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Cadmium, KH.

Wave-lengths.			Quotients.		Theoretical.	
647·22	647·08		1·0000	1·0000	1·0000	1
644·59	.....	.....	1·0041	.....	1·0041	$1 + a \div 28$
531·27	531·01	.....	1·2182	1·2186	1·2300	$1 + 2a$
509·00	508·83	.....	1·2715	1·2717	1·2727	$1 + 5b$
480·56	480·27	.....	1·3468	1·3473	1·3450	$1 + 3a$
468·10	.....	.....	1·3826	.....	1·3818	$1 + 7b$
441·94	441·81	.....	1·4645	1·4646	1·4600	$1 + 4a$

The quotient of Kirchhoff's sixth wave-length by the seventh ($468\cdot10 \div 441\cdot94$) is equal to the quotient of the fourth by the fifth ($509 \div 480\cdot56 = 1\cdot0592$).

Lanthanum, K.

Wave-lengths.			Quotients.		Theoretical.	
538·56	.....	.....	1·0000	1·0000	1	
538·43	.....	.....	1·0003	1·0003	$1 + \frac{1}{4}a$	
538·00	.....	.....	1·0011	1·0011	$1 + a$	
534·48	.....	.....	1·0077	1·0077	$1 + 7a$	
520·80	.....	.....	1·0341	1·0340	$1 + 31a$	
519·20	.....	.....	1·0373	1·0373	$1 + 34a$	
518·69	.....	.....	1·0383	1·0384	$1 + 35a$	
481·59	.....	.....	1·1183	1·1183	$1 + 108a$	

XLII. *The Bearing of the Kinetic Theory of Gravitation on the Phenomena of "Cohesion" and "Chemical Action," together with the important connected Inferences regarding the existence of Stores of Motion in Space.* By S. TOLVER PRESTON*.

No. IV †.

1. **I**T would be natural to expect that any theory competent to explain the effects of gravity ought to be able to throw some light upon the subsidiary effects of molecules exhibited in "cohesion," "chemical action," &c. Before proceeding to consider this question, and in order to have a clear conception of the point we have to deal with, we will recapitulate in a few words the physical conditions involved in the case of gravity as already dealt with. It has been our object to point out that the molecules of a gas *within the range of free path* are moving in precisely the right way to produce

* Communicated by the Author.

† The three previous papers treating of the subject of gravitation are in the Philosophical Magazine for September and November 1877, and February 1878.

gravity in two masses immersed in the gas within the range of free path. For since it has been proved from the kinetic theory that the particles of a gas adjust their motions so as to move *uniformly or equally in all directions*, and since the particles within the range of free path are moving in unbroken streams, it follows that two masses immersed in the gas at a distance apart within this range will (owing to the one sheltering the other) be struck with more particles on their remote (unsheltered) sides than on their adjacent (sheltered) sides, so that the two masses will be urged together. This, therefore, fulfils Le Sage's fundamental idea without the necessity for accepting any of his postulates. We need not accept the scarcely realizable postulates of streams of particles coming from indefinite distances in space (at uniform angles), each stream moving continuously in one direction; but we can substitute for this the natural conception of the normal motion of the particles of a gas within the range of free path, where, although *each* particle is continually changing the direction of its motion, yet the *general character* of the motion of the system as a whole remains unchanged; or the system of particles automatically correct their motions so as to continue to move *uniformly or equally in all directions*, as demonstrated in connexion with the kinetic theory of gases. This movement of the particles *equally* in all directions is the condition required to produce equal gravific effect in all directions. Thus all we require to admit in order to produce all the effects of gravity as *necessary* results, is the existence of a gas in space. This gas differs from an ordinary gas only as to scale, *i. e.* in the proximity, velocity, and extreme *minuteness* of its particles, whereby a length of free path commensurate with the greatest observed range of gravity is insured, the extreme minuteness of the particles being at the same time adapted to that high velocity which the effects of gravity require, and which also necessarily renders the medium itself impalpable or concealed from the senses. The range of free path, though great in one sense, may be considered small and suitable for a gas that pervades the vast range of the visible universe.

