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the proportion which this difference in the width of the gauge at its narrowest end might bear to the whole of its present width at the same end, should be accurately ascertained to enable chemists in different countries to obtain a uniformity in their results.

XX. *An Attempt to prove that the Matter of Heat, like other Substances, possesses not only Volume but Gravity; being a Second Essay on Caloric. By ALEXANDER TILLOCH. Read before the Askejian Society November 1800.*

IN the hasty essay read before this Society in the course of our last session * I ventured to call in question the truth of certain commonly received doctrines respecting heat or caloric, mentioned several facts which admit of conclusions very different from those which have been drawn from them to support the doctrines referred to; and endeavoured to show that heat retains uniformly the same character, properties, and mode of action; in opposition to those who contend that it is sometimes *sensible* or *free*, and at other times *latent* or *fixed*.

I also endeavoured to prove that heat is a real distinct substance, and not a mere quality or accident resulting from the modification of matter. I showed, by many proofs, that it possesses volume, which is a characteristic of matter; that, when expelled by chemical combinations, the volume of the compound is less than the sum of that of the ingredients; and that, probably, the diminution is exactly equal to the volume of the heat that has been thrown out: that, on the other hand, when the compound is increased in volume, it has acquired, from the contiguous bodies, a portion of caloric, probably, exactly equal in volume to that increase: and, to be brief, that the general laws enumerated in my former essay, and which, I believe, are universally admitted, being sufficient to explain all the known phenomena, without having recourse to the doctrine of *latent*, as distin-

* See *Philosophical Magazine*, Vol. VIII. p. 70, 119, and 311.

guished from *free heat*, the doctrine ought to be rejected, on the received axiom, that no more causes should be admitted in physics than what are true, and sufficient to account for the phenomena.

I also suggested the propriety of philosophers turning their attention to the determining the masses or volumes of heat necessary to produce the various effects and changes which that substance operates upon bodies, instead of contenting themselves with speaking of *degrees*, to which they annex no correct idea; and expressed a hope that, at no very distant period, this improvement might be expected in science.

In venturing to call in question the truth of the received doctrines, it was not my intention to depreciate the discoveries of a Black, a Crauford, a Lavoisier, or a Cavendish; men whose memories will be cherished, while the world endures, by every lover of science. Their genius, their persevering industry, their penetrating judgment, first brought to view those luminous facts which must serve as the basis of all true theory respecting the subjects of which they treated; and those facts will remain, whatever may be the fate of theories already established, or of others that may supersede them.

But as truths, once established, become a common property in science, those whose genius would never have discovered are not debarred the use of them. It may also be observed, that the original discoverers of important facts have often, in drawing their inferences and making their deductions, given an undue weight to considerations that were no other way connected with the subject than by being unfortunately *stumbled over* in some part of the journey, in which they chanced to be out of the right road; for who, that first explores an unknown region, can be expected to get on without interruption or impediment? Such accidents, however, have an unavoidable influence on the mind; and to exempt any man from their consequences, when they occur, would be to deny that he is human.

Those who are not aware of the difficulties of this kind with which genius has to encounter, can never rightly appreciate the merits of those who, in spite of their influence, give

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an unbiaſſed account of the facts they diſcover. It is one of the greateſt efforts of human probity to give them undisguiſed, unwarped by theory. This praiſe is due to the men to whom I have alluded : their labours, therefore, are invaluable, even if it ſhould be proved that, in ſome few inſtances, they have been miſtaken in their inferences.

It was my intention, in addition to the facts generally mentioned in my former eſſay, to have brought forward, on the preſent occaſion, a number of further evidences of the ſubſtantiality of heat ; but my ſtate of health, ſince our laſt ſeſſion, has been ſuch that I have not been able to go into a wide field. I ſhall, however, bring to the recollection of the Society a few well-known facts, which, according to my view of them, ſerve to prove that heat is a ſubſtance *ſui generis*.

Volume, as I frequently had occaſion to notice in my former eſſay, is a characteristic of matter ; but liquids, on being mixed, are reduced in volume, without parting with any thing except heat—therefore heat is matter.

