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(b. Edinburgh, Scotland, 1811; *d*. near Edinburgh, 18 June 1883), *physics, physical chemistry, astronomy*.

During his lifetime Waterston was considered a minor, somewhat eccentric scientist, known chiefly for his investigations of solar radiation: his other publications on astronomy, physical chemistry, and molecular physis attracted little notice. After his death a manuscript on the kine'tic. theory of gases that he had submitted in 1845 to the Royal Society of London was discovered in the Society's archives. Had this paper been published when it was first presented, an important branch of physics would have been advanced by ten or fifteen years (in the judgment of Lord Rayleigh and other modern commentators) and Waterston would have been generally recognized as one of its leaders Instead, Waterston's case has become a classic example of the suppression of originality by an established scientific institution.

Waterston's father, George Waterston, was an Edinburgh manufacturer of sealing wax and other stationery requisites. The family was related to Robert Sandeman, the leader in extending the Sandemanian (or Glasite) religious sect to England and America, and to George Sandeman, founder of the London firm of port wine merchants.

George Waterston was greatly interested in literature, science, and music; his family thus grew up in an atmosphere of culture and came into contact with young literary men. John James was the sixth of nine children, all of whom were educated at the Edinburgh High School, then the leading school in Scotland. Following graduation Waterston became a pupil of Messrs. Grainger and Miller, civil engineers, but also attended lectures at the university, where he took an active part in the student literary society. He studied mathematics and physics under Sir John Leslie and was medalist of his year in Leslie's class. He also attended lectures on anatomy, chemistry, and surgery.

Like John Herapath, another early kinetic theorist, Waterston was interested in the problem of explaining gravity without invoking action at a distance. At the age of nineteen, he published a paper in which he discussed the properties of a system of colliding cylindrical particles, arguing that the latter could generate a gravitational force. Some of the ideas developed in this paper were later utilized in his kinetic theory, particularly the idea that collisions could result in a transfer of energy from the rectilinear to the rotatory mode of motion.

At the age of twenty-one Waterston went to London, where he did drawing and surveying in connection with the rapidly developing British railway system. He became an associate of the Institution of Civil Engineers and contributed a paper to the *Transactions* of that group on a graphical method of estimating the earthwork in embankments and cuttings. In order to have more time free to pursue his scientific interests, he obtained a post in the hydrographers' department of the Admiralty. The head of the department was Captain (afterwards Admiral) Francis Beaufort, who subsequently communicated Wasterston s paper on kinetic theory to the Royal Society. On Beaufort's suggestion, and with his backing, Waterston applied in 1839 for the post of naval instructor to the East India Company's cadets at Bombay. He was successful, and found the position satisfactory in that he had sufficient leisure and access to scientific books and journals at the Grant College, Bombay. He taught the theoretical aspects of such subjects as navigation and gunnery.

During his stay in India, Waterston sent home the manuscript of a short book and several scientific papers. The book, an essay on the physiology of the central nervous system, was published anonymously at Edinburgh in 1843. It contains the first expression of Waterston's views on molecules and on the possible application of molecular theory to on the possible application of molecular theory to biology. Some basic principles of the kinetic theory of gases are included, such as "A medium constituted of elastic spherical atoms that are continually impinging against each other with the same velocity, will exert against a vacuum an elastic force that is proportional to the square of this velocity and to this density…. The proportion of the whole rectilinear to the whole rotatory momentum is probably constant, and might be found perhaps by calculation" Increase in temperature might correspond to increase of molecular, *vis viva*. The distance traveled by a molecule, after hitting one and before encountering another, is inversely related to the density of the medium and to the square of the diameter of the molecules.

These propositions, along with some more fanciful notions, attracted little attention at the time. In December 1845, Waterston presented a more systematic exposition of his theory of gases in a paper entitled "On the Physics of Media That Are Composed of Free and Elastic Molecules in a State of Motion." As a physical justification for his theory he mentioned the wave theory of heat, adopted by analogy with the wave theory of light as a result of the recent experiments by J. D. Forbes and Melloni on radiant heat. He found that "in mixed media the mean square molecular velocity is inversely proportional to the specific weight of the molecules"; this was the first statement of the "equipartition theorem" of statistical mechanics (for translational motion only). Since this conclusion was printed in an abstract of the British Association meeting in 1851, Waterston seems to have established his priority in announcing the theorem even though the rest of his paper was not published until much later (see below). Another original (but quantitatively incorrect) result was that the ratio of the specific heats, at constant pressure and constant volume, for monatomic gases should theoretically be equal to 4/3. (Because of a numerical slip, Waterston failed to obtain the correct value, 5/3.)

Waterston submitted his paper for publication in the *Philosophical Transactions of the Royal Society of London*. At that time the custom of the Society was that a paper submitted by someone not a fellow of the Society could be "read" (officially presented) if it were communicated by a fellow, but it then became the property of the Society and could not be returned to the author even if it was not published. The two referees who examined Waterston's paper recommended that it should not be published. One of them, Baden Powell (professor of geometry at Oxford), said that Waterston's basic principle — that the pressure of a gas is container– was "…very difficult to admit, and by no means a satisfactory basis for a mathematical theory." The other referee was the astronomer Sir John William Lubbock, who said, "The paper is nothing but nonsense, unfit even for reading before the Society." These judgments seem rather harsh, not because Waterston's theory was essentially the same as the one successfully proposed in the 1850's by Clausius and Maxwell, but because even by 1845 the physical basis for such a theory—the relation between heat and mechanical energy—was accepted by a substantial portion of the scientific community. Nevertheless, only a brief abstract of Waterston's paper appeared in the *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society* in 1846.

