearing. He had blond hair, a large head, and a high voice. Pauli used to refer to him as "the little bird from the fourth floor" [36].

In November 1928, Neville Mott wrote to his mother from Copenhagen: "Gamow, who is working at the Institute, is a pleasant and lively young man who has developed an exceptionally clever theory concerning radioactive nuclei. Nobody would have thought that he was a Russian. He is a man of the type of Oliver Walker†: he frequently visits the cinema and would have enjoyed a

† In reply to my question who Oliver Walker was, Prof. Mott stated that Oliver Walker was a character in popular satirical articles in the English newspapers at that time.

motorcycle if he had one. He reads Conan Doyle and does not go to concerts, which does not stop him from being a brilliant physicist. He obtains results without misusing mathematics. He is almost never silent and is approximately of my height''. Gamow's height was 194 cm — V F) ([37], p. 28).

In his book, Mott continues his description of Gamow, no longer reporting to his mother but on the basis of direct reminiscences: ``Gamow was my closest friend in Copenhagen. Together we went to the cinema and discussed our scientific work and anything else. He frequently borrowed from me 25 ore in order to buy cigarettes. At that time he achieved a major success, having shown that the new quantum mechanics can account for the phenomenon of radioactivity — how an atom can slumber for millions of years and then disintegrate suddenly. I should add that I actually envied him!†. ``Ah, Motty'' (Gamow's affectionate nickname for Mott — V F), he used to say to me, ``you should construct an α-particle!''. He had in mind the construction of a theory which would explain how this particle is bound into a single whole'' [37, p. 29].

Here is an excerpt from the interview with Weizsäcker, obtained by an American historian of physics: ``I think that Gamow is one of those people with whom you can discuss whatever you like. He was interested in everything and he always had new ideas about different matters. He conveyed these ideas to others, suggesting that they decide whether they are right or not''.

This is what Otto Frisch said about Gamow in 1934 (i.e. a little later than the time which we are considering):

``One of the first lectures which I attended in Copenhagen was delivered by Gamow. I asked cautiously in what language the celebrated Russian physicist intended to lecture and received the reply: 'in Danish, but do not worry you will understand him'. How could I understand him since I had been in Denmark only a few days? I had not even begun to take lessons in Danish. However, despite this, I understood Gamow; he 'peppered' his Danish with English and German worlds, gesticulated, and illustrated it with amusing drawings. In fact he knew how to find a common language with his audience' ([38], p. 81).

Having returned in the Spring of 1931 to Leningrad, Gamow became immersed in the atmosphere of intense nuclear research; he was an active participant in studies on this topic at the Physicotechnical Institute under the supervision of I V Kurchatov and A I Alikhanov, and at the Radium Institute under the supervision of V G Khlopin and L V Mysovskii.

At the end of the 1920s and the beginning of the 1930s none of the physicists, with the exception of perhaps A F Ioffe, enjoyed as much freedom in visiting scientific centres abroad as Gamow. A turning point in this situation occurred in 1931. In October of this year an International Congress devoted to problems of nuclear physics was to be held in Rome. This field of science was at the threshold of the major discoveries of 1932 (the positron, the neutron, the proton–neutron model of the nucleus). The Congress assembled the entire flower of European physics at the time — here are some of the participants: F Aston‡, N Bohr‡, H Bethe‡, L Brillouin, W Heitler, Geiger, H Heisenberg‡, P Debye‡, M Delbrück‡, A Sommerfeld, Marie Curie‡, Lise Meitner, N Mott‡, W Pauli‡, O Richardson‡, L Rosenfeld, R Fowler, E Fermi‡, O Stern‡, K Ellis, and P S Ehrenfest; S Goudsmit, A Compton‡, and R Millikan‡ arrived from the USA. Gamow, who prepared and sent to Rome a report on ``Quantum theory of nuclear structures'', was also invited, but this time he did not receive permission for his trip.

Gamow's report at the Congress was read by his friend Max Delbrück. Gamow received unusual greetings from Rome: a postcard sent on the initiative of Pavel Sigizmundovich Ehrenfest, which was signed by almost all the participants of the Congress mentioned above.

On 10th November 1931, Ehrenfest wrote to A F Ioffe: ``The fact that Gamow in the end could not come was naturally a very great disappointment to all those interested in young Russian physics'' ([39], p. 230).

In relation to the 'Rome fiasco', as he later called it, Gamow felt a definite change, compared with the end of the 1920s, in the internal political climate in our country and it is thought that it was then that he began to consider a possible departure from the USSR for abroad, for a long time if not forever.

At the same time, almost immediately after his arrival, he was invited to and began to work at several scientific establishments — at the Radium Institute, at the Institute of Physics at the University, at the University itself (as a lecturer), and at the Physicomathematical Institute of the Academy of Sciences of the USSR. The Physicotechnical Institute soon joined these institutions. He continued his research into nuclear physics, wrote books and papers, consulted experimenters, and associated with theoreticians.

There were also changes in his personal life. Gamow's friend, Sergei Leonidovich Mandel'shtam, introduced him to Lyubov' Nikolaevna Vokhmintseva, who used to be his fellow student. She graduated from the Physicomathematical Faculty of Moscow State University in theoretical physics; she was virtually the same age as Gamow (a year younger). Soon Lyubov' Vokhmintseva became Gamow's wife (and in 1935, already in the USA, a son was born to them — Rustam-Igor Gamow). The Gamows began a happy family life in Leningrad. Thus his 'productive' and financial (and family!) situation was more than satisfactory. Both scientific and popular science journals willingly made their pages available to him. As already mentioned, his book *The Constitution of Atomic Nuclei and Radioactivity* [33], greatly expanded compared to the 1930 edition [12], was published in the prestigious series 'Modern Physics' issued by the State Technical-Theoretical Publishing House.

