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HYLE Biography

Wilhelm Ostwald (1853-1932)

by *Mi Gyung Kim**

Wilhelm Ostwald (1853-1932) was one of the most celebrated German scientists at the turn of the twentieth century. He gained an early reputation as a leading figure in the studies of chemical affinity, then the central theoretical question in chemistry. In the 1870s, he coordinated the previously disparate concerns about affinity into collaborative efforts and an independent discipline of physical chemistry by writing voluminous textbooks, founding the *Zeitschrift für physikalische Chemie*, and expanding the Leipzig Institute. His laboratory became a site of pilgrimage for aspiring scientists worldwide, as can be seen in the Einstein's 1901 letters soliciting an assistantship.[1] It was in recognition of his international renown that the Prussian *Kultusministerium* solicited and appointed him as the first exchange professor to Harvard University in 1905.[2] He was awarded the Nobel Prize in chemistry in 1909. His turn to energetics from the 1890s, first as a unifying scientific program and then as a cultural imperative, led, however, to his growing alienation from the scientific community. As a scientific prophet that led a mass exodus from the church, he envisioned a new century of organization and organizers based on the efficient use of energy.

Ostwald's successes and failures owed equally to his unconventional training at the periphery of German academic culture. He was born in Riga, Latvia to a German cooper master.[3] Although Germans constituted the social elite in the Baltic region and administered their own judicial, religious (Lutheran), and educational institutions until the intensification of the Russification policies in the 1880s, Ostwald missed the humanistic curriculum of the German schools. He attended a local *Kronsschule* along with other Russian and Latvian children and a *Realgymnasium* where the curriculum included physics, chemistry, mathematics, and foreign languages. Taking advantage of the brief relaxation in the regulation that tracked the graduates of the *Realgymnasium* to Riga Polytechnikum, he matriculated in 1872 at Dorpat University where he enjoyed fraternity life which included, other than constant beer-drinking and singing, free-floating conversations on poetry, music, art, sciences, philosophy, and worldview (*Weltanschauung*). Prompted by his father to pay attention to academics, Ostwald set his sight on the 'scientific paradise' – the chemical laboratory headed by Karl Schmidt. Having studied physiological chemistry with Liebig, Wöhler, and H. Rose, Schmidt was working on the mineral composition of waters. His assistant Johann Lemberg, who was interested in chemical geology, taught Ostwald the basic techniques of inorganic analysis and the concepts of chemical equilibrium, mass action, and reaction velocity. He took up the question of affinity for his *Kandidatenschrift* in 1875 through the examination of bismuth chloride solutions.[4]

After graduation, Ostwald obtained permission to work in the physics laboratory of Arthur von Öttingen who had studied in Berlin amongst the members of the Berlin Physical Society (Magnus, Kirchhoff, Helmholtz, Wiedemann, Poggendorff, and Kundt) and then worked briefly with Regnault in Paris. When

Öttingen's assistant took the job at Riga Polytechnikum, Ostwald became the paid assistant and began to work earnestly on the measurement of chemical affinity. He followed Julius Thomsen's path, albeit with a different, 'volumo-chemical' method, which he hoped would serve as a method as general and exact as calorimetry, but easier and more accessible. This work became the basis of his *Magister* and doctoral dissertations (Ostwald 1876-80, 1877, 1878). Employed afterwards as the assistant back in Schmidt's laboratory and as the teacher of mathematics and natural sciences at Dorpat *Kreisschule*, Ostwald married in 1880 and began to work on the *Lehrbuch der Allgemeine Chemie* (1885-7) while continuing the determination of affinities with chemical analysis (Ostwald 1879-84).

The search for a general method of measuring affinities shaped Ostwald's early investigative trail. His long-term agenda lay in preparing a three-dimensional affinity table that would include temperature in addition to the specific affinity constants of acids and bases. In 1882, he became ordinary professor of chemistry at the Riga Polytechnikum where he gradually built up a laboratory and a research program on 'chemical dynamics' (Ostwald 1883-88). With a reliable thermostat, he sought to determine the 'intensity of chemical forces' from the velocity of the course of chemical processes. He also succeeded in persuading the administration to build a new chemical laboratory for which he was granted a travel stipend throughout Germany and Switzerland to inspect the university laboratories. The trip occasioned his first meetings with leading German scientists, such as Landolt, Hofmann, Helmholtz, Kolbe, Horstmann, Erlenmeyer, and Baeyer.

The appearance of Svante Arrhenius' dissertation on electrolytic conduction in 1884 set Ostwald on a new path. It contained a close scrutiny of the electrical conductivity of acids and bases with extreme dilution, along with highly speculative hypotheses on the constitution of these solutions (Ostwald 1884-88). The most promising aspect of Arrhenius' work for Ostwald lay in the possible use of electrical measurements for the quantification of chemical affinities. Ostwald immediately proceeded to test the numerical correspondence between the affinity coefficients from his previous measurements and the electrical conductivities of acids and published a preliminary note, which he used to secure a dozentship for Arrhenius. He traveled to Sweden during the summer to meet him and other Scandinavian scientists whose works he had utilized – Guldberg, Waage, and Thomsen. Arrhenius traveled to Germany with him and later to Riga. Soon, van't Hoff joined the roster, completing the core of what was to become the Leipzig school of physical chemistry (Root-Bernstein 1980).