The ſame effects take place when gaſes are preſented to any ſubſtances to which they can unite. Thus, muriatic acid gas eaſily combines with ice cold water ; but in doing ſo it parts with its heat, which forms the greateſt part of its volume. The gas is in fact decompoſed : one of its principles, the muriatic acid, joins the water, and its other, the heat, being thus ſeparated from its former aſſociate, then, according to the general law, firſt heats the ſubſtances neareſt to it, the acidulated water and the containing veſſel, and afterwards paſſes off to ſurrounding objects till equilibrium is reſtored. If ice, inſtead of water, be preſented to this gas, it will be melted by it as ſpeedily as if thrown into the fire.

If certain gaſes be united, this diminution of volume, this paſſing off of matter, (which, though in union in the ingredients, finds the capacity of the new compound for it ſo different that it muſt diſſuſe itſelf,) is, if poſſible, ſtill more ſtriking. When, for example, oxygen gas and nitrous gas, in the proportions neceſſary to form nitrous acid, are preſented to each other, in a bell-glaſs, over water, what an

abridgement

abridgment of volume takes place ! It cannot be otherwise, the capacity of the new compound for heat being so much less than the sum of that of the ingredients ; for the moleculeæ now respectively arrange themselves with each other in such a manner, that they can afford but a small quantity or lodging-room for the heat, compared with what it occupied in the gases ; and it is therefore forced, by the general law, to diffuse itself among and through the contiguous bodies till each is with each in equilibrium. But each thereby receives an increase of volume, that is, an increase of matter ; and it is extremely probable that, if we could get at the sum of their increase, it would be found exactly equal to the difference between the volume of the gases before mixture and that of the acid produced.

If any quantity of nitrous gas be joined to twice its bulk of atmospheric air, we all know that the same effects take place as in the case just mentioned ; that is, the substance *heat* changes its associates.

We may observe here that, as heat passes freely through all bodies, and tends to an equilibrium ; and as this equilibrium, when established in any system of bodies, is sometimes higher than at others, it seems far from being correct to talk of heat being then *in a state of confinement*. If a colder body be made one of this system it will soon be seen that the heat, instead of being latent in the other bodies, finds itself *free* to pass from them into the colder body till it has received the portion suited to its capacity compared with that of the others.

If there be any state in which heat is less in a state of confinement than another, it is when in equilibrium ; and it is only when it has, by any means, been accumulated in individual bodies, in greater proportion than, by their capacity, compared with that of the surrounding bodies, they ought to be supplied with, that any thing like restraint can be considered as imposed upon it. The impediments that retard its equal diffusion, are, in fact, the only restraints it experiences ; and to me this appears so obvious, that I cannot help wondering how men of science should ever have thought of calling it *free* in such circumstances. It is free, to be sure, but not in their sense of the word, for it has restraints to overcome ; but

when in equilibrium it suffers no restraint whatever, for then every individual substance has its own proper quantity of the common stock.

I shall now examine for a little several facts which appear to prove, if duly weighed and applied, that heat possesses another characteristic of matter, I mean GRAVITY. If this fact can be established, we shall have another strong proof of the substantiality of heat; and the facts I mean to bring to your recollection are, I think, sufficient to establish it as a truth—a truth which has been forcing itself on the notice of men, for many centuries, with much stronger evidence than many others which have received general admission, though it has not only been overlooked, but many experiments have been brought forward to establish the opposite.

Heat poured into bodies lessens their specific gravity; and yet heat may not be weighed, even comparatively!! There appears to me to be something so extremely repugnant to reason in this assertion, that ever since I have dared to reason for myself I have found myself forced to refuse my assent to it. If heat lessens the specific gravity of bodies, (and we can even determine, in many cases, the ratio in which this takes place,) I think we are then weighing the heat itself, or, rather, the difference of the quantity in a body at one temperature and at another.

In the various direct attempts that have been made to weigh heat, I fear philosophers have been following a plan just about as rational as it would be in the inhabitants of the ocean to attempt to weigh water by employing a balance suspended in the medium that surrounds them, and putting into one shell a substance that to them should seem wet, and into the other a substance which they might call dry!