It is thought that Gamow's relations with his colleagues (both with physicists who were his contemporaries and younger ones — students) were good. The brotherhood of the musketeers met again: Gamow and Landau returned from a long foreign journey and Ivanenko returned from Kharkov, where he had spent more than two years at the Physicotechnical Institute in that city (Bronstein remained in Leningrad throughout this period).

As regards the relations between the musketeers and the older generation of physicists, here a certain strain arose

† If he had known this, Gamow could have amused Mott by a quotation from his beloved Pushkin: ``Envy is sister to competition and therefore of good family''.

‡ Those physicists who were Nobel laureates at the time of the Rome Congress had been convened or became so later.

quite quickly. It was associated with specific incidents based on the conflict between generations so characteristic of Russia. Turgenev defined this conflict by the title of his celebrated novel *Fathers and Sons*, which became a byword. Bronstein and Landau were especially deeply involved in this conflict (perhaps because they were the youngest?).

Gamow, who was at the epicentre of such situations, remained calm and confident by virtue of his easy-going character and not out of caution. As stated in the literature dealing with this period, Ivanenko began to turn away from his comrades, but perhaps it would be best if he told of this himself and the 90th anniversary of his birth, which occurs in 1994, may serve as a good opportunity for this.

Without going deeply into the remote past, and confining oneself to the consideration of the Petersburg physics community, one may say that this kind of strain between those about to leave the scene and young physicists manifested itself in the first decade of our century between the professors of the Physicomathematical Faculty of the St Petersburg University O D Khvol'son, I I Borgman, and N A Bulgakov, on the one hand, and young assistants, postgraduates, and university students, on the other. V R Bursian, G G Veikhardt, A F Ioffe, Yu A Krutkov, and D S Rozhdestvenskii united around P S Ehrenfest and embarked on a struggle for the new physics and for reform in lecturing at the Faculty and protested against the dominance of mathematics. They did not admit the professors to the meetings of their physics circle and sharply criticised them both verbally and sometimes in the pages of journals.

The distribution of forces and the development of relations in Leningrad at the very beginning of the 1930s was, however, somewhat different. The criticism by the theoretical youth was directed at A F Ioffe and the middle generation of members of the Physicotechnical Institute. They included in the first instance Ya I Frenkel', the head of the Theoretical Division, where the musketeers worked. The arrows of criticism reached also Moscow. Here one of the targets was Professor B M Gessen — a Corresponding Member of the Academy of Sciences of the USSR. The collision with the latter created quite a stir.

It was associated with the paper written by Gessen for the forthcoming volume of the first edition of the *Great Soviet Encyclopedia* (Gessen together with Ioffe was the editor of the physics section of the encyclopedia). In his book, Gamow is clearly unjust towards Gessen: "He knew little about physics and was more interested in photography". I E Tamm, who knew Gessen well, valued his contributions to Soviet physics; Gessen was also respected by his other colleagues. The above paper was called 'Ether' and described the long and dramatic history of this physical and, in the view of many, pseudophysical, substance. Among the Leningrad theoreticians, the attitude to ether was unambiguous, at any rate if one bears in mind the concept attributed to ether before the appearance of the special theory of relativity. In his article "Mystique of world ether", Ya I Frenkel' rebuked the adherents of ether in the XIXth and preceding centuries [40]. M P Bronstein wrote in 1929 a brilliant paper about ether and its historical development, including the decade preceding 1929 (i.e. after the appearance of the general theory of relativity) ([10], pp. 254–265). It was in fact Bronstein who discovered Gessen's paper in the 65th volume of the *Great Soviet Encyclopedia* and saw that its author set out to defend the concept of ether during the period before the general theory of relativity. Having met his friends — Gamow and Landau — in the library of the Physical Institute of the Leningrad State University, he showed them this article by Gessen. Phototelegraphic communication was established between Moscow and Leningrad by that time. The young physicists decided to make use of its services and sent to Gessen the following telegram: "Having read what you have described in the 65th volume, we proceed to study ether with enthusiasm. We impatiently await articles on the caloric and phlogiston". This was signed by Bronstein, Gamow, Ivanenko, Izmailov, Landau, and Chumbadze.

Many years later, Gamow recalled with evident satisfaction this story in his autobiography and reproduces the contents of the phototelegram from memory. In translation from Russian, it reads as follows: "Being inspired by your article on the light-bearing ether, we are enthusiastically pushing forward to prove its material existence. We call for your leadership in the search for caloric, phlogiston, and electric fluids. G Gamow, L Landau, A Bronshtein, Z Genatsvali, S G Grilokishnikov"† ([5, p. 96).

The 38 year old Gessen was outraged by the fairly unceremonious message from the young theoreticians, particularly since, with the possibilities of the phototelegraph, the text of the message was illustrated by a drawing executed by I L Sokol'skaya, who was associated with the Jazz Band (she subsequently became a professor at Leningrad State University, specialising in electronics). The drawing represents a rubbish heap filled tins, cans, bottles, etc. with labels of the type 'caloric', etc., while an even less honourable container was provided for poor ether — a chamber pot. A cat is scrambling on to this rubbish heap, its face resembling somewhat, under Sokol'skaya's skillful hand, that of B M Gessen. Gamow reproduces this drawing, also from memory, in his book — the bottles in his 'copy' were filled, judging from the labels, with positive and negative electrical liquids and the caloric. Ether was transferred from a chamber pot to a large bottle, apparently from a feeling of special respect towards it. All the inscriptions on the labels were in English except one on which a familiar Russian word is written. Here we shall quote its English equivalent: 'shit'.