2. In applying these principles to cohesion, or the approach of molecules in chemical reactions, it is so far easy to see that when two molecules of matter come very close together, or if we suppose them actually to come into contact, then they will cut off the *entire* stream of particles of the gravific medium from between the parts in *contact*; and therefore, as the gravific particles now only strike against the remote sides of the two molecules, the latter will be urged together with very great

force, thus explaining "cohesion"*. But then a difficulty at once presents itself here. When two masses (or molecules) are gradually approached towards each other, instead of the tendency to approach gradually increasing up to a maximum (as we should expect from the theory), they begin to repel at a certain distance, and very considerable force is in general required to overcome this first repulsion, when the masses then unite into one. Thus two freshly cut pieces of lead may be made to unite with some pressure, also glass, or various metals, with more or less pressure. There is therefore a *neutral point* which has to be passed, when the tendency to recede changes into a tendency to approach. The same thing is exhibited (conversely) when a substance is broken into two parts by tension. If pulled (nearly) up to the neutral point, the two parts recoil or return into their old positions. If pulled beyond the neutral point, the parts repel and will not return into their old positions, *i. e.* they separate permanently. The thing, therefore, to be explained is the existence of this *neutral point*, or, in other words, the repulsion that exists at a certain distance from the surfaces.

3. The explanation we have to offer here depends upon quite recent investigations. It must be observed first that facts prove the existence of a second medium in space besides the gravific medium, viz. the heat- or light-conveying medium (the æther). If we admit the existence of *one* medium in space constituted according to the kinetic theory (the gravific medium), it would be natural to conclude that the second medium (or æther) was constituted in an analogous manner. We shall give independent reasons afterwards that lead to infer this constitution, and endeavour to answer possible objections; but in the mean time it is only necessary to suppose it to be so constituted (in the absence of proof to the contrary); and if this supposition serves to explain in general principle a number of facts, this will be one argument for its truth. On account of the extreme shortness of the waves of light and heat, it would be reasonable to suppose that the length of free

* The spectroscope proves molecules to be complex bodies, on account of the number of different periods of vibration they can take up; and it was pointed out in the last paper that there are grounds for inferring them to possess interstices, or a more or less open structure. It is evident, therefore, that the *shapes* of molecules, as to whether their parts *fitted* over each other or not (and thus afforded more or less shelter from the impinging particles of the gravific medium), would have some influence on the behaviour of molecules as to the energy of their approach (reactions). This might account in some degree for the varied behaviour termed "chemical affinity," though possibly there are, besides this, other modifying physical conditions.

path of the æther particles was contained within compact limits, or was, at any rate, shorter than the length of the wave itself. It has been proved recently, in investigations by Mr. Johnstone Stoney in connexion with the radiometer*, that a medium constituted according to the *kinetic* theory has a special power of propagating a pressure *unequal* in various directions, or that, when a layer of the medium (such as a layer of air) is intercepted between two surfaces whose distance apart is a small multiple of the *length of free path* of the particles of air, the layer can then transmit a pressure in the line perpendicular to the surfaces which is *in excess* of the transverse pressure; and thus a repulsion is produced, accounting for the spheroidal state, the motion of the radiometer, &c. In fact it is evident (as pointed out) that, since in a medium constituted according to the kinetic theory the particles move in straight lines, the particles (when the distance of the opposed surfaces approximates to the range of free path) get reflected backwards and forwards repeatedly between the opposed surfaces, the increments of energy received by the particles accumulating by successive reflections, so that the particles produce a bombardment tending to separate the two opposed surfaces†. The increments of velocity imparted by the heated

* Philosophical Magazine, December 1877.

