Chapter 5
Marian Smoluchowski (On the Tenth Anniversary of His Death)

Boris Hessen

In September of this year (1927) ten years will have passed since the death of Marian Smoluchowski[1] His works are of outstanding general value not solely for physicists, but their methodological value is also very significant.

Atomic science flourished in the second half of the nineteenth century due to works by Clausius, Maxwell and Boltzmann but began to fall from grace among physicists by the end of the nineteenth century. The reality of atom was questioned while the attraction of "overcoming the materialism of natural science" increased.

In the introduction to his classical work on kinetic gas theory Boltzmann wrote in 1898 with regret, "it would be a great tragedy for science if the theory of gases were temporarily thrown into oblivion because of a momentary hostile attitude toward it, as was for example the wave theory because of Newton's authority."[2] Smoluchowski's work on the theory of Brownian motion presented a new brilliant proof of the reality of atoms. Einstein noted that the universal acceptance of kinetic theory, mainly due to Smoluchowski's work, is dated to this time, as well as the confidence of physicists in the reality of atoms.

[1] BH: A general evaluation of Smoluchowski's work was given by Einstein (1917) and Sommerfeld (1917).

[2] TN: English translation from Boltzmann (1995, p. 192).

TN: Translated from *Pod Znamenem Marksizma* (*Under the Banner of Marxism*), 1927, No. 9, pp. 144–148. The preface to a Russian translation of "On the concept of chance and on the origin of probability laws in physics", von Smoluchowski (1918).

B. Hessen (✉)
Abingdon, UK
e-mail: chris.talbot@protonmail.com

C. Talbot and O. Pattison (eds.), *Boris Hessen: Physics and Philosophy in the Soviet Union, 1927–1931*, History of Physics,
https://doi.org/10.1007/978-3-030-70045-4_5

However, by no means is the significance of Smoluchowski's work limited by this. Boltzmann in his work destroyed the metaphysical gap between reversible and irreversible processes. He demonstrated that the "global clock does not need winding up".[3]

Thanks to Smoluchowski's work Boltzmann's concept received a brilliant experimental proof and a final theoretical completion. The huge methodological significance of eliminating the metaphysical difference between reversible and irreversible processes is really obvious. If we take Clausius's view, then as Engels wrote with brilliant insight, "Clausius' second law, etc., however it may be formulated, shows energy as lost, qualitatively if not quantitatively. *Entropy cannot be destroyed by natural means but it can certainly be created.* The world clock has to be wound up, then it goes on running until it arrives at a state of equilibrium from which only a miracle can set it going again. The energy expended in winding has disappeared, at least qualitatively, and can only be restored by an *impulse from outside*. Hence, an impulse from outside was necessary at the beginning also, hence, the quantity of motion, or energy, existing in the universe was not always the same, hence, energy must have been created, i.e., it must be creatable, and therefore destructible."[4]

Boltzmann succeeded in eliminating this flaw and interpreting the natural processes with the help of dialectics because he used a statistical approach to the molecular processes. What was considered irreversible in the past in Boltzmann's view was fundamentally reversible, but the *probability* of reversing the processes that are considered practically irreversible, is vanishingly small (but not equal to zero!).

If we put a pan with water on a primus the heat transfers from the flame to the water and the water boils. This is something routinely observed in everyday life: heat transfers from a body with higher temperature to a body with the lower one. As we have never in our human experience observed the reverse, we are convinced that there are fundamentally irreversible processes, e.g. the transfer of heat from a warmer body to the less warm one.

However, if heat is nothing more than the motion of molecules, then it is not clear at all why an aggregate of molecules where each one performs a motion that is fundamentally reversible, results in such an irreversible process as the transfer of heat from a warmer body to the less warm one.

Boltzmann's contribution is that on the basis of the kinetic theory he introduced a concept of the *probability* of a process continuing in a certain direction, instead of the impossibility of reversing the process. If we put a pan on a hob, then the probability of the water in the pan boiling is so high that in practical terms we assume it to be the case. However, it is quite possible that the water in the pan freezes, i.e. the heat from the pan transfers to the hob; this is not impossible but very improbable.

In this case, as after the revolution performed by Copernicus, nothing changes in our practical life, but our theoretical views turn completely upside down.

---

[3]TN: Reference to Engels on Clausius—see quotation in next paragraph.