Boris Mikhailovich Gessen informed the management of the Physicotechnical Institute about the escapade of the Institute's members, particularly since the signatories to the text of the phototelegram thought it necessary to follow their signatures by the place where it was written: the Physicotechnical Institute, its Physical Cabinet (this was the name given to the Division at that time). It was decided at the Physicotechnical Institute to support Gessen. The result turned out to be deplorable. Gessen, who was an extremely decent man [according to the statements by I E Tamm (already mentioned above), who had known him since the Secondary School], apparently did not foresee such a development of events. And the events developed in such

†The mistake in Bronshtein's initial is understandable: Gamow habitually thought of him as the Abbot (Abatik) and not Matvei Petrovich. Chumbadze (referred to as the 'ranging Georgian' by N N Kanegisser in the letters to her sister [10]) has been replaced by 'Genatsvali' (which means comrade in Georgian). It remains unclear why Sergei Valentinovich Izmailov (who subsequently became an outstanding physicist) was given such an unpleasantly sounding name.

a way that Bronstein and Landau were barred from lecturing at the Leningrad Polytechnic Institute ("for the antisocial statement concerning Comrade Gessen's article in the Great Soviet Encyclopedia"). An invitation to Bronshtein to lecture at the Leningrad State University was postponed.

Il'ya Silovanovich Chumbadze perhaps fell into the most severe straits. In the middle of November 1931, he was included in the Theoretical Division of the Physicotechnical Institute (as a 'scientific postgraduate'—this is how he is referred to in the relevant order, an excerpt from which is preserved in brief in Chumbadze's personal papers in the archive of the Physicotechnical Institute). In the application for admission directed to Leningrad from the Tbilisi University, the "exceptional ability" of the young man is mentioned. However, on 19 January 1932, at the general meeting of the members of the Physicotechnical Institute and the Institutes which had split off from it comparatively recently (constituting at the time the so called 'Complex of Physicotechnical Institutes'), the resolution was adopted, as can be seen from paragraph 7 of the Minutes of the Meeting, "to agree with the proposition by the active members of the Komsomol (Young Communists' League) and the postgraduates to exclude comrade Chumbadze from membership of the postgraduates of the Physicotechnical Institute". Having been a postgraduate at the Physicotechnical Institute for only 3 months, Chumbadze was barred from working in the Institute on 14 February.

As regards Gamow, who had played an important role in this tragicomical story, his action led to no investigation with the corresponding practical consequences and he continued to carry out his duties exactly as before. The explanation is probably that by that time Gamow was not an official member of either the Leningrad Polytechnic Institute or the Physicotechnical Institute, whereas at the Radium and Physicomathematical Institutes no meetings associated with the 'ether affair' were held. In addition, Gamow's rating after his return to Leningrad from abroad was fairly high and no purpose would have been served by attacking him with a repressive criticism.

There is yet another tentative factor. All the participants in the ether saga probably felt more than uncomfortable when after 6 years they learned of Gessen's arrest. Ivanenko heard of this in exile, the news reached Gamow in the USA, Landau was still free, while Bronstein had already been arrested.

We shall now describe (on the basis of the documents collected in Gamow's private papers kept at the Khlopin Radium Institute) the conflict between Gamow and the city authorities. These documents require no comments. The private papers begin with a letter from the Leningrad City Voenkomat [Military Registration and Recruiting Office] and the chairman of the ZhAKT [Cooperative Rented Dwelling Association] Administration at ul. Krasnykh Zor' (at present Kamennoostrovskii prospekt) No. 21/1.

'Pre-conscript Gamow Georgii Antonovich, whose parents are citizens of the city of Odessa, is due to be called up this year in the Petrograd region. I request that a social-political opinion about him be sent within 3 days of the receipt of this letter. All positive and negative aspects should be indicated in the assessment, and immoral acts and participation in social and Party-Komsomol [Young Communists' League] activities, in industry, and in agriculture should be noted.

The formulation of the assessment should be treated with all seriousness and responsibility. In conclusion, it should be stated whether his admission into the ranks of the RKKA [the Workers' and Peasants' Red Army] would be permissible.

The assessment and all the available compromising information should be sent to the Petrograd Raivoenkomat [Regional Recruiting Office].

Commander of the Mobilisation Division, Silant'eve.

Assistant to the Commander, Dmitriev."

The next document (p. 20) is as follows: "Criminal case No. 1618-1932 concerning the charging of G A Gamow, born in 1904, with failure to report for call up in 1931 in accordance with st. 64. Sentence—25 rouble fine. The fine has been paid, against receipt No. 95438, to the Militia [police] Station of the 17th Division on 11 March 1932."

Finally, we have "opinion concerning pre-conscript Gamow G A"—sent to the Voenkomat of the Petrograd Region on 5 June 1932 (confidential):

"In reply to your request on 27/V-32 No. 2705, the [Radium] Institute reports as follows:

Georgii Antonovich Gamow, son of a secondary school teacher in Odessa, has been a senior expert at the State Radium Institute since the Autumn of 1931. He is not a Party Member.

He graduated from the Leningrad State University in 1925 but remained as a postgraduate in the Department of Theoretical Physics, starting in 1925. In 1928 and 1929, he was sent abroad by Narkompros, where he worked in the top physical institutes in the world, specialising in problems of nuclear structure.

At the present time, he is one of the best known young theoretical physicists in the world. On 6th February 1932, he was elected Corresponding Member of the USSR Academy of Sciences for his contributions to science.

He has expressed no views on scientific-political matters throughout his stay at the Radium Institute. He has kept away from politics and social activity. In his behaviour, he is relatively undisciplined and is a typical representative of the literary-artistic bohemia. No immoral acts by G A Gamow have come to light during his stay at the Institute.

On the grounds of the position which G A Gamow occupies, he has deferred his call up into the ranks of the RKKA [The Red Army]. The Institute will offer its support in this matter at the proper time.

The present opinion is provided by the Institute because there is no ZhAKT Administraiton in the building of the Institute.

Deputy Director, V Khlopin."

Apparently, after the summons received even before the letter by the Commander of the Mobilisation Division Silant'ev had been sent, Gamow called at the Voenkomat and his replies to the questions addressed to him irritated the Commanding Officers there such that the situation became complicated. The enquiries from the Petrograd Regional Military and Mobilisation Office [Voenkomat] were not preserved among the papers. It is not clear why the date on which Gamow was elected Corresponding Member of the USSR Academy of Sciences is given as 6 February in the opinion (instead of 29 March).