† There is another point in connexion with the motion of the particles, which no doubt, however, has been already noticed. Under normal conditions, a body vibrating opposite to another tends (as is known) to produce rarefaction in the intervening medium; but in the case of a film whose thickness is near the range of *mean path* of the particles, there would appear to be a special cause tending greatly to reduce this effect, and even perhaps to produce the contrary effect, viz. a condensation (which would greatly increase the repulsion). Thus, under the increments of velocity received, there is a tendency for the molecules of the gaseous film to be turned round so as to move more *normal* to the film. Suppose, for instance, an elastic sphere to be rebounding *obliquely* between two planes. Suppose increments of velocity to be given to the sphere by vibrating one of the planes. Then these increments of velocity given to the sphere will evidently make it rebound more *normal* to the surfaces. So in the case of the molecules of a gaseous film, rebounding backwards and forwards between two surfaces (such as the air film which supports a drop in the so-called "spheroidal" state, the air film which supports a grain of powder in some experiments of Professor Barrett, referred to by Mr. Johnstone Stoney), the molecules of the film will tend, by the increments of velocity given them, to turn round so as to move in a direction more normal to the surfaces. This evidently makes the lateral pressure exerted by the film less, and consequently its lateral expansion (or rarefaction) less. If we imagine the extreme case where the molecules of the film are all turned round so as to move *exactly* normal to the surface of the film, then whatever the velocities of the molecules of the film (*i. e.* whatever the *longitudinal* pressure, or repulsion, exerted by them), the film would exert no *lateral* pressure at all. There would consequently be a lateral inrush of air, increasing the *density* of the film, and therefore in-

surfaces are also mainly received in the line joining the surfaces (not so much transversely); so that this conduces to the pressure on the surfaces, or *repulsion*.

4. This is precisely what we have to put forward, *in its application to the æther*, as an explanation of the repulsion in the cases referred to, such as for example the repulsion of two lenses or glass surfaces placed together in such proximity as to exhibit "Newton's rings," the repulsion of two molecules &c.; for if the æther be constituted according to the kinetic theory, we shall inevitably have the same phenomena here, though on an infinitely more energetic scale; for the particles of æther come into direct contact with the vibrating molecules of matter, whose energy of vibration is known to be enormous at normal temperature; and the layer of æther is very thin, and the motion of the æther particles very rapid*, so that the successive increments of velocity imparted by the vibrating molecules accumulate by successive reflections (backwards and forwards) between the opposed surfaces, producing a forcible repulsion. These results have been theoretically demonstrated to follow on the basis of the *kinetic* theory, and have been established by experimental facts. It is a point of great importance to observe that it is specially the *kinetic* theory that explains this otherwise most curious fact of an *excess* of pressure in a medium in one direction (producing a repulsion), with *normal* pressure existing in transverse directions, which otherwise it would be so difficult to explain, and which must be explained in order to account in a realizable manner for the phenomena observed. It is difficult to conceive how any other means of explaining this curious fact could be afforded than that supplied by the kinetic theory. Moreover it is generally admitted that *heat* has the property of producing repulsion. The "heat" of the molecules in the cases mentioned is known to consist in their *vibrations*, by which they generate *waves* of heat in the æther. We have therefore to explain under what particular constitution of a medium *vibrations* can (within certain limits) produce repulsion. The *kinetic* theory of the constitution of the medium solves completely this peculiarly difficult problem.

creasing the repulsion (since those molecules which enter the film become themselves available for producing repulsion). Possibly, from this cause, these films may be actually *denser* than normal density. At all events the above cause makes their density greater than it otherwise would be, and the repulsion exerted by them greater.

* It may be noted that, *if* the æther be constituted according to the *kinetic* theory, the normal velocity of its particles is $\frac{3}{\sqrt{5}} \times$ velocity of a wave of light. See appendix to paper "On the Mode of Propagation of Sound" (Phil. Mag. June 1877), added by Prof. Maxwell.

5. When the two surfaces (or two molecules) are pushed up closer to each other, then the energy of the gravific medium directed against the remote sides of the molecules prevails more and more, since the mutual sheltering-power of the molecules increases in an enormously rapid ratio as contact is neared, and so the unbalanced energy of the gravific medium directed with full force against the remote sides of the opposed molecules at length outweighs the action of the intercepted æther particles, and the two molecules are propelled together (or unite).