If we could abstract heat entirely from a body, as we can air from a glass balloon, we should be at no loss in weighing it: but is there no other way of weighing air but that one? If I take a bladder containing an unknown quantity of air, I easily find out how much weight is required to sink it in water: if I afterwards pour into the bladder a known bulk of air, I can come at a knowledge of the weight of the air so added by attending to the quantity of weight now necessary

to sink the bladder in the water, the specific gravity of the water being known. But if I weigh, in water, any substance containing an unknown quantity of heat, and find that, upon adding a known bulk of heat to the body, it will then require a less weight to make it sink, I am to draw no inference respecting the weight of the caloric that has been added!! Is this reasonable? Should philosophers stop short in this manner, and not seize upon the truth which such effects exhibit to them? Is it not obvious, in all experiments which have for their object the determining the specific gravity of any body in different temperatures, that they are doing nothing but weighing comparative quantities of heat, by observing how much water is displaced by those quantities?

Though I think the truth I have just stated is self-evident, I hope I shall not be thought tiresome if I endeavour to set it in a clear point of view by an illustration.

If I suspend a piece of metal in water at one end of a balance, and if to this metal I join a small bit of any substance lighter than water, say a bit of cork, will not the mass, by having its absolute gravity increased, have become specifically lighter? I am now considering the metal and cork as one compound body. In this case no one hesitates in admitting that the addition of the cork, though possessing absolute gravity, is the cause of the compound body appearing lighter when weighed in water; a medium more rare than one of the ingredients, but denser than the other: but *if heat instead of cork had been added to the metal, would not the effect have been the same*, an increase of volume and a diminution of specific gravity? And for the same reason too, the metal being heavier but the heat lighter than water.

Let us reverse the case — A compound body, iron and cork, possesses a certain specific gravity. Remove the cork, that is, take away from the mass a portion of its absolute bulk and weight, and on weighing what remains it is found to be increased in weight—in water.

Yet, if I detach from a piece of gold, silver, platina, copper, a certain quantity of heat, by mechanical means, and thereby reduce its volume, I am not to conclude, though I find its specific gravity increased, that the matter expressed possessed

absolute gravity, though less specifically than that of water ! Is this consistent with sound physical principles ? I think not : for the same effects should always be ascribed to one cause.

It is admitted on all hands that cast metals, that is, metals in their largest natural volume, are specifically lighter than when drawn into wire or rolled into plates, that is, when reduced in size, by having something separated from them, namely, heat.

If a piece of dense wood, that has been soaked in oil or alcohol, be weighed in water ; and if a portion of the imbibed liquid be expressed, and the wood be again weighed, its specific gravity will be found to have increased ; because the fluid expelled from it was lighter than water. Every one can *see* and *feel* the oil or alcohol driven out of union with the wood ; and every one may feel the heat driven out of metals by passing them through rollers. Is it because heat is only cognisable, in the first instance, by one gross sense that its existence as matter is denied ? It may be seen as well as felt, as I have before had occasion to remark ; for when driven from one body, the volume of which is in consequence diminished, it enters into others, and theirs become *visibly* enlarged. If it were not so, even the common thermometer could have no existence.

I shall here mention the different specific gravities of a few metals in their cast state, and when a portion of heat has been separated from them, by their *moleculæ* being brought so much closer together, by mechanical means, as to increase the power of aggregation, or, in other words, to diminish their capacity for heat.

	Cast.	Hammered.	Rolled.	Drawn into wire.
Pure gold	19258	19362		
Standard gold	17486	17589		
Pure silver	10474	10511		
Pure platina	19500	20377	22069	21042
Copper -	7788			8878
Brass -	8396			8544

The fact is, I suspect, universally true, that where the specific gravity of a body is diminished, its absolute gravity is and must be increased ; and these terms ought always to be considered

considered as convertible. When a diminution of the specific gravity is declared, an increase of the absolute gravity is by the same enunciation asserted, whether the speaker means to do so or not. Now, in the case before stated, the diminution of the specific gravity is admitted; and therefore a question naturally presents itself—Why has the increase of absolute weight not been hitherto observed? I take the reason to be this: they attempted to determine it *in the air*; overlooking this plain fact, namely, that air may be considered as bearing the same relation to heat that water does to gold, or rather, to a substance many times heavier, if such could be found; that is, the air, though a rarer substance than the solid bodies weighed in it, is a denser one than heat; and they have been demanding, that a substance specifically lighter than air should descend in it. In other words: that the laws of nature should be inverted, and that the heavier fluid, air, should ascend to make room for a lighter one, heat, to descend.

