



## XI. Observations on the expansion and contraction of water

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*XI. Observations on the Expansion and Contraction of Water.* By WILLIAM CRANE, F.R.M.S. Edin.

EVERY deviation from the general effects of caloric forms an important subject for investigation, and claims the attention both of the student and the philosopher. Amongst these curious and interesting facts, that water at the temperature of  $40^{\circ}$  has its maximum density, and on being reduced to a lower degree begins to expand until it is converted into ice, has given rise to many hypotheses and theories respecting its cause. Some have supposed this to be owing to the contraction of the vessel in which the water is contained. One of the most strenuous supporters of this opinion is Mr. Dalton, who says, "it is only apparent;" although the experiments both of Dr. Hope and Count Rumford were made with the greatest care and precision, as were also those of Lefevre Gineau. The result of Mr. Dalton's experiments, when a glass vessel is employed, is certainly very much in favour of what he maintains, as, according to the tables in Dr. Thomson's Chemistry, the contraction of the glass and the expansion of the water coincide; yet this is not the result of the experiments made upon water contained in different vessels, as in brown earthen ware, queen's ware, iron, copper, &c. The coincidence, therefore, as the doctor observes, is only apparent; for the other bodies deviate as their expansion increases. Mr. Leslie, in his *Inquiries upon the Nature, &c. of Heat*, seems to be nearly of the same opinion. Others have adopted the idea of its arising from a peculiar arrangement of its particles which observe a certain polarity, as is shown by the position of its crystals; and this was the opinion of the illustrious Dr. Black.

As water is a body the particles of which possess great mobility among themselves, and the shape of a body that moves with the greatest ease being a sphere; let us consider that this is the form of a particle of water when at the  $40^{\circ}$  and above, or, according to Mr. Dalton\*, at the  $36^{\circ}$ , which he estimates to be its maximum density. In the following part of this paper I prefer the  $40^{\circ}$ , as between that and  $39$  is the point agreed to by the majority of writers, and which agrees with the experiments I have made. The difficulty of proving this to be the shape of an atom of water is perhaps in some measure removed by considering the figure which a globule of water assumes when thrown

\* Dr. Henry's Elements of Chemistry.

upon a hot iron. Haüy\* observes that this was the opinion of Descartes, who thus endeavoured to account for the formation of the six radii which are observed to form a floccule of snow. But Descartes says, when treating on the shape of the particles of water, “Deinde † suppono exiguas illas partes, quibus aqua componitur, longas, læves et lubricas esse anguillarum parvularum instar, &c.” and that they only assumed the shape of a sphere when converted into vapour, from the rapid motion into which they are thrown, in these words; “Sed ‡ contra quum vaporis formam habent, agitatio illarum adeo est concitata, ut celerimè rotentur in omnes partes, et eadem opera in longitudinem suam porrigantur; unde fit ut singulæ illarum reliquas suis similes, irruptionem in parvas sphæriculas, quas describunt, molientes, arcere atque abigere possint, &c.” Hence he had recourse to this reasoning to account for the formation of the radii already mentioned, as his theory respecting the particles of water could not be adapted to this phenomenon.—But to return to our subject.

Then, at the degree above mentioned, I would say that the particles of water are in contact only at certain points; but from the caloric, granting it to be a fluid, filling up the interstices, their mutual affinity is prevented from acting so forcibly as to change their figure. In illustration of this, we may take a pile of balls, as a rough comparison, each ball having for those around it a strong affinity, and which are prevented from acting upon each other, or running into a solid mass, by sand or some substance being poured into the various crevices, which nevertheless does not prevent their touching in certain points. But as by the reduction of temperature part of the caloric is withdrawn, which being interspersed throughout the water, as just explained, prevented these particles from affecting each other, the affinity they exert among themselves now begins to take place, and their shape becomes altered from that of a sphere to some other figure. Hence, as a sphere contains the greatest quantity of matter under the least given superficies, the superficial contents of these atoms will be increased in proportion as they deviate from that form.

