



LXVI. On the physical causes of the principal phænomena of heat

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line being simultaneously impelled in a horizontal direction, would, by virtue of their repulsion, cause a similar motion in those immediately in front of them, whilst the latter particles would tend to check the impetus of the former, and thus vibrations in the direction of transmission are simple to conceive and easy to explain. But suppose the forces attractive. Let the system of particles in a vertical line have a *vertical* motion, and the slightest consideration will show us that the immediate consequence is the production of a vertical motion in the particles immediately in advance of them; whilst, as before, the reciprocal action of the latter particles tends to impede the motion of the former. Here, then, we have as clear a case as before, and our general conclusion from the whole is, that repulsive forces allow of *direct*, attractive of *transversal*, vibrations only."—(Trans. Camb. Phil. Society, vol. vi., Part I., p. 178.)

The three equations of motion will then finally be reduced to the form

$$\frac{d^2 \alpha}{dt^2} = + 2c^2 \alpha$$

$$\frac{d^2 \beta}{dt^2} = - c^2 \beta$$

$$\frac{d^2 \gamma}{dt^2} = - c^2 \gamma.$$

The first of these I have developed in a paper read in May, seeing reason for its application to the phænomena of heat.

[To be continued.]

LXVI. *On the Physical Causes of the principal Phænomena of Heat.* By JOHN BARTON, Esq.*

IT has always appeared to me that the corpuscular hypothesis is capable, with some modification, of affording a more complete and satisfactory explanation of the phænomena of heat and light than the undulatory hypothesis. On the present occasion I propose, without entering into any controversial discussion, to show in what manner the principal phænomena of heat may be deduced from the action of two forces. An attractive force between the particles of heat and those of solid matter, a repulsive force between the particles of heat themselves.

I assume that the particles of heat are very small in comparison of the particles of solid matter, and that these last are very small in comparison of the intervals by which they are

* Communicated by the Author.

separated from each other. The phænomena also require that the repulsive force should decrease more rapidly than the attractive force. These premises being admitted, the following consequences may, if I do not mistake, be deduced from them. For brevity's sake I omit the demonstrations, presuming that they will be readily supplied by those versed in mathematics.

1. If a particle of heat approach a particle of solid matter, it will either fall to the surface and remain there, or it will describe a curvilinear orbit thereabout. According to the direction and velocity of its approach, this orbit will either be confined within a certain limit, like an ellipse, or will go off to an infinite distance, like an hyperbola. To avoid circumlocution, I will take leave to call these two classes of curves respectively, *ellipsoidal* and *hyperboloidal* curves. A particle of heat reposing on the surface of a particle of solid matter, or revolving about it in an ellipsoidal curve, will have no tendency to fly off or to pass into a contiguous body, unless disturbed by some exterior force. It is therefore *latent*.

It must not be supposed that latent heat exists only in fluid or gaseous bodies. The phænomena of softness and malleability must be considered as resulting from the presence of a portion of heat in this state. Nay, it is probable that even the hardest and most brittle substances are not entirely deprived of it.

2. When a solid body is exposed to friction or percussion, a certain number of the particles of heat which had evolved tranquilly in ellipsoidal curves are forced out of their orbits, and fly off beyond the reach of the attractive force of the particle to which they belonged; just as our earth might be driven out of the limits of the solar system by the stroke of a comet; supposing the latter of sufficient density and magnitude. And thus we have an explanation of the heat produced by friction or percussion; which has been supposed to form one of the strongest objections to the corpuscular hypothesis.

It confirms this theory, that a piece of iron which has been heated by hammering becomes *brittle*; indicating that a portion of its latent heat has been lost, while sensible heat has been disengaged.

3. If we suppose a particle of matter to be of an oblong form, or to have one of its axes greater than the others, the particles of heat will collect chiefly about the middle of its length. And thus we have an explanation of a remarkable fact discovered by M. Mitscherlich, that crystallized bodies, when heated, do not expand equally in all directions*.

* See Phil. Mag., First Series, vol. lxiv. p. 162; and Lond and Edinb. Phil. Mag. vol. i. p. 413.—EDIT.