6. We may allude to a few examples serving to illustrate the application of the above principles. Supposing we take the common case of the ignition of a gas jet. Then when the gas is turned on, the molecules of gas and air mingle with each other and are known to be exchanging motion and rebounding from each other, and yet they do not unite. According to the above principles the molecules, as they approach each other in their encounters, are kept apart by the forcible vibrations (which the molecules are known to possess*) which, through the increments of velocity imparted to the particles of the intervening æther, produce a repulsion in the manner described, as soon as the molecules in their encounters have approached nearly within range of the *mean path* of the æther particles. When a flame is applied to the jet, the rapidly moving gaseous molecules of which the flame consists naturally produce a disturbance, jostling some of the molecules of the mixture of gas and air against each other, so that the neutral point is passed, whereby the molecules are brought into such proximity that their mutual sheltering action causes the gravific medium to impinge with full energy upon their remote sides, thus urging the molecules together (producing combination). The molecules are thrown into forcible vibration by the shock of approach, and become luminous through the energy of the waves thus generated by them in the surrounding æther. These vibrations of the compound molecules after combination naturally cause the forcible rebound of any other molecules that happen to be in their proximity, the disturbance thus set up sufficing to effect the successive (practically instantaneous) combination of the entire jet of gas. The same considerations of course apply to the practically instantaneous combination (explosion) of a mixture (in definite proportions) of gas and air, by an initial disturbance

* The molecules of matter in the gaseous state are known to possess, *in addition* to the translatory motion peculiar to that state, a vibratory motion, in virtue of which the molecules generate waves of regular periods in the æther (these periods having in many cases been measured by the spectroscope).

produced by a flame. In the case of solid bodies, where the molecules are fixed or under control, a forcible pressure or concussion may serve to bring the molecules over the neutral point (and thus effect combination), as illustrated by the effect of the blow struck in "percussion" powders. It would not appear that matter in the gaseous state could ever be exploded by pressure (so long as the gaseous state was retained); for the molecules of gases cannot be pressed against each other by any amount of pressure, since, the molecules being in free translatable motion among themselves, the only effect of pressure would evidently be to put a greater number of molecules into unit of volume, without thereby causing the molecules in their encounters to approach nearer to each other than before. The degree of approach of the molecules (in their encounters) depends evidently on their momentum or velocity; and this remains the same whatever the pressure.

7. Heat could not apparently be said to augment the energy of chemical combination, since, in general, heat is known to possess the exactly opposite effect, or to disintegrate matter. The part played by heat in effecting chemical combination would seem to consist simply in producing a molecular *disturbance*, whereby unavoidably some molecules are urged towards each other so as to pass the outer neutral point, which is the necessary preliminary to combination. No doubt, when heated elements combine, the original heat adds itself to the work thus to be derived, as the heat cannot be destroyed, though it cannot increase the work of combination. Heat may (as is known) entirely prevent chemical combination, and even dissociate combined elements. The action of heat in preventing chemical combination and producing dissociation would on the above principles consist in the fact that, when the vibratory motion of the molecules becomes excessive, this vibratory motion generates such a pressure in the intervening layer of æther on the approach of the molecules as to prevent them from passing the neutral point: or, indeed, no neutral point may exist, provided the pressure or repulsion thus generated be such as to outweigh the action of the gravific medium, as appears actually to take place in the dissociation of matter by excessive heat. Thus it would appear probable from this, that when combination ensues in the case of a mixture of gases previously considerably heated (but not so much so as to produce dissociation), the molecules on combination do not at once settle down into that full proximity (which belongs to a lower temperature), but they do so gradually as the temperature falls. Thus the work of combination is prolonged over the falling temperature, and the cooling thereby

somewhat retarded. Precisely the same thing is illustrated in the aggregation of groups of molecules (to form masses), as in the aggregation of single molecules to form compound molecules. Thus when a bar of iron is welded by heat, the molecules (though aggregated or combined) do not settle down into their final positions of proximity until the bar cools, the bar being observed to contract on cooling. In this instance also the cooling of the bar is somewhat retarded by the approach of the molecules in the act of cooling.

8. In the case of the ignition of a solid body, the same considerations no doubt apply as in the case of a gas. Thus, for example, the molecules of oxygen are impinging against the surface of a piece of coal, but do not produce ignition. To effect this a certain number of the molecules must be impelled with sufficient energy against the coal so as to carry them over the neutral point (*i. e.* beyond the initial repulsion). The application of a flame, which consists of matter in a state of violent agitation, suffices to effect this, and, no doubt by loosening some of the molecules of carbon (of the coal) and giving them translatable motion and mixing them with the air, facilitates the process.