Although they are thus enabled to act upon each other, still they attract around them a quantity of caloric, by means of which they are kept so far separate as to remain

\* Haüy's Natural Philosophy; trans. by Dr. O. Gregory.

† *Renati des Cartes Specimina Philosophiæ*: Amstelodami, anno cio ipc lxxii.

‡ Ibid.

in a fluid state. But owing to the reciprocal affinity of these *moleculæ* this attraction is very feeble, and on suddenly shaking the water they rush together, forming a crystalline mass, setting free the caloric they held around them, causing by that liberation a rise in the thermometer. In the same manner we can bring so near as to touch, globules of mercury, which have been previously moistened with water, without their running into one homogeneous mass; but giving the vessel in which they are placed a sudden shake, they become united, parting with the water each had attracted around it. This experiment is easily shown by throwing quicksilver upon any flat surface that has had some water poured upon it; then gently pushing the globules of mercury, so as just to touch each other, they will not unite, owing to the pellicle of water which surrounds each. Upon the vessel being agitated, an union instantly takes place.

The next remarkable occurrence is the great and sudden expansion that takes place upon the water being converted into ice. I would now suppose that these atoms have reached their maximum of expansion, or that they deviate in the greatest possible degree from their spherical shape, and assume probably that of the primitive crystal. For after having obtained the primitive crystal of any body, we have, if we continue the chipping and diminish it ever so much, always the same figure. Again, if we apply heat, from the  $32^{\circ}$  there is observed a contraction, until the thermometer rises to the  $39^{\circ}$  or  $40^{\circ}$ , owing to these integrant molecules of the crystals again assuming the spherical form: after this the water begins to expand, which I should imagine is owing to the caloric gradually forcing these spheres further apart, and, if continued, separates them beyond the limit of the attraction they exert amongst themselves. These atoms, being lighter than air, fly off in a state of vapour; and as they are now out of the sphere of each other's attraction, they are enabled to attract more forcibly around them the particles of caloric; and hence the increase of capacity for caloric which is observed to take place when water is converted into vapour.

In the above paper, the words *contact* and *touch* have been frequently employed: these terms are not to be understood in an abstract sense, but merely to denote that the particles of matter approach each other extremely near;—as in the experiment on the globules of mercury it is said they are placed so near as to touch. That this is not the case is  
evident,

evident, for they are separated by the pellicle of water around each. Lavoisier, in his Chemistry, says, that the particles of the hardest bodies are not in actual contact. If that were the case, it is probable that their cohesive affinity would be so powerful as not to be affected by caloric.

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XII. *Description of Improvements in a Mathematical Dividing Engine.* By Mr. J. ALLAN\*.

SIR, I BEG leave to send to you, herewith, for the inspection of the Society of Arts, &c. a model of my improvement on the mathematical dividing engine which I have lately made, containing that part which differs in principle from those made by the late Mr. Ramsden and others; the drawings or engravings of which are, I suppose, in the Society's possession. I therefore am of opinion the Society will think that the wooden wheel I have sent with the moveable ring on its edge, will be sufficient to demonstrate its good effect in correcting the teeth or rack where the screw acts. You will please to observe, that it is cut by a screw-cutter, and it is required to go many times round the engine before the teeth are full. To effect this, I reversed the moveable ring not less than twenty times, so that I have not the least doubt of the one ring having corrected the other to a degree of perfection which had not hitherto been obtained in engines.

This simple, easy, and correct way of making engines, may be applied with great advantage to circular instruments, for the purposes of astronomy and land-surveying. If the Society will do me the honour to appoint a committee to view the engine itself, I will demonstrate its effects.

I am, sir,

Your very humble servant,

No. 12, Blewit's Buildings,  
Fetter-Lane, Nov. 20, 1809.

JAMES ALLAN,  
Divider of Mathematical Instruments.

To C. Taylor, M.D. Sec.

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*Mr. Allan's Description of his Mathematical Dividing Engine, and his Method of forming it.*

My engine is of bell-metal, thirty inches in diameter. I turned a brass ring about three-sixteenths of an inch thick,

\* From *Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce*, vol. xxviii.—The Society voted the gold medal to Mr. Allan for this communication.

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