We shall now turn from military conflicts to conflicts in physics.

In his book, Gamow never mentions the Physicomathematical Institute (PMI) at the Academy of Sciences of the USSR, where he worked from September 1931. During the 1920s the PMI was the only Physical Institute of the Academy. The number of staff members in its Physical Division was very small (we may note that Bronstein and Ivanenko worked there at different times); in fact, the entire Institute together with mathematicians corresponded in size approximately to that of the large laboratories of comparative giants such as the Physicotechnical Institute and the State Optical Institute. In this sense, the PMI resembled the tiny foreign Institutes which Gamow came to know well during his stay in Gottingen. This was in the first place Bohr's Institute of Theoretical Physics and the tiny experimental Institutes of D Franck and R Pohl. In essence, they were Departments of the Gottingen University and were called Institutes either as a matter of tradition or as a sign of respect to the physicists heading them. Niels Bohr's Institute in Copenhagen was initially a miniature establishment of this kind but by the time Gamow arrived there (in the Autumn of 1928) it had grown significantly and experimental laboratories began to function there. However, in purely quantitative terms (as regards the number of staff members), it was much smaller than the Physicotechnical Institute and the State Optical Institute.

After the revolution, the Directors of the PMI were, in succession, V A Steklov, A F Ioffe, and, by the time Gamow joined it, A N Krylov; all three were Full Members of the USSR Academy of Sciences. However, the importance of the roles which this Institute played in the scientific and organisational work of A F Ioffe can be judged indirectly from the fact that Ioffe's directorship (1926–1928) is not even mentioned in 'The Principal Dates in the Life and Career [of A F Ioffe]', which initiated the publication of bibliographic data concerning the scientists of the USSR and was devoted to Ioffe. A N Krylov found the work at the PMI burdensome. In an extensive collection of his documents, stored at the Archive at the Russian Academy of Sciences in St Petersburg, only one document deals with his activity in the post of Director of the PMI.

Bearing in mind that the question of the transfer of the Academy of Sciences from Leningrad to Moscow, where there were virtually no Physical Institutes (the Physical Institute at the Moscow State University was an important exception), had already arisen at the beginning of the 1930s, one may claim that the fate of the PMI had already been sealed.

It is probably in connection with this situation that Bronstein, Gamow, and Landau decided to try to organise the Institute of Theoretical Physics (ITEF) on the basis of the Physical Division of the PMI. For this purpose, they initiated a fairly vigorous campaign (its stages have been traced in fair detail by Gorelik [41]), which proceeded in parallel with the campaign to elect Gamow to the Academy of Sciences. In the case of the PMI, Gamow played an extremely active role in the proposed transformation. He prepared the proposal for the Institute and developed and justified the subjects of its future researches.

In the tradition of Bohr's Institute, attention should have been concentrated in the new Institute, according to the intentions of its organisers, on studies in theoretical physics. However, studies on experimental physics, were not disregarded either. They had been prosecuted, albeit on a very minor scale, already in the PMI — on molecular physics, the photoeffect, and physical electronics (here the most active person was S Artsybashev). The concrete proposals for the reorganisation of the PMI began with a memorandum concerning the necessity to separate its Mathematical Division (headed by I M Vinogradov) and its Physical Division†. It was suggested that the studies in the new Physical Division should be mainly theoretical. They should have been based on the physics of the atomic nucleus, i.e. on asubject with which Gamow had been vigorously concerned throughout more than 3 years. The leaders of the Academy, the so called Groups (mathematical, astronomical, physical, and technical) were involved in the consideration of this proposal. The appropriate Commissions were also set up.

Without listing all the stages of the campaign, which lasted from the end of 1931 until May 1932, we may note that the idea of creating the Institute of Theoretical Physics did not gain support in academic circles — Commissions, Bureaux, and Groups as well as individual academician-physicists, who became acquainted with the corresponding plans. A F Ioffe and D S Rozhdestvenskii objected particularly sharply to these plans. The 'plan for the Institute of Theoretical Physics of the Academy of Sciences of the USSR', put forward by Gamow alone, was not approved either. The following topics are indicated in this plan ([41], p. 12):

"(1) Theory of the atomic nucleus (radioactivity, nuclear energy). (2) Theory of the structure of atoms and molecules (molecular beams, chemical reactions). (3) Theory of the solid state (magnetism, electric conductivity, the photoeffect). (4) Theoretical astrophysics (the structure of the interior of the stars, problems of cosmology)."

These topics were evidently 'adjusted' (and this is entirely natural!) to suit particular persons. It is significant that they were all members of the Jazz Band: Gamow and Ivanenko (No. 1), Landau and Bronstein (Nos 2 and 3), and Ambartsumyan (No. 4). The younger theoreticians specified in the 'plan' were I S Chumbadze, K V Nikol'skii, and S P Shubin — a Moscovite and a student of I E Tamm. The experimental studies were correspondingly revised to suit Artsybashev (molecular physics and molecular beams) and T P Kravets (the photoeffect). The plan provided for the involvement of D V Skobel'tsyn in experimental studies at the Institute (laboratory of nuclear structure and, although this is not stated explicitly, cosmic rays). The total number of persons employed in both Divisions —Theoretical and Experimental — should have been 17. To this number, Gamow added the term x, without indicating the upper limit to which it should have been restricted.

A more detailed plan for the Physical Institute of the Academy of Sciences, i.e. no longer ITEF, also devised by Gamow and put forward in the middle of April of 1932 for comment by the Academicians A F Ioffe and N S Semenov, did not differ very significantly from that described above. Their view was extremely negative; they called the plan absolutely unacceptable and the idea of separating theoretical physics from powerful centres of experimental studies, i.e. from the Physicotechnical Insti-

†The report was compiled on 23 December 1931 and was signed by G Gamow and S Artsybashev.

tute and the State Optical Institute, as harmful. In a milder form, S I Vavilov also failed to support the idea of creating the ITEF.