4. When the coefficients of the attractive and repulsive forces bear a certain relation to each other, and to the original velocity of approach, the orbit described will resemble a *conchoid*, its two branches being ultimately in one and the same line. In this case the body is *diathermanous*, the rays of heat passing through it apparently in a straight course. The course of a ray through a solid body can never be in fact straight, unless its velocity be infinite; but in proportion as the velocity approaches this limit, the ray will experience less disturbance in passing through bodies imperfectly diathermanous. And accordingly it is found, that rays from incandescent bodies pass through some media which do not admit the passage of rays issuing from bodies of lower temperature, the velocity of projection evidently depending on the repulsive force; and this, in its turn, on the temperature.

5. It must not however be supposed that opaque or *adiathermanous* bodies are impervious to the rays of heat. They differ from transparent or diathermanous bodies only in this, that the entering ray, instead of passing through immediately, and escaping from the opposite side, is entangled in a circuitous and irregular course among the particles, until by chance it reaches the surface, when it escapes, unless the angle of its direction with the tangent be so small that it is drawn back again by the attractive force. A particle of heat is therefore detained much longer in passing through an opaque than through a transparent body, and contributes much more to raise its temperature, and hence it also appears why the passage of heat through opaque bodies is very much slower than through transparent media.

6. The particles of solid bodies are drawn towards each other by two forces, their mutual attraction, and their attraction for the atmospheres of heat about the others. They are also kept apart by two forces, the mutual repulsion of those atmospheres of heat, and the repulsion of the particles of free or sensible heat, which happen at the time to be passing between them. As long as the number of these last remains unchanged, the balance of the opposing forces is a balance of stable equilibrium, in as much as the attractive force diminishes with the distance in a less ratio than the repulsive force. If the number of particles of sensible heat is increased, the body dilates till the equilibrium is restored; but if this dilatation proceed to a certain point, the orbits of a certain number of the revolving particles of heat will be changed from the *hyperboloidal* to the *ellipsoidal* form; that is to say, a certain quantity of sensible heat will be converted into latent heat. At the same time another portion of sensible heat will be acquired from the surrounding bodies and the united re-

pulsive force of these two portions of heat will overbalance the forces of attraction. Thus we have an explanation of the phænomena of *vaporization*.

An account of the causes of this last class of phænomena somewhat resembling the above has been given by Laplace in the twelfth book of the *Mécanique Céleste*. Laplace however gives no explanation of the difference between latent and sensible heat: he attributes the phænomena of expansion exclusively to sensible heat, but does not explain why heat when it becomes latent should lose its repulsive force: he supposes the particles of heat to form atmospheres about the particles of solid matter, which are at rest unless disturbed; and in order to explain why sensible heat tends continually to fly off, he supposes the particles of matter to be in a state of continual agitation.

7. In the same chapter Laplace has given an explanation of the phænomena of liquefaction, which appears to me to require modification. "Every molecule of solid matter," he says, "is subjected to the action of three forces: 1st, the attraction of the surrounding molecules; 2ndly, the attraction of the caloric of those molecules, *plus* their attraction for its caloric; 3rdly, the repulsion of its caloric by the caloric of those molecules. The first two forces tend to bring the molecules nearer together, the third tends to separate them. The three states of *solidity*, *fluidity*, and *gaseous elasticity* depend on the respective efficacy of those forces. In the state of solidity, the first force is the most powerful; the influence of the figure of the molecules is very considerable, and they are united in the direction of their greatest attraction. The increase of caloric lessens this influence by dilating the body; and when this increase is such that the influence in question is very small or none, the second force predominates, and the body takes the liquid form."