Waterston was not able to get his manuscript back, and had failed to keep a copy for himself, so he was unable to publish it elsewhere. He did attempt to draw attention to the paper by privately printing and circulating another abstract of it about twelve pages long, and by raising the subject in later papers presented at British Association meetings and in *Philosophic Magazine*. The only immediate response was a critical discussion by W. J. M. Rankine (who preferred a theory of rotating vortices) and an abstract by Helmholtz in *Fortschritte der Physik* that may have had some influence on A. Krönig's revival of the kinetic theory in 1856.

In the paper "On Dynamical Sequences in Kosmos," read at the British Association meeting in 1853, Waterston pointed out that substantial amounts of heat could be generated by the fall of matter into the sun. He thought that the earth might have grown in size over long periods of time by the accretion of such meteoric material, and mentioned other possible astrophysical applications of the theory that heat is equivalent to mechanical energy and may be simply the motion of the elementary parts of bodies. William Thomson adopted a meteoric theory of the sun's heat from this paper, though he later learned that a similar theory had been presented earlier by J. R. Mayer.

In 1857 Waterston resigned his appointment at Bombay and returned to Scotland, apparently having saved enough money to be able to devote his time to scientific work. About this time he published some papers on the experimental measurement of solar radiation, yielding an estimate of about 13 million degrees for the sun's temperature; this figure was frequently quoted in the debate on the sun's temperature during the 1870's. Waterston began experimental work on liquids; and during the next few years he published a series of papers on physical chemistry, mainly in *Philosophical Magazine*. Apparently, he never met any of the scientists who might have recognized the value of his work on the kinetic theory, with the possible exception of Rankine (who spoke at the same session of the British Association meeting at which Waterston presented a paper on gases in 1851).

Among Waterston's chemical papers is one on capillarity and latent heat that reports a calculation of the diameter of a water molecule. The result was 1/214,778,500 inch (approximately 10^{-8} cm.). This estimate was published in 1858, seven years before Joseph Loschmidt's determination of molecular sizes from kinetic theory but forty-two years after Thomas Young's estimate, which was somewhat similar to Waterston's

In 1878 the Royal Astronomical Society rejected two papers by Waterston. A few months later he resigned, having been a member since 1852. This event reinforced his isolation from the scientific world. According to a memoir by his nephew, Waterston "would not attend the meetings of the Royal Society of Edinburgh though some friends sent him billets, and rather avoided the society of scientific men.… We could never understand the way in which he talked of the learned societies, but any mention of them generally brought out considerable abuse without any definite reason assigned"[1]

Waterston's paper on the theory of sound, published in *Philosophical Magazine* in 1858, was the ultimate reason for his posthumous recognition by the scientific community. In 1876, S. Tolver Preston wrote to Maxwell about this paper, noting that Waterston had investigated the kinetic theory of gases as early as 1845, although his work had not yet been published.[2] But Maxwell apparently took no interest in this matter; and it was not until 1891, eight years after Waterston's death, that Lord Rayleigh rediscovered the 1858 paper on sound because of his interest in another of Waterston's papers that cited it. The mention of a manuscript lying in the archives of the Royal Society finally reached the right reader, for Rayleigh was secretary of the Royal Society in 1891, and had no difficulty in retrieving this manuscript. The paper was published in the *Philosophical Transactions* for 1892, with an introduction by Rayleigh, according to whom:

The history of this paper suggests that highly speculative investigations, especially by an unknown author, are best brought before the scientific world through some other channel than a scientific society, which naturally hesitates to admit into its printed records matter of uncertain value. Perhaps one may go further and say that a young author who believes himself capable of great things would usually do well to secure the favourable recognition of the scientific world by work whose scope is limited, and whose value is easily judged, before embarking on greater flights.

NOTES

1. R. J. Strutt, *Life of John William Strutt, Third Baron Rayleigh* (London, 1924: augmented ed., Madison, Wis., 1968), 171.

2. I am indebted to Dr. C. W. F. Everitt for informing me of this letter.

BIBLIOGRAPHY

I. Original Works. Most of Waterston's published works are reprinted in *The Collected Scientific Papers of John James Waterston*, edited with a biography by J. S. Haldane (Edinburgh, 1928). This volume omits the following papers: "An Account of an Experiment on the Sun's Actinic Power," in *Monthly Notices of the Royal Astronomical Society*, **17** (1856-1857), 205–206; "On Certain Inductions With Respect to the Heat Engendered by the Possible Fall of a Meteor Into the Sun: and on a Mode of Deducing the Absolute Temperature of the Solar Surface From Thermometric Observation," in *Philosophical Magazine*, 4th ser., **19** (1860), 338–343, and *Monthly Notices of the Royal Astronomical Society*, **20** (1860), 196–202; "Note of an Experiment on Voltaic Conduction," in *Philosophical Magazine*, 4th ser., **31** (1866), 83–84. In addition there are brief reports of his papers presented at British Association meetings in *Athenaeum* (1851), 776; (1852), 980; (1853), 1099-1100. Unpublished materials may be found in the archives of the Royal Society of London.

II. Secondary Literature. J. S. Haldane's "Memoir of J. J. Waterston" is printed in the *Papers* (see above); it includes biographical information, portraits, and extensive discussion of Waterston's scientific work and opinions. See also S. G. Brush, "The Development of the Kinetic Theory of Gases. II. Waterston," in *Annals of Science*, **13** (1957), 275–282, and :John James Waterston and the Kinetic Theory of Gases," in *American Scientist*, **49** (1961), 202–214; and E. E. Daub. "Waterston, Rankine, and Clausius on the Kinetic Theory of Gases," in *Isis*, **61** (1970), 105–106.

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