As was to be expected, the structure of the PMI was re-examined in the Autumn of 1932 on the grounds of purely practical considerations, far from the ambitions of the older generations of physicists, with the aim of creating in the near future two independent institutes — the Mathematical Institute (for the stages of its organisation and its Leningrad branch, see T Ya Kochina [42]), named after V A Steklov, and the Physical Institute, which soon became the P N Lebedev Moscow Physical Institute of the Academy of Sciences of the USSR. As is well known, its first Director was S I Vavilov — a representative of P N Lebedev's school. Both Institutes exist to this day. Their role in the development of Russian mathematics and physics cannot be overestimated.

The half-year prehistory of the Physical Institute of the Academy of Sciences (PIAN), associated with G A Gamow's name (who was during this period the acting Deputy Director of the PMI), is, we believe, no more than an episode which did not have a significant influence either on Gamow himself or on the PIAN. However, this episode is not without interest. It is difficult to understand the rational motives which guided Bronstein, Gamow, and Landau in undertaking the initiative concerning the creation of the ITEP. Both in the State Optical Institute and (especially) the Physicotechnical Institute, there existed at the time Theoretical Divisions, set up comparatively long ago, which had developed good working relations with the Directors of these Institutes. The Theoretical Division of the new Institute — the Institute of Chemical Physics (N N Semenov) — began to function. According to the recollections of his contempories, the theoreticians in all the Institutes enjoyed enviable freedom in the selection of the subjects of their researches, they were not subjected to any kind of pressure, their work was encouraged, and their successes were welcomed. We recall that Gamow's trip to Denmark was supported and in essence organised by A F Ioffe; Landau's application for the Rockefeller grant was signed by Ya A Frenkel' [32]; Frenkel' had already recommended M P Bronshtein for the Rockefeller grant ([43], p. 254). The Physicotechnical Institute supported D D Ivanenko in his decision to move in 1929 to Kharkov, where he headed the Theoretical Division of the local Physicotechnical Institute and the Leningrad Physicotechnical Institute received him when Ivanenko decided to leave Kharkov.

Here one should perhaps keep in mind the aspirations of the young theoreticians themselves, who seem to have survived quite easily the failure of their initiative. Gamow soon became, at the end of 1932, an official consultant of the new Nuclear Physics Division of the Physicotechnical Institute. Bronstein continued to work in the Theoretical Division of the Physicotechnical Institute, being concerned simultaneously, in accordance with his tastes, with the theory of the nucleus, the theory of semiconductors, quantum gravitation, and astrophysics combined with cos-mology. Their relations with A F Ioffe and Ya I Frenkel' (we may note that neither the latter, nor Yu A Krutkov from the university and V A Fok from the State Optical Institute even appear in the comments referring to the documents concerning the attempt to organise the ITEP) did not improve as a result of this entire story, but they were not impaired either.

The situation was not quite so obvious as regards L D Landau. He issued a sharp countercriticism of A F Ioffe's negative conclusion concerning the plan to create the ITEP and unjustly deeply hurt Ioffe by recalling the failure of his work on thin-layer insulation. As a result, in August 1932 Landau moved to Kharkov, where he initially shared with L V Rosenkevich (Frenkel's former postgraduate student and a member of the Physicotechnical Institute) the management of the Theoretical Division of the Ukrainian Physicotechnical Institute (UPTI) and soon became its sole head. Landau's celebrated school was established in Kharkov. Whereas initially Landau might have regarded his transfer as being forced on him, ultimately it proved to be lucky.

The 'putsch' — this was the term applied to all these activities concerned with the attempt to reorganise the PMI to the ITEP by N N Kanegisser in a letter to her sister — ([10, p. 88), was thus at least pacified if not suppressed and the life of its participants returned to the usual and well travelled rut, but unfortunately not for a long.

The next encounter of our young theoreticians with the physics community occurred in connection with the periodic elections to the Academy of Sciences planned for 1932. Events developed in parallel with the previous story about the ITEP. Bearing in mind the deserved success of Gamow's work and his authority among foreign and Soviet physicists, it appeared natural to put forward his name as a candidate at these elections. Bronshtein and Landau decided to organise a direct advance to the ranks of Full Members. Independently of the musketeers, this step, without any backstage manoeuvres, was undertaken by the Radium Institute, which, we may recall, was regarded as Gamow's principal place of work (elsewhere he held supplementary posts). However, here the intention was to raise Gamow to the ranks of Corresponding Members. On 17 December 1931, the following application was sent from the Radium Institute to the Permanent Secretary of the Academy of Sciences of the USSR Academician B A Volgin:

"The Presidium of the State Radium Institute comprising Academician V I Vernadskii, Prof. V G Khlopin, and Prof. L V Mysovskii decided on 10 December of the current year (1931 — V F) to put forward G A Gamow as a candidate for Corresponding Member of the All Union Academy of Sciences†. Enclosed are a note about G A Gamow's research into the atomic nucleus, his curriculum vitae, and a note signed by the Scientific Council of the State Radium Institute who join in supporting the application by the Presidium."

The application was supported by the signatures of all the persons indicated (Vernadskii, Director of the State Radium Institute; Khlopin, his Deputy, and Mysovskii, Head of the Physical Division in which Gamow worked). The documents mentioned in the application have also been preserved in the archive of the Radium Institute. In a brief comment (note) about Gamow's researches, their high

†Until 1925, the Academy was referred to as Russian, after which it became called officially the Academy of Sciences of the USSR; the name 'All-Russian' was unofficial. Now, of course, our Academy is again called Russian (in accordance with the double negation principle).

assessment in a recently published monograph by Rutherford, Chadwick, and Ellis [44] is emphasised. Here we shall quote the concluding part of the comment: ''In the view of the Presidium of the State Radium Institute, it is desirable that henceforth G A Gamow should present communications about his work directly to the highest scientific establishment of the country — the Academy of Sciences. In view of this, the Presidium puts forward G A Gamow's candidacy for admission as a Corresponding Member of the Academy of Sciences.'' We have long become unaccustomed to this form of application!