[4]TN: English translation from *Dialectics of Nature*, Engels (1988, p. 563). Engels adds "*Ad absurdum*!" Italics as in the original and as given by Hessen.

This turn could be achieved only thanks to the development of the kinetic theory of matter. However, the kinetic theory of matter regards a body as an aggregate of a vast number of atoms. This theory made physicists widely use the methods that are most appropriate for the study of collectives, i.e. statistical methods. Since all natural phenomena are based on atomic and internal atomic processes, statistical methods become more and more one of the most important tools in physics. Boltzmann's brilliant results are closely connected to the vital importance of statistical methods in his work.

As justly noted by Sommerfeld, Smoluchowski is a direct successor and continuator of Boltzmann's approach. "Statistics was as vital for him as air".[5]

Lately the statistical approach has become more and more acceptable and popular in physics. Indeed, it became essential to each physicist "like air".

However, while a dynamical concept of natural laws is methodologically easier and clearer, a statistical one poses a whole number of deep methodological questions, first and foremost the problem of causality and chance.[6]

The statistical approach requires a deeper development of causal laws. Probability theory is the mathematical apparatus used by the statistical approach. Therefore, research into the methodological foundations of the statistical method necessarily results in the research into the foundations of the theory of probability. But the concept of probability is closely connected with the concept of chance.[7] This is why the wide popularity of the statistical method highlights the problem of causality, necessity and chance.

Classical physics' interpretation of these concepts becomes inadequate.

Lack of clarity and confusion around these basic concepts leads to the rejection of the law of causality and the resurrection of teleological views etc.

What is the essence of chance? What is the significance and where are the boundaries of applicability of the statistical method in physics? These are the unavoidable questions posed by modern physics.

We all recently witnessed fierce attacks on Dialecticians[8] who dared to suggest that chance was not a subjective category, i.e. a consequence of our ignorance, but a real *objective* category.

Clearly the answer to this question is of immense importance, including for physics. Indeed, if chance is a result of the limitation of our knowledge then the statistical method acquires a subjective colouring. It becomes a temporary crutch for our ignorance. It is impossible to define an objective criterion for the conditions and boundaries of its application. All such criteria will have a subjective colouring similar to our ignorance. Smoluchowski's article below is particularly significant for

[5]BH: Sommerfeld (1917, p. 537).

[6]BH: On statistical and dynamical concepts related to the problem of causality in modern physics see: On the bicentenary of Isaac Newton's death. Foreword to articles by A. Einstein and J. J. Thomson by Boris Hessen, *Pod Znamenem Marksizma* (*Under the Banner of Marxism*), 1927, 4, pp. 152–165. TN: See Chap. 4.

[7]TN: Here and in the following "chance" is taken as the translation of the Russian sluchainost'.

[8]TN: i.e. on the Deborinite philosophers by the Mechanists.

us as it both fully confirms Hegel's and Engels's views on chance as an objective category and defended by Dialecticians and concretises this concept using physical examples.

This article is the last work by Smoluchowski. It was published after his death. It analyses the main ideas that are vital for the understanding and evaluation of the statistical method. This is the only purely methodological work by Smoluchowski.[9] The choice of its topic signifies the utmost importance the author attributed to the analysis of certain ideas.

Smoluchowski highlights the *objective* side of the concepts of probability and chance as his main thought in the article.

He says, "…all probability theories which perceive chance as an unknown 'partial cause' must …from the outset be regarded as insufficient. The physical probability of an event can only depend on the conditions which influence its coming about, but not on the degree of our knowledge."[10]

But if chance is an objective category then its essence requires an objective definition and it is necessary to show the conditions when probability theory, i.e. the statistical research method, can be applied and must be applied. Smoluchowski's article looks into these questions. A methodological analysis of the concept of chance is given by a detailed study of simple cases that, as it were, serve as a "model of chance events."

Further, the usual interpretation of chance opposes the concepts of chance and necessity: an event is either necessary or accidental. One excludes the other. Chance is the antithesis of the necessary and the regular. But once we adopt this metaphysical opposition of the accidental and the necessary, i.e. regular, then we unavoidably arrive at the contradiction which Smoluchowski formulated as follows. If we adopt the viewpoint of absolute metaphysical determinism then how can chance arise at all? How can regular causes lead to chance events? If we try to resolve this question by declaring chance a subjective category and a consequence of our partial ignorance then another difficulty immediately arises: objectively there is no chance. Everything that is happening is strictly and singularly determined. However, in our practice and in science we calculate the results of chance (even as a subjective category). The work of an insurance company is a suitable example. So how can one calculate the results of chance? How can *accidental* causes result in *regular* actions? Although we abstractly suppose that chance exists as an unknown necessity, in each specific case we do not know this necessary connection and even do not attempt to establish it. However, the result of the calculated chances produces a steady regularity. "If

[9]BH: Smoluchowski made a brilliant review of his own works on physics in von Smoluchowski (1913, 1914, 1916).