9. As a further illustration of the exact similarity of behaviour of *single* molecules and groups of molecules (masses) as regards the existence of the above-mentioned neutral point, we may take the case of the substance iodine. This substance gives off a visible vapour at normal temperatures. The single molecules of iodine composing the vapour rebound from each other without uniting; and this can only be due to the existence of the above-mentioned neutral point, outside which there is a repulsion. If the colliding molecules were to approach within the neutral point, they would unite and form solid iodine. No doubt *some* of the molecules of the vapour (as their velocities are known to be very diverse) do pass beyond the neutral point; and thus molecules of vapour striking against the fragments of solid iodine in the bottle, will sometimes unite with the solid iodine and form part of it, while, on the other hand, other molecules of the solid which happen to possess excessive vibrating energy are thrown off, this being the known way in which the balance in evaporation is maintained. The masses of iodine have the same neutral point as the single molecules, since two masses of the substance when pressed together will not readily unite; *i. e.* the neutral point, where the outer repulsion terminates, must be passed first*.

* The above effects were described in a little book 'Physics of the Ether' (E. & F. N. Spon), published by me in 1875; but the *cause* of the reduction of the pressure of the medium, which determines the approach

10. Just as increase of vibrating energy (temperature) tends, by the increase of pressure thus produced in the intervening film of the medium, to dissociate molecules, so reduction of vibrating energy (attendant on reduction of temperature) tends to facilitate the approach of molecules, on account of the reduction of the pressure or repulsive action of the intervening film. Thus the molecules of a vapour when their vibrating energy is reduced (by a fall of temperature) may by the simple momentum of their own encounters, carry themselves over the neutral point, and thus effect the condensation of the vapour. Numerous other cases might be cited illustrative of the application of the above principles, as, indeed, the molecular effects are very similar in their fundamental aspects. The molecular phenomena, however diverse, may be all correlated in one fundamental respect, viz. as consisting in phenomena of *approach* and *recession*. The fundamental conditions to be explained, therefore, are the conditions capable of producing the *approach* and *recession* of molecules. Whatever may be said of the above deductions, it is at least so far certain that the conditions investigated, and based upon experimental facts, are competent to produce these fundamental movements of approach and recession in the case of molecules, and to do so in the *simplest* manner, the constitution of media according to the kinetic theory being admittedly the *simplest* conceivable. To look therefore to other conditions than the simplest would be to imply that the same results are brought about by a superfluity of mechanism. This superfluity is known *not* to be the characteristic of nature; and all the teaching of mechanism points to the fact that superfluity or unnecessary complication entirely prevents the attainment of precision and certainty in the mechanical effects. The great precision and unflinching certainty of the molecular effects would therefore render it *necessary* to infer that the regulating mechanism was simple, or that there was no unnecessary superfluity.

11. The fundamental conclusion above drawn regarding the mechanism concerned in the *approach* of molecules is grounded upon the only explanation of the mechanism of gravity that has withstood criticism and received support by competent judges, viz. the kinetic theory of gravity, of which Le Sage's ingenious idea forms the fundamental basis, and is at once the *simplest* explanation of gravity conceivable. The

of molecules, was there wrongly stated, the error having arisen from a seeming analogy between the approach of bodies to masses (tuning-forks &c.) vibrating in air—in the absence of the knowledge recently acquired of the repulsion of gaseous layers. Much of the main principles of the book, however, remain as they were—to be supplemented by the investigations contained in the present papers.

application of this theory to molecules in close contact ("cohesion" &c.), is *necessary* and inevitable, and it serves to correlate the molecular effects generally under *one* cause. The explanation of the fundamental condition capable of producing the *recession* of molecules, as above given, rests upon experimental facts recently established, and upon a basis for the constitution of the æther which is the *simplest* conceivable.