As regards Gamow's curriculum vitae, two of these exist in his papers at the Radium Institute. One of them was written in a standard form for documents of this kind. It was written immediately after Gamow began to work at the State Radium Institute (on 28th September 1931). Here is the text of this short document:

''I was born in Odessa in 1904 and, having graduated from the Secondary School, I entered the Physical Division of the Physicomathematical Faculty of Leningrad State University in 1922. Having graduated in 1925, I became a postgraduate in the Department of Theoretical Physics at Leningrad State University and began to study the theory of atomic structure and the new quantum mechanics. In the Summer of 1929, I was sent to carry out research in Germany, where I worked at the Institute of Theoretical Physics of the Gottingen University and devised a theory of the radioactive decay of the atomic nucleus.

In the Winter of 1928/9, I worked at the Institute of Theoretical Physics of the Copenhagen University by invitation from Prof. N Bohr, where I continued my researches into the theory of radioactive decay and problems of artificial fission of the elements. In the Spring of 1929, I returned to the USSR, where I stayed until the Autumn; according to the terms of the Rockefeller grant which I received I had to arrive in Cambridge in September 1929 to work with Prof. Rutherford in the Cavendish Laboratory, which is the best laboratory in the world for the study of radioactivity. During my stay in Cambridge, I was occupied with problems of the nature of the mass defect curve and questions of the energy balance in the artificial fission of the nucleus.

My last year abroad was again spent at Prof. Bohr's Institute in Copenhagen, where I was engaged in the theory of γ-emission in connection with the so called long-range and short-range α-particles from certain radioactive substances.

Having returned to the USSR in the Autumn of the same year, I intend to continue further research into the theory of the atomic nucleus at the State Radium Institute in Leningrad.''

The second curriculum vitae, with a date close to that of the application for admission as a Corresponding Member (27 January 1932), differs greatly from the standard form and contains concise and apparently most accurate data on the periods and places where Gamow studied and worked, and also on his official position and duties at the time when the document was written. We have used these data in the previous pages of this communication (without referring directly to the questionnaire).

Thus the fact that the application requesting Gamow's admission to the Academy came from the Radium Institute is quite natural: he himself states that the State Radium Institute was his principal place of work.

We shall now consider which of the physicists, who became known in the post-revolutionary years, had been elected to the Academy by 1932. We shall begin with the elections in 1929. At that time, three of A F Ioffe's students entered the Academy as Corresponding Members from Leningrad, namely P L Kapitsa, N N Semenov, and Ya I Frenkel' (Moscow was represented by V V Shuleikin and N K Shchodro). S I Vavilov and N D Panaleksi became Corresponding Members in 1931. V S Ignatovskii, G S Landsberg, and A N Terenin (all three specialising in optics), as well as V A Fok, a representative of mathematical physics, were elected in 1931 as Corresponding Members together with Gamow. Finally, here are the results of the elections of Corresponding Members in 1933: Moscow is represented by I E Tamm and Leningrad by N N Andreev, A F Val'ter, Yu A Krutkov, P I Lukirskii, I V Obreimov (who incidentally already worked in Kharkov by that time), D A Roshanskii, A I Tudorovskii, and A V Shubnikov.

Among all those elected in 1929 – 1933, Gamow was the youngest. However, I believe that he was not the most outstanding as assessed by the results achieved by that time.

This assessment applies not only to those elected before him but also to those elected subsequently: it is sufficient to name I E Tamm and Yu A Krutkov (resistricting the list to theoreticians). Here we may add that neither the American physicist E U Condon nor his coauthor, the Englishman R W Gurney, in the communication concerning the mechanism of α-decay, were honoured by academic distinctions in the USA and England respectively.

The campaign in support of his election directly into the ranks of Academicians, initiated on the eve of the elections of 1932 by two members of the triumvirate — M P Bronstein and L D Landau — must therefore be considered extremely inappropriate and even harmful to Gamow. N N Kanegisser described vividly and in a jocular manner (entirely appropriate in private correspondence) to her sister the vicissitudes of this 'elect Johnny an Academician' campaign; her letters have been published [10]. In order to characterise the heated atmosphere, we quote here two documents which have been preserved in the archives. One of them is a letter from L D Landau to P L Kapitza. It has been published ([10], p. 88) (and the reply to it is given in the footnote to the Gamow – Kapitza correspondence).

Dear Peter Leonidovich

It is essential to elect Johnny Gamow an Academician. After all he is undoubtedly the best theoretician in the USSR. Abrau (not Dyurso but Ioffe) is trying to oppose this through slight envy. It is necessary to curb the old man, who has abandoned all restraint and imagines God knows what about himself. Be so kind and send a letter to the Permanent Secretary of the Academy of Sciences in which, as a Corresponding Member of the Academy, you could praise Johnny; it will be best if you send it to my address so that I could publish it simultaneously in 'Pravda' or 'Izvestiya' together with letters from Bohr and others. It would be a notable success if you succeeded in involving also the Crocodile [Rutherford] in this message.

Yours sincerely, L Landau

One cannot rule out the possibility that the somewhat sharp reply which Kapitza sent to Landau was due to the fact that Kapitsa was himself at the time a Corresponding Member of the Academy and not its Full Member. And, after all, his contributions to physics, with all due respect to Gamow, were incomparably greater than the young theoretician's achievements in 1932. It was hardly proper to turn to Kapitza concerning such a delicate question in the given situation.