The electrochemical studies marked the final destination in Ostwald's journey searching for a general method of measuring affinities by occasioning his transition to energetics. Throughout the journey, Ostwald always correlated the results of the different kinds of measurement to obtain a constant set of numbers for the relative affinities of acids and bases, which he considered as invariable natural constants. A close scrutiny of the process of dilution with the measurement of electrical conductivities indicated, however, that the affinity coefficients of acids lost their value with increasing dilution. Ostwald attempted to deal with this problem by developing the law of dilution as 'one and the same function' common to all acids and bases. With Arrhenius' formulation of the dissociation theory of electrolytes, however, he was compelled to seek an alternative, more general foundation for his affinity chemistry.

When Ostwald was called in 1887 to Leipzig, the first chair of physical chemistry in Germany, he responded with an inaugural address, 'Energy and its Transformations', that contained his nascent program of energetics. He sought to legitimize his young discipline and himself – a 'Russian' educated in a *Realgymnasium* – in a prestigious German university.[5] To this end, he presented physical chemistry as a new boundary discipline that would remedy the 'atomistic' fragmentation of scientific disciplines by dealing with the most general problems – the transformations of matter and energy, the two 'realities' that constituted the objects of all scientific investigations (Ostwald 1916, pp. 185-206). By 1891, he developed a 'radical' or monistic energetics that granted the status of reality only to energy. Matter no longer constituted an independent reality, but became a complex of energy factors. While the new scheme was apparently reductionist, Ostwald's intention was the opposite: the overriding theme in his discourse of energetics was *unification through systematization*. Various kinds of energy were accommodated not through a reduction to a single entity, such as mechanical energy, but through functional coordination.

Ostwald's energetics as a comprehensive scientific program contained two main features: a new system of absolute measurement and a new interpretation of the second law of thermodynamics. Criticizing the Gaussian system of absolute measurement for its arbitrary nature, Ostwald proposed space, time, energy (instead of mass), and an intensity or capacity factor of energy (except in mechanics) as the four dimensions of the new system. He identified the capacity/intensity factors of the known forms of energy – for example, heat capacity/temperature for heat energy, the amount of electricity/ electrical potential for electrical energy, and the combining weight/affinity for chemical energy. The factorization of energy allowed not only a dimension specific to each field of investigation, but also a way of correlating different forms of energy through their 'transformations': when one kind of energy disappeared, the other kind appeared in compensation, exactly as in the transformation of chemical substances. The two laws of energetics (rather than those of thermodynamics) governed the conservation and the transformation of energy: the first law expressed "the fact that energy is an independent and [...] homogeneous magnitude whose total amount proves invariable" throughout various transformations. The second law governed these transformations according to the difference in the intensity factor of energy. Instead of reducing all other kinds of energy to the mechanical energy, however, Ostwald saw them in "mutually functional relations" to each other: "one cannot change the factors of one kind of energy without simultaneously changing the factors of the other kinds of energy" (Ostwald 1892). His mammoth book, *Elektrochemie: Ihre Geschichte und Lehre* (1896), was meant to illustrate this functional coordination between different forms of energy, and correspondingly, between different branches of science. Ostwald's vision of monistic and holistic energetics ran into a unified opposition from mathematicians, physicists, and chemists at the 1895 Naturforscherversammlung, however, which killed it as a scientific program (Deltete 1983).

Ostwald's energetics as a discourse of unification matured in the Leipzig context. In part thanks to the Saxon government policy that aimed at restoring the preeminence of her flagship university, Leipzig university harbored a number of distinguished scholars who challenged the dominance of Prussian schools and cultivated a vision of unified cultural sciences: Wilhelm Wundt, Karl Lamprecht, and Friedrich Ratzel (Wundt 1900-1920, Lamprecht 1891-1909, Chickering 1993). Their shared concern with *Kulturwissenschaft* and *Kulturpolitik* – valuing culture as a whole over the individual, pursuing the laws of historical change and coordination of different cultures – had a significant bearing on the evolution of Ostwald as a natural philosopher. His energetics explicitly refuted the mechanistic reductionism of classical physics and offered an alternative framework for the unification of the physical sciences that avoided two prevalent criticisms. By eliminating the discussion of atoms and forces altogether, Ostwald sought to silence the critique of scientific materialism often associated with the mechanistic conception of nature. At the same time, by reinterpreting the second law of thermodynamics as a subsidiary law that regulated the transformation and coordination of energy, he sought to circumvent the common characterization of the law as the dissipation of energy and consequently of the universe, which was held responsible for the decadent modernist culture.