12. We now propose to show some *independent* reasons in support of this constitution for the æther, in addition to the argument afforded by the numerous molecular effects which this constitution, in principle, serves to explain. First, if the subject be reflected on, it will be apparent that, in principle, a movement of the component particles of the medium in *straight lines* is the only possible constitution for the *ultimate* medium in space. For a particle of matter cannot move in a curved line unless it have a medium about it to control its motion. Thus a planet can move in a curve because it has a medium about it (the gravific medium) to cause it to move in a curve. It is a known principle that a *particle of matter cannot of itself change the direction of its motion*. The particles of the *ultimate* medium in space must therefore move in *straight lines*. This deduction is surely of great importance in the inquiry as to the constitution of the physical media in space. Also in addition to this, the observed facts of gravity prove that the particles of the *gravific* medium move in straight lines, since no other motion than this can harmonize with the observed effects of gravity. It would therefore surely be a strange thing if the particles of the æther, as a second medium immersed in the gravific medium, did not move in straight lines. To suppose this would be very like supposing that when the particles of a second gas are immersed among those of another, the particles of the first gas acted upon those of the second to make them move otherwise than in straight lines, which is known to be impossible. Moreover the fact of the kinetic theory representing the *simplest* conceivable constitution for a medium would by itself be a strong argument for this constitution in the case of the æther. The very fact of the great precision and delicacy of the operations performed by the æther as the mechanism for the transmission of the varied phenomena of colour &c. would point to a simple constitution; just as the complex effects of sound with all its intricate and varied gradations of tone are known to be transmitted by a medium (the air) of the *simplest* conceivable constitution, viz. that represented by the beautiful kinetic theory of gases*. The more intricate the functions of a mechanism,

* There would surely be nothing to admire in complication in itself. The whole aim of mechanical design is directed towards the attainment of *simplicity*, which being *unique*, entails intellectual labour to find it.

the more is simplicity indispensable, and superfluity incompatible with precision and certainty in the results. To assume a constitution for the æther that could not be realized or clearly explained would surely be futile, since the explanation or clear conception forms the logical support of any theory, without which the theory resembles a mere dogmatic statement incapable of being sustained by reason.

13. There is one other point which we would notice in connexion with this subject. The idea would appear to be to a certain extent prevalent that the æther must have a constitution essentially different from the air, because the vibrations producing light are transverse, while those producing sound are longitudinal. It seems to be sometimes inferred from this that the vibrations of the æther are *only* transverse, and those of the air *only* longitudinal. There would be no warrant for this conclusion; and we think that it has done harm and greatly hindered any rational idea from being formed of the nature of the æther. According to the kinetic theory, which is known to represent the constitution of the air, the vibrations of the particles of air disturbed by a vibrating body and propagated in the form of waves, are not *only* longitudinal; for since according to the kinetic theory the particles of air in their normal state are moving equally in *all* directions, it follows that these particles are accelerated and retarded both in *transverse* and in longitudinal directions at the passage of waves. It is true that the *transverse* component of the motion probably may not affect the ear, on account of its special structure. It would be wrong, however, to infer from this that the *transverse* component of the motion did not exist. So in the case of the æther, it would be unwarranted to infer that the longitudinal component of the motion did not exist, because this component was incapable of affecting the eye. The eye and the ear may be very differently constituted; and a motion that affects the one might not affect the other. Sir John Herschel says regarding this point in his essay "On Light" ("Popular Lectures on Scientific Subjects," page 358):—"According to any conception we can form of an elastic medium, its particles must be conceived free to move (within certain limits greater or less according to the coercive forces which restrain them) in every direction." He then goes on to explain how the efficacy of the transverse component of the movement in the case of light, and the longitudinal component of the movement in the case of sound, may be accounted for by the diverse structure of the eye and ear. Any inference which is not valid, invariably does some harm; and this idea of a forward movement being propagated in a medium by *only* transverse vibrations, being almost inconceivable, has

naturally led to some incongruous ideas regarding the structure of the æther, in the effort to explain it. Thus some have supposed the æther to resemble a solid, which is in direct opposition to the teaching of the senses; for we move about so freely in this "solid" as to be unconscious of its existence. Another supposition has been that "lines of tension," behaving somewhat in analogy to stretched chords, exist in the æther. Such a mechanism would be, to say the least, somewhat deranged by the passage of a planet through the æther. Indeed it is sufficiently evident that these are the hopeless attempts made to surmount an impossible condition, or a difficulty for whose existence there is really no warrant. If the æther be not a solid, or a liquid (for liquids oppose enormous resistances to the passage of bodies through them at high speeds), then what other resource have we than to conclude that it is a gas?