M P Bronstein's approach to A F Ioffe on the same matter was also unsuccessful. As we have already mentioned, Ioffe valued and supported Gamow, but we believe he was busy with the election to the Academy of 'his own' members of the Physicotechnical Institute, whose contributions he valued no less. Furthermore, the activities of the triumvirate in organising the ITEP with the palpable hurt which he himself suffered in this connection did not predispose Ioffe in their favour.

Echoes of the dialogue between Bronstein and Ioffe conducted at the time can be found also in another document (from Niels Bohr's archive in Copenhagen) — a letter from Landau to Bohr. Here is its translation from German [via Russian]:

Leningrad, 25/II.31

Dear Mr. Bohr,

It is proposed here that Gamow should be made a Member of the Academy of Sciences of the USSR. Many are opposed to this, particularly Ioffe, who regards this entire idea as ridiculous and actually claims that foreign physicists (especially yourself) regard Frenkel' (!) a much greater theoretician — a claim which is quite funny and merely serves as a poor concealment of more important reasons. You could render our campaign a great deal of help if you sent a letter to the Secretariat of the Academy in which you would express, as a Foreign Member of the Academy, your opinion about Gamow's candidacy. It would be extremely useful if you sent this letter to my address, because I would then be able, with your permission, to publish your letter immediately in one of the Moscow papers, which is the usual custom here.

Please convey my sincere greetings to Pauli and Ehrenfest. I do not recall whether they are both Foreign Members of our Academy; if they are, I could send a similar request to them.

Landau's letter remained unanswered (Bohr's invitation sent to Gamow concerning his next trip to Copenhagen had no bearing on the elections).

Gamow's election to the ranks of Corresponding Members of the Academy was by a record majority compared with others who were elected: 42 : 1. It was his major and deserved success. The election strengthened to an unusual extent Gamow's formal position in Soviet physics and was evidence of the support offered to Gamow and his work by the highest scientific establishment in the country and its most outstanding representatives.

This entire story did not bring distinction to M P Bronstein and L D Landau; their relations with Ioffe were greatly impaired for a long time (see the correspondence between Ioffe and Ehrenfest on this topic [39]). As regards Gamow, he maintained an honourable stance in this story so far as one can judge from the existing documents — he did not approach academicians and did not canvass on his own behalf except perhaps through his work!

In the history of nuclear physics, much has been written about 1932; it was called the year of miracles. In fact, it brought new particles — the neutron and the positron, the alchemical nuclear reaction effected by protons accelerated in a linear accelerator, and the discovery of deuterium. One of the musketeers (D D Ivanenko) proposed a proton–neutron model of the nucleus.

A F Ioffe decided to initiate research into nuclear physics at the Physicotechnical Institute. I V Kurchatov was asked to head the corresponding Division. He invited to work there his old co-workers, with whom he studied the Seignette salt [potassium sodium tartrate] and semiconductors, as well as new ones who had just graduated from the Physicotechnical Institute. A special seminar was organised on nuclear physics. D T Ivanenko, its 'Permanent Secretary', took the minutes of the meetings and announced the forthcoming lectures. The first lecturers naturally included also Gamow: he delivered three lectures on nuclear theory. He did this as part of his duties as Consultant to the Division of Nuclear Physics of the Physicotechnical Institute.

In accordance with the practice which had been previously successful, A F Ioffe decided to convene an All-Union conference on the nucleus. He invited to it both Soviet and foreign experts (the latter included H Beck, W Weiskopf, P A M Dirac, Frederic and Irene Joliot-Curie, F Perrin, F Rasetti, etc.). The conference went off very successfully (24–30 September 1933). Earlier still, it was decided to publish the conference proceedings. The lecturers were asked to present the texts of their speeches for publication in a collected volume. It was given the brief title *Atomnoe Yadro* [The Atomic Nucleus] [45] and was published through the efforts of the Editorial Board (M P Bronstein, V M Dukel'skii, D D Ivanenko, and Yu B Khariton). The contributors included G A Gamow. The topic of his report was "The Quantum Levels of the Nucleus" (under a somewhat altered heading, the report was repeated at the end of October at the XIIIth Solway Congress in Brussels). A group of members of the Physicotechnical Institute was given the task to record carefully the speeches made in the discussions of the reports. At the end of the conference, some of its participants (A F Ioffe, G A Gamow with his wife, the Curies, Dirac, and Perrin) travelled to Brussels. The Editorial Board of the collected volume quickly prepared its publication. It was sent to the publisher on 28 December 1933 and its printing was authorised on 9 February 1934; it was apparently published in the same month.

The foreword to this volume contained a phrase which was in a code that was secret to the uninitiated: "G A Gamow's report could not be included for technical reasons" ([45], p. 5). By the time of its appearance [45], the origin of the technical causes became clear, at any rate to the readers in Leningrad. Gamow left the Soviet Union, at least for a very long time, but he was immediately spoken of as a defector. His report was removed at the very last moment. Nevertheless, this time undoubtedly for technical reasons, it was not possible to exclude his brief speeches in the discussions (on the reports of F Perrin and D D Ivanenko).

Having spent much time in England, Gamow appreciated the advantages which Peter Leonidovich Kapitza enjoyed there (compared with the situation of the physicists of his rank in the USSR). Apart from the possibility of carrying out complex experiments, requiring a large expenditure and sophisticated instruments (which Gamow did not require in his profession as theoretical physicist), these were in the first place contacts between Kapitza and the leading scientists of Europe, the ease with which he could move throughout the Continent, attending conferences and seminars, becoming acquainted with the work of physics centres in Germany, France, and Holland whilst being there, and participating in the discussion of these studies. And, what was undoubtedly important for Gamow, all this was done by Kapitza — a citizen of the USSR. Kapitza did not think of changing his citizenship and rejected such propositions. He naturally retained the right to visit the Soviet Union as frequently as he wished. He regularly made use of this right, particularly as like Gamow he was an official Consultant to the Ukrainian Physicotechnical Institute in Kharkov. Kapitza maintained a lively contact with his contemporaries. This was an ideal situation for Gamow himself (and incidentally not only for him!), who knew of it not by hearsay but to some extent experienced it himself. It was not without reason that, having already decided not to return home after the elapse of the authorised short (two weeks) stay in Belgium, he wrote to Kapitsa (see the letter published in this issue) that he would like to find himself in the Kapitza-Zustand [State], using a very familiar term from quantum mechanics.