[10]TN: The same quotation is used in Chap. 4, p. 56, n. 41. German original: *…alle Wahrscheinlichkeitstheorien* von vornherein als *ungenügend* zu betrachten, *welche den Zufall als "unbekannte Teilursache" auffassen. Die physikalische Wahrscheinlichkeit eines Ereignisses kann nur von den Bedingungen abhängen, welche sein Zustandekommen beeinflussen, aber nicht von dem Grade unseres Wissens!* (Italics in original, p. 254).

one views chance, as popular theories do, as the negation of …laws, then these contradictions are indeed completely unbridgeable."[11] states Smoluchowski.

Yet this contradiction must be resolved, and Smoluchowski shows how such contradictions are resolved if one rejects the metaphysical opposition of chance and necessity (regularity) and accepts that chance is an objective category.

In his article *The Role of the Individual in History*[12] Plekhanov gave brilliant examples of concretisation of the dialectical concept of chance applied to social processes based on the acceptance of chance as an objective category and on the dialectical synthesis of the concepts of chance and necessity. Smoluchowski's article specifies the dialectical concept of chance applied to physical phenomena.

This is why this article is of special interest to Marxists and presents an obvious proof of fruitfulness of the dialectical concept of chance.

Editor's Note—CT

As statistical laws became increasingly important at the micro-level, with many quantum physicists arguing that causality could be abandoned entirely, it was necessary to make an assessment from the standpoint of Marxist philosophy. Hessen clearly concentrated on statistical physics, as is clear from his research work with Mandelstam.[13] Hessen based himself on Engels (who derives his ideas from Hegel) in a section of *Dialectics of Nature*. Engels called for chance to be taken as an objective category, with a dialectical relationship between causality and chance.[14] Hessen considers chance in the last part of Chap. 4, here in Chap. 5 as well as the exposition in Chap. 8.

Hessen's emphasis on the only philosophical paper by the Polish theoretical physicist Marian Smoluchowski, published posthumously in 1918, deserves special attention. While Smoluchowski is well known in the history of statistical physics as a major figure—he can be said to have originated the whole subject of stochastic processes—there is practically no mention of his 1918 paper. In an introduction to a collection of some of Smoluchowski's technical papers translated into English,[15] a leading mathematician in this field, Mark Kac, mentions it briefly, stating that Smoluchowski's "claims are modest" and "the article is full of sharp and incisive observations and

[11] TN: This quotation is also used in Chap. 4, p. 46, n. 40. German original: Betrachtet man in populärer Weise den Zufall als die Negation des Gesetzmäßigen, so sind diese Widersprüche gewiß vollständig unüberbrückbar (pp. 253–4).

[12] TN: Plekhanov (1976). Available via https://www.marxists.org/archive/plekhanov/1898/xx/individual.html, cited 13.03.20.

[13] To give some indication of Hessen's interests, note that he published a paper "The Interpretation of the Ergodic Hypothesis by the Theory of Probability", published in Uspekhi Fizicheskikh Nauk (Advances in Physical Sciences), No. 5, 1929, pp. 600–629. We considered translating it but realised that it was an entirely technical introduction to ergodic theory in statistical mechanics as understood at that time, hardly suitable for this collection.

[14] See Chap. 4, p. 54, notes 34–35, Chap. 8, p. 104, n. 10, Chap. 11, pp. 150–151, n. 26.