14. A gaseous constitution of the æther according to the kinetic theory would perfectly satisfy the two fundamental conditions of a medium highly elastic in all directions, and opposing no appreciable resistance to the free movement of bodies (the planets &c.) through its substance. For it is a known fact that the resistance opposed by a medium constituted according to the kinetic theory to the passage of bodies through it *diminishes* as the normal velocity of the particles of the medium increases. The high normal velocity of the particles of the æther, proved by the velocity of light, therefore necessarily renders the resistance inappreciable, and the medium itself impalpable and undetected by the senses.

15. A difficulty has been raised in the way of the æther being constituted as a gas on the following grounds, which, being only anxious for truth, we are bound to consider *. It has been argued that if the æther be constituted as a gas, the specific heat of unit of volume of the æther would be the same as that of any ordinary gas at the same pressure, and that therefore it would appear that the presence of the æther could not fail to be detected in the experiments on the specific heat of ordinary gases. We have to offer the following as a means of meeting this difficulty. It will be admitted that the detection of the æther in the experiments on specific heat will depend, *not* on the specific capacity for heat possessed by the æther, but on the *rate* at which the heat passes from the gas experimented on to the æther. The molecules of the gas are moving through the æther with their normal translatory motion, this motion of the molecules representing the "heat" of the gas. It will be evident that the rate at which the

* See paper "On the Dynamical Evidence of the Molecular Constitution of Bodies," by Prof. Maxwell ('Nature,' March 11, 1875).

motion ("heat") of the molecules of the gas passes to the æther will depend on the *resistance* the æther offers to the passage of these molecules through it. But we have shown that this resistance may (on account of the high normal velocity of the æther particles) be inappreciable. Hence the rate of passage of the heat from the gas to the æther will be inappreciable. This, we submit, removes the difficulty in question. It is clear that, if the æther opposes no appreciable resistance to the passage of a planet through it (moving at several miles per second), it cannot be affected by the passage of a molecule of a gas through it, which in its relatively slow rate of translatory motion may be considered *at rest* compared with the æther particles. The high normal velocity of the æther particles is only appropriate to their *minute* mass.

16. It must be apparent to any reflecting observer, that in physical science we have a vast array of *facts* accumulated through years of experiment, but a great paucity of *causes*; or the number of facts known is quite out of all proportion to the number of causes known, these latter being replaced by more or less vague and unsubstantial theories. As, therefore, we have no paucity of facts as a basis to reason upon, it surely cannot be too soon to make an effort to correct this anomalous state of things, and to replace the above unsubstantial theories by rational conceptions of the processes of nature. Clearness of conception is the test of truth, and constitutes its real dignity; and theories, however elaborated, if vague, have no real dignity*. Since there is nothing occult about the physical media in space, in so far as they differ in no way from ordinary matter excepting in the mere scale or dimensions of their parts, and since it is obviously just as easy to reason of matter of one dimension as of another, any hesitation in entering upon this course of study would be wholly uncalled for; indeed, surely there is reason for a rational interest in realizing the admirable adaptation of these media in a mechanical point of view for their special functions; and the question as to the utilization of the stores of motion enclosed by them to the best advantage may present a problem of the highest practical interest and importance†. It should be observed that these stores of

* Vagueness, paradox, and mystery surely belong rather to those intellects which are incapable of rising to clear and definite conceptions.

† As an instance of the change of views on the most practical subjects that the acceptance of these principles entails, we may cite the case of the employment of coal, which by the recognition of the existence of the stores of motion in space, becomes a *mechanism* or machine for deriving motion. The expenditure of coal, therefore, represents the expenditure of mechanism or *machinery*. Hence in deriving motion through coal we expend a quantity of *machinery* proportional to the power derived. Without asking the question whether it is necessary in every case, in deriving motion from a source, to expend machinery proportional to the