After the failure of energetics as a scientific program, Ostwald became increasingly interested in its philosophical, social, and cultural applications. He established a new journal in 1902, *Annalen der Naturphilosophie*, which shunned mechanism and materialism while advocating historicism and organicism. The overriding theme was unification through systematization. A standard repertoire of Ostwald's *Naturphilosophie* was the 'system of sciences' that provided a new map of university disciplines. In his 'pyramid of sciences,' a modification of August Comte's, the energetical sciences (*Energetische Wissenschaften*: mechanics, physics, and chemistry) occupied the current historical stage or 'epoch' in the development from the sciences of order (*Ordungswissenschaften*: logic, mathematics, and geometry) to the life sciences (*Lebenswissenschafent*: physiology, psychology, culturalogy, and genealogy). The new disciplinary map subverted the traditional disciplinary hierarchy, downgrading humanists – the traditional guardians of German *Kultur* since the Humboldtian reform of the early nineteenth century. Ostwald criticized philology sharply, characterizing it as a 'paper science' (*Papierwissenschaft*) for its lack of predictive power, the hallmark of scientificity (Ostwald 1902, 1910, 1912, 1914).

After he resigned from the Leipzig faculty in 1906, Ostwald retired to his country estate, christened 'Landhaus Energie', and focused on promoting the energetical *Weltanschauung* that would build a harmonious *Weltreich.* His vision of an organized society was that of a well-functioning body that coordinated individual organs to maximize its energetical efficiency, which served as the measure of cultural progress. He was an ardent supporter of artificial languages, or *Weltsprache*, that he thought would save energy by eliminating the irregular and unsystematic natural languages, shape the students' minds more logically, and facilitate science and technology education by eliminating the language barrier (Ostwald 1907). He also applied the energetical imperative to the problem of industrial labor, or the 'social question'. He thus named energetical science as *Arbeitswissenschaft*, arguing that energetical efficiency should provide the underlying rationale for the organization of labor. Ostwald's technocratic vision invited a scathing critique from Max Weber who lambasted the 'technologists' who 'raped' sociology (Weber 1909).

The award of the Nobel Prize in 1909 brought Ostwald into the public spotlight. The following year, Ernst Haeckel, the founder of the Deutscher Monistenbund, invited him to join the organization as president. As the acting president of a popular movement, Ostwald promoted energetics as the organizing principle of all facets of society and culture, which culminated in his famous energetical imperative: *waste no energy, utilize it!* As the scientific rationale for 'universal monism,' the energetical imperative would bring about a 'harmony' of human activities. He envisaged monistic student organizations as 'a movement from below' that would provide a new 'spiritual leadership of Germany [*geistige Führung der Nation*]', led an exodus from the church alongside the social democrats, delivered Monist Sunday Sermons, formed an alliance with international peace movements, and organized international societies (Ostwald 1912). Two organizations Ostwald founded in 1911 enacted the energetical imperative. The Association of Chemical Societies, an international organization of national chemical societies, was meant to alleviate the duplication of work and the waste of resources. The Brücke was supposed to function as the 'Brain of Mankind' that would allow an efficient use of mental energy by organizing the organizers.[6] Politics, or 'the technology of human perfection', as an energetical science required the diminution in the 'biological law of inertia' that slowed down the progressive pace of man's dominion over nature. Education, emancipation from traditional religion, and international cooperation would provide the necessary steps.

Ostwald's liberal and pacifist vision of energetics was crippled by the First World War. Working with the Werkbund, an association of painters and architects, he began to focus his energy on systematizing the color schemes with his characteristic zeal, preparing elementary textbooks, inventing instruments for measurement, and devising color standards. After the war, he continued to work on standardizing color schemes through measurement, hoping to establish the laws of color harmony and founded the journal *Die Farbe*. He sought to institute his color schemes in schools, factories, and state art institutions (Domschke & Lewandrowski 1982, Ball & Ruben 2004). An accomplished painter (Ostwald 1992), Ostwald saw his efforts in developing and instituting the science of color as his most enduring and beneficial contribution to the world culture, one that would embody and carry on his monistic vision. He died on April 4, 1932, before the Nazi propaganda machinery began to distort the monistic imperative of unity and efficiency to destructive ends.

Notes

[1] Ostwald Nachlass, Berlin Academy, nos. 677 and 678; published in Körber 1964.

[2] For Ostwald's American students, see Servos 1990.

[3] The best available biography is still Ostwald 1933.

[4] Ostwald 1875. For an account of Ostwald's affinity studies and his precursors, see Kim 1990.

[5] When he learned of the vacancy, Ostwald inquired cautiously to Wilhelm Wundt, betraying his insecurity, "whether my person – I am neither a German national [*Reichsbürger*], nor has been educated

in a German university – can be considered at all for the vacancy in question." Ostwald to Wundt, April 4, 1887 [Ostwald Nachlass, no. 3379]. For the continuing harassment from his colleagues, see Grete Ostwald 1953, p. 44.

[6] Ostwald, 'Eine Weltreich der Wissenschaft' and 'Die Organisierung der Organisatoren', [Ostwald Nachlass, nos. 5844 and 5833].

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Mi Gyung Kim:
Department of History, North Carolina State University, Raleigh, NC 27695-8108, U.S.A.; Kim@social.chass.ncsu.edu

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