I am unable to comprehend why the attractive force between two solid particles should be suddenly reduced to nothing when they are separated to a certain distance one from the other. And this suggestion appears still less probable when it is considered that many crystallizable bodies cease to contract, and even undergo a degree of expansion, at the moment of congelation. The act of changing from fluid to solid depends then on some other cause than the approximation of the particles. Laplace has, I think, truly assigned the immediate physical cause of solidity, when he says that in solid bodies the particles are placed relatively to each other in the position of greatest attraction; but he has not given an adequate reason for their assuming this position. To

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supply this deficiency, it may be useful to revert to an explanation above given of an observation of 'Mitscherlich' on the unequal expansion of crystallized bodies in different directions. It was suggested that the particles of heat do not accumulate equally round every part of a particle of solid matter if its axes are of unequal length. Now, this inequality of distribution is such, by the nature of the case, as to counteract the tendency of the particles to place themselves in the position of greatest attraction. In other words, the compound force exerted by the central solid nucleus, with its surrounding atmosphere of heat, will approach more and more nearly to that of a sphere as the heat increases; and by consequence the figure of the particles exercises a less and less influence on their mutual position. When that influence is completely neutralized, the body is a fluid.

8. As the mutual attraction of the particles is not however destroyed in fluids, these particles still arrange themselves in the position of greatest attraction. But this position is no longer influenced by their figure; it is now such precisely as would be assumed by them if spherical, that is to say, the position in which the distance of their centres is a minimum. Now this is the position in which the sum of the intensities between them is also a minimum; therefore the whole bulk of the fluid just before congelation is a minimum. If we suppose other forces to come into operation, those, for instance, resulting from the figure of the particles, the dimensions of the body will consequently be enlarged; and thus it appears why so many substances are found to expand in the act of congelation.

9. Further, as the position of greatest attraction amongst the particles of a solid is that in which their salient angles are presented towards each other, it follows that at the moment of solidification, when this arrangement is established, the orbits of a certain portion of the accompanying particles of heat will be 'changed from the *ellipsoidal* to the *hyperboloidal* form; that is to say, a certain quantity of latent heat is converted into sensible heat.

10. Those solid bodies which are composed of the largest, or rather the heaviest particles, are at once the best conductors and the worst radiators of heat; for the velocity increases with the mass. Hence the metals are the best conductors of heat, and as far as the experiments hitherto made enable us to judge, their conducting power seems to follow the same order with the magnitude of their component atoms, the differences not being greater than may be reasonably supposed to arise from errors of observation. For a similar rea-

son a particle of heat attempting to escape from the surface of a metallic body is more strongly drawn back by the attractive force of the particles than at the surface of other bodies. The metals have therefore less radiating power than any other substances.

11. The particles of heat emerging from the surfaces of solid bodies at angles so small as to be drawn back again into their substance, form collectively an atmosphere enveloping those surfaces, and extending, there is reason to believe, to distances considerably greater than the interval which separates the solid particles from one another. It is to this atmosphere that we must attribute the repulsive power exerted at the surfaces of bodies, metallic bodies especially, by virtue of which mercury is depressed in a barometer tube, and a steel needle floats on the surface of water. By strong pressure this enveloping atmosphere may be expelled from between two metallic surfaces, and the attractive force of their particles then coming into play, they adhere with considerable force. The reflexion of heat at the surfaces of bodies also appears to be due to the action of this enveloping atmosphere.

12. It may facilitate the apprehension of my meaning to observe, that a particle of matter, with its revolving particles of heat, is supposed to have a resemblance to the sun, with its accompanying bodies, in the solar system. The planets, revolving in elliptic orbits, represent the particles of latent heat; the comets, if indeed any of them revolve, as formerly supposed, in parabolic or hyperbolic orbits, represent the particles of sensible heat. Future observations will, perhaps, enable us to determine the law of the forces by which these minute movements are regulated, as accurately as we are now acquainted with the law of gravitation. The preceding conclusions are, however, independent of the particular law of those forces.

January 27, 1837.

P.S. I have assumed, in conformity with the views of Laplace and other mathematicians, that the particles of solid matter mutually attract each other. But the preceding conclusions hold good though no such force of attraction exists, or even if we suppose with *Æpinus* that the particles mutually *repel* each other, a supposition which is by no means incompatible, as Dr. Roget has observed*, with the phænomena of gravitation. There are certainly strong reasons in support of this last hypothesis.

* See SCIENTIFIC MEMOIRS, Part III. p. 469.—EDIT.