But Nature will not bend to our whims and fancies. We must court her, and take her as she is, or remain in error. The heated body, though increased in size, remains in equilibrium in the balance; and it ought to do so (if not to ascend), being buoyed up by a greater quantity of air than before it was heated. But is this the only case in which that effect takes place, and where we know at the same time that not only volume but real substance is added to one end of the beam? No: a bladder capable of easily containing a gallon of air will always weigh the same (in air) whether you put into it a pint, a quart, or a gallon.

Aye, says a caviller, but you have not put into the bladder any thing heavier than the surrounding medium, though you have put in a real gravitating substance; therefore the bladder cannot weigh heavier. Instead of answering him, I shall leave him to his own meditations.

Are philosophers always to continue in the belief that bodies can be made specifically lighter and heavier at pleasure, without any thing being either abstracted or added? Can a nonentity produce the effects of which we have been speaking? or, is gravity itself a nonentity? It either is, or
heat

heat is material. But, when I consider the rapid advances that have been made in various branches of science within these few years past, I cannot allow myself to believe that its votaries will much longer doubt of the existence of the most powerful and most generally diffused substance in nature, or long remain of the opinion, "*that all attempts to discover any effect of heat upon the apparent weight of bodies will be fruitless.*"

The ingenious philosopher (Count Rumford) whose words I have just quoted, and to whom every inquirer into Nature must feel himself highly indebted for the unwearied patience with which he has watched and traced her steps in many of her most intricate operations, and for the zeal which he has manifested in applying scientific truths to the common purposes of life, will be among the first to abandon the opinion; for, when he shall have better considered the subject, he will find the evidence lies wholly on the other side. If the opinions I have controverted were held only by men, like him, enlightened and candid, I should be sanguine enough to believe that what I have advanced would suffice to convince all of their absurdity without the necessity of saying a word more on the subject: but we know well how difficult it is for the human mind to shake off imbibed prejudices, especially when they have been theorised, and applied, like the salt, sulphur, and mercury, of the alchemists, and the phlogiston of the Stahlans, to explain all the phænomena of nature; and therefore I cannot promise myself, that the mere treaders in trammels and day-labourers in science will adopt my ideas without something more level to their capacity being first offered in addition to the evidence already produced. Indeed it would be unreasonable to expect that men of the cast to which I now allude should at one glance perceive the force of truth when presented to their view. If they ever apprehend truth, it is when it chances to be a part of the system they have been taught; and that system, however false, they always adhere to, till every person of superior intellect has abandoned it.

With a Society, however, instituted for purposes like ours, truth will meet with a proper reception. Those who are
associated

associated for the express purpose of exploring philosophical facts, will ever lend a ready hand to separate the fine from the dross; and, I doubt not, will by their labours give form and solidity to the structure for which I have humbly endeavoured to collect a few materials.

I intended, before concluding these remarks, to offer a few experiments for the consideration of the Society, which, if properly conducted, would, I persuade myself, furnish direct evidence of the gravitating power or property belonging to heat in common with other kinds of matter: I consider the point as established by the arguments already advanced, but I mean to say, that, by certain experiments, (if I have been under no mistake in the reasoning that led me to frame them) its absolute weight, in certain specific cases, may, I think, be ascertained; but having run the present essay to a greater length, and encroached further upon the time of the Society than was perhaps proper, I shall reserve them for a supplement, which I may offer hereafter, or perhaps make them the subject of a future essay.

XXI. *Account of the Manner in which the Tartars and Kalmuks make their Kumis, or fermented Mare's Milk*.*

TAKE of mare's milk of one day any quantity; add to it a sixth part of water, an eighth part of the fourest cow's milk that can be got, but at a future period a smaller portion of kumis will better answer the purpose of fouring; cover the vessel with a thick cloth, and set it in a place of moderate warmth, leaving it to rest for twenty-four hours; at the end of which the milk will have become sour, and a thick substance gathered at top: then with a stick, made at the lower end in the manner of a churn staff, beat it till the thick substance above mentioned be blended intimately with the subjacent fluid: let it rest twenty-four hours in a high narrow vessel like a churn. The agitation must be repeated as before, till the liquor appears to be perfectly homogeneous; and in this state it is called *kumis* (or *koumis*), of which the taste

* From *Eton's Survey of the Turkish Empire.*