motion simply consist in small particles of matter in a state of rapid motion ; or there is nothing occult about the subject at all, as indeed obviously principles of reasoning are independent of size. The minute size (and consequent invisibility) of the particles is necessary to the *efficiency* of the media as powerful motive agents, since minuteness of size is necessary to render a high velocity possible for the particles, without producing disturbing effects among the matter immersed in these media. There is one very noteworthy point that cannot be too distinctly kept in view in connexion with this subject. It is the fact that the high intensity of the stores of motion possessed by these media, and which renders them so important, serves to conceal their existence from the senses. Thus the higher the intensity of the store of motion enclosed by these media, and consequently the greater their capacity for practical utility, the more likely (if the mere evidence of the senses were relied on) is their existence to be forgotten. For it may be *proved* beforehand, by the kinetic theory of gases, that the greater the velocity of the component particles of a medium, and consequently the *greater the value of the store of energy enclosed* (which may even reach an explosive intensity), the more does the presence of the medium elude detection, because the resistance opposed by the medium to the passage of bodies through it *diminishes* as the velocity of the particles increases. The less indication the mere senses (unaided by reason) afford of the existence of such media, the higher, therefore, should we be warranted in inferring their importance to be. Even independently of all question of the existence of these media, it may be *proved* beforehand that, *if* media did exist and enclose stores of motion to an enormous intensity, *they would be concealed*. This is, no doubt, a remarkable fact, and contrary to preconceived ideas, as it would doubtless appear on the first thought that the *higher* the intensity of a store of energy existing in space, the *more* likely would it be to make itself apparent to the senses, whereas precisely the contrary is found to be the fact. This forms a notable instance of one of those cases where analysis completely reverses preconceived ideas. It is possibly the absence of appreciation of this fact that may in some way account for the failure of the most striking proofs of nature to carry their practical teaching, as for example, the sudden setting free of concealed motion in the explosion of a mass of gunpowder. Here to the mere bodily senses, we have apparently an actual *creation of motion*. Something

power derived (*i. e.* that the work done should be the equivalent of the *machinery* expended), it is at least so far certain that no remedy for this could be discovered unless the physical conditions of the case were recognized.

more, however, than the evidence of the mere bodily senses may be required, to appreciate the truths of nature, as it is a notorious fact that the most important truths generally lie below the surface. It should be noted that these media would not be *efficient* as working agents unless they were concealed; for concealment (as observed) is the *necessary* condition to the enclosure of a store of motion to a high intensity. Possibly the absence of realization of this fact, and perhaps that prejudice which besets every new path, may in some degree account for what must otherwise appear an extraordinary indifference and absence of inquiry in a subject of great mechanical interest and involving possibly issues of the highest importance and practical utility. When this, like every other illogical prejudice to change, comes to be broken down by the light of reason and reflection, there may be just ground for surprise at the previous delay, and at the shallow and unsubstantial character of the theories which so long supplanted rational conceptions of the processes of nature.

London, March 13, 1878.

XLIII. *Notices respecting New Books.*

Des Paratonnerres à Pointes à Conducteurs et à Raccordements Terrestres Multiples. Description détaillée des Paratonnerres établis sur l'Hotel de Ville de Bruxelles en 1865. Exposé des motifs des dispositions adoptées par MELSENS, Membre de l'Académie Royale des Sciences de Belgique. Bruxelles : Hayez. 1877.

THE work, of which the title is given above, possesses an interest not only to the electrician and man of science, but to the architect and antiquary; and Professor Melsens, already so favourably known to the world of science, has done further good service in applying sound scientific principles to the preservation of those grand monuments of mediæval architecture of which his country is so justly proud. The origin of the work which we now notice was in the circumstance that, in a thunder-storm in 1863, one corner tower of the Hotel de Ville at Bruxelles was struck by lightning, and that portion of the building seriously injured, whilst the very much higher central tower and spire were not touched. The municipal authorities of Bruxelles at once proceeded to consider the steps to be taken to preserve the building from any future like injury, and requested the assistance of the Academy of Sciences, which appointed a committee. Opinions were very much divided, and no practical conclusion was arrived at; so the Municipal Council very sensibly passed over the Committee and placed the whole matter in the hands of Professor Melsens, who had formed definite ideas on the subject, and was prepared to take the responsibility of carrying them out. The great difference of opinion among scientific men was as to the comparative advantages of concentrating the means of defence in one or a very few lightning-conductors extended to a great height, overtopping the most elevated portions of