[15] Ingarden (1999) (Containing a brief biography by Smoluchowski's son, as well as introductions by Kac and the astrophysicist Subrahmanyan Chandrasekhar, this seems to be the only book specifically on Smoluchowski in English).

it leaves no doubt that the author has given the subject much time and thought."[16] The article is no doubt "modest"—in line with Smoluchowski's character—but we suggest that Hessen was correct in giving it some attention. Though no doubt Smoluchowski did not realise it, it does gives powerful support to the dialectical materialist view of causality and chance. Sections of Hessen's translation of the article are translated here into English with the corresponding German in footnotes.[17]

A brief but useful exposition of Smoluchowski's 1918 paper is given by von Plato in his well-known history of probability.[18] Von Plato includes an English translation of a paragraph of the paper,[19] a longer version of one of the translations given here.[20] He points out that Smoluchowski's approach to chance is an objective one[21]:

> First, chance is defined as instability, the typical element in many games of chance. Second, it is required that a physical and objective notion of probability be determined, not from our degree of ignorance concerning an event, but from the conditions that have an effect on its occurrence

Von Plato also notes Smoluchowski's idea that a small variation in a cause can give rise to a great variation in effect, which was, of course, taken up in modern chaos theory. By considering a simple mathematical model Smoluchowski explains that "It shows that the *apparent contradiction* [between chance and lawlike effects of causes] *does not exist* and that chance—in the sense of physics—can very well be brought by exactly defined lawlike causes."[22] In Hessen's terminology there is no "metaphysical opposition of chance and necessity".[23]

Finally it is worth adding that the dialectical conception of causality and chance, based on *Dialectics of Nature*, was the viewpoint of David Bohm in his approach to quantum theory as set out in *Causality and Chance in Modern Physics*[24] with no knowledge of Smuluchowski's 1918 paper. It enabled Bohm to challenge the viewpoint of absolute indeterminism or randomness that is central to "standard" quantum mechanics.

References

Bohm, D. (1957). *Causality and Chance in Modern Physics* (p. 1984). Routledge and Kegan Paul: London, first edition. Second edition with new preface by Bohm.

[16] Ibid., p. 20.

[17] Chapter 4, p. 55, n. 38, p. 56, notes 39–43 and p. 57, n. 44; Chap. 5, p. 64, n.10 and p. 65, n. 11; Chap. 8, p. 106, notes 16–18.

[18] von Plato (1994), pp. 171–173.

[19] von Smoluchowski (1918, p. 262).

[20] Chapter 4, p. 57, n. 44.

[21] von Plato (1994, p. 171), referring to von Smoluchowski (1918, p. 254).

[22] von Plato (1994, p. 173) quoting from von Smoluchowski (1918, p. 262), italics in original.

[23] See p. 64 above.

[24] Bohm (1957).

Boltzmann, L. (1995). *Lectures on gas theory* (S. G. Brush, Trans.). New York: Dover. Reprint of 1964, University of California edition.

Einstein, A. (1917). *Marian v Smoluchowski. Die Naturwissenschaften* [The Science of Nature], *5*(50), 737–738.

Engels, F. (1988). *Marx Engels collected works* (Vol. 25). Moscow: Progress Publishers.

Ingarden, R. S. (Ed.). (1999). *Marian Smoluchowski: His life and scientific work*. Warsaw: Polish Scientific Publishers.

Plekhanov, G. V. (1976). *Selected philosophical works II*. Moscow: Progress Publishers.

Sommerfeld, A. (1917). Zum Andenken an Marian von Smoluchowski (In Memory of Marian von Smoluchowsk). *Physikalische Zeitschrift*, *22*(15), 533–539.

von Plato, J. (1994). *Creating modern probability, its mathematics, physics and philosophy in historical perspective*. Cambridge University Press.

von Smoluchowski, M. (1913). Gültigkeitsgrenzen des zweiten Hauptsatzes der Wärmetheorie [Limits to the validity of the second law of thermodynamics]. *Physikalische Zeitschrift*, *15*, 261.

von Smoluchowski, M. (1914). Gültigkeitsgrenzen des zweiten hauptsatzes der wärmetheorie (Limits to the validity of the Second law of thermodynamics). In M. Planck (Ed.), *Vorträge Über Kinetische Theorie der Materie und Electrizität* (pp. 87–121). Leipzig: Teubner.

von Smoluchowski, M. (1916). Drei Vorträge über Diffusion, Brownsche Molekularbewegung und Koagulation von Kolloidteilchen [Three lectures on diffusion, brownian molecular motion and the coagulation of colloidal particles]. *Physikalische Zeitschrift*, *17*(23), 557–571.

von Smoluchowski, M. (1918). Über den Begriff des Zufalls und den Ursprung der Wahrscheinlichkeitsgesetze in der Physik [On the concept of chance and the origin of the laws of probability in physics). *Die Naturwissenschaften [The science of nature]*, *6*(17), 253–263.