It is therefore not surprising that, in the official documents sent from Paris (he worked there at the Pierre Curie Institute) to Ioffe at the Physicotechnical Institute and to Khlopin at the Radium Institute, he wrote about the same matter. We may quote one of these letters:

To the State Physicotechnical Institute (Leningrad).

Application

In view of the invitations to me to participate in studies on the structure of the atomic nucleus which I have received from the L'Institut de Radium in Paris and from Cambridge University, I ask to be granted leave without pay, from 1 October 1934.

L'Institut de Radium, 11 rue Pierre Curie, Paris

G Gamow, 5 November 1933''

A letter was sent to L'Institut de Radium on the same day and did not differ from the above in its content.

We see that Gamow did not desire a final break with his fatherland. We believe that this does not conflict with his known attempts up to 1933 to leave the country illegally. These were in fact previously most frequently recalled when speaking of Gamow (in this connection, I venture to mention the response to one of my recent propositions to write about Gamow: "We hope that this will not be merely a description of his attempts to cross or swim through our frontier?"). It may be that even then, if these attempts had been successful, he would have tried to patch up his relations with his country. However, things turned out differently. A F Ioffe, who learnt about Gamow's intentions already in Brussels, issued the following instruction almost immediately after receiving Gamow's application (20 November 1933): 'The payment of Consultant Gamow's salary is to be stopped from 15 October (i.e. in arrears in accordance with the date of his departure from Leningrad — V F), since he intends to stay indefinitely abroad after the completion of his official journey"†. The position of L'Institut de Radium was less rigid. This can also be said about the Physicomathematical Institute. It was not until 4 October 1934, i.e. a year after Gamow's departure abroad, that S I Vavilov, who became Head of the Institute, sent the following communication to the Permanent Secretary of the Academy of Sciences of the USSR V P Volgin: "The senior expert of the Physical Institute G A Gamow did not return from his official trip abroad by the latest agreed date of 1st September of the current year. In view of this, I request that he be excluded from the staff at the Institute" ([41], p. 26). Gamow was excluded from the ranks of Corresponding Members of the Academy of Sciences of the USSR even later — in 1938.

In the Autumn of 1933, Gamow's world line forever moved outside the boundaries of the Soviet Union. He recalls the last day before his departure abroad. Together with his wife, they travelled to Brussels by train through Finland, Sweden, and Denmark. From there, from Copenhagen, they travelled together with the Bohrs to Belgium.

I Varzar [46], an acquaintance of George and Lyubov Gamow from Leningrad, recalls this last day. In the morning, the Gamows took their things from the Petrograd side [the Gamows lived in a spacious and bright apartment in ulitsa Rentgena next to the Radium Institute] to the left luggage office in the Finland station and returned from there for lunch ('duck with apples') with I Varzar and her husband (the architect G Efros) on the naberezhnaya Krasnogo Flota — one of the most attractive places in Leningrad. ''After lunch, before boarding the train they planned to visit also Mariinka [The Marinskii Theatre] to attend a performance of the ballet there, as I remember 'Romeo and Juliet' with Ulanova ('as a dessert', they said). It was a quiet warm autumn evening. We strolled with them on our quay, reached Novaya Gollandiya, and bade each other adieu — until we meet again soon! This is what we said but the meeting never took place'' [46].

As we have seen, the Gamows travelled from Brussels to Paris and from there to Cambridge. From Cambridge they went to Copenhagen and soon after that to America where Gamow obtained the position of professor at the George Washington University. His new life began on the American continent, but this is another story, also filled with discoveries, meetings, and journeys...

The author expresses his sincere indebtedness to the workers at the Archives of the V G Khlopin Radium Institute (G S Sinitsyn and T I Starik), the A F Ioffe Physicotechnical Institute of the Russian Academy of Sciences (L F Gavrikov), the Niels Bohr Archive in Copenhagen (Drs F Oserud and H Levi), and the Archive of the Aaserud Center for the History of Physics of the American Institute of Physics in New York (Dr S Weart) for permission to become acquainted with the materials stored in these archives and to use them in the present

†A F Ioffe had reasons for the sharp response to Gamow's application — it is said that he not only participated in the efforts to organise Gamow's and his wife's departure from the USSR, but also served as his guarantor. In this respect, V M Molotov rendered Gamow the greatest assistance (Gamow was received by him through the assistance of Bukharin, who supported him). Gamow also states that the letter supporting his invitation to the Solway Congress was written by P Langevin, to whom Gamow felt especially obligated. After a conversation with M Curie, Langevin freed Gamow from any kind of obligation.

publication†). The photographs included in this article were obtained from the last two archives and from A V Kravtsov's personal collection.

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Note from the translator

The names of some Russian scientists and writers who lived for long periods abroad or who were frequent contributors to English, German, and Western journals do not conform to the correct transliteration rules. These include, apart from Gamow [Gamov] himself, Bronstein [Bronshtein], Ehrenfest [Erenfest], Friedmann [Fridman], Gorky [Gorkii], Kapitza [Kapitsa], and Trotsky [Trotskii].

†The foregoing applies particularly not only to the letters but also to the excerpts from interviews of G A Gamow, von Weizsäcker, and L Nordheim by American historians of physics.

‡Unfortunately the collected volume, containing Delbruck's excellent article with reminescences about Gamow, is not available to the author. An excerpt from this article is quoted on the basis of a Xerox copy from this volume..