Latent Heat

ON THE CONNECTION OF THE PHYSICAL SCIENCES

Pgs. 226 – 228

BY MARY SOMERVILLE

Besides the degree of heat indicated by the thermometer, caloric pervades bodies in an imperceptible or latent state; and their capacity for heat is so various, that very different quantities of caloric are required to raise different substances to the same sensible temperature; it is therefore evident that much of the caloric is absorbed, or becomes latent and insensible to the thermometer. The portion of caloric requisite to raise a body to a given temperature is its specific heat; but latent heat is that portion of caloric which is employed in changing the state of bodies from solid to liquid, and from liquid to vapor. When a solid is converted into a liquid, a greater quantity of caloric enters into it than can be detected by the thermometer; this accession of caloric does not make the body warmer though it converts it into a liquid, and is the principal cause of its fluidity. Ice remains at the temperature of 32° of Fahrenheit till it has combined with or absorbed 140° of caloric, and then it melts, but without raising the temperature of the water above 32°; so that water is a compound of ice and caloric. On the contrary, when a liquid is converted into a solid, a quantity of caloric leaves it without any diminution of temperature. Water at the temperature of 32° must part with 140° of caloric before it freezes. The slowness with which water freezes, or ice thaws, is a consequence of the time required to give out or absorb 140° of latent heat. A considerable degree of cold is often felt during a thaw, because the ice, in its transition from a solid to a liquid state, absorbs sensible heat from the atmosphere and other bodies, and by rendering it latent maintains them at the temperature of 32° while melting. According to the same principle, vapor is a combination of caloric with a liquid. By the continued application of heat, liquids are converted into vapor or steam, which is invisible and elastic like common air. Under the ordinary pressure of the atmosphere, that is, when the barometer stands at 30 inches, water acquires a constant accession of heat till its temperature rises to 212° of Fahrenheit; after that it ceases to show any increase in heat, but when it has absorbed an additional 1000° of caloric it is converted into steam. Consequently, about 1000° of latent heat exists in steam without raising its temperature, and steam at 212° must part with the same quantity of latent caloric when condensed into water. Water boils at different temperatures under different degrees of pressure. It boils at a lower temperature on the top of a mountain than in the plain below, because the weight of the atmosphere is less at the higher station. There is no limit to the temperature to which water might be raised; it might even be made red-hot, could a vessel be found strong enough to resist the pressure. The expansive force of steam is in proportion to the temperature at which the water boils; it may therefore be increased to a degree that is only limited by our inability to restrain it, and is the greatest power that has been made subservient to the wants of man.

It is found that the absolute quantity of heat consumed in the process of converting water into steam is the same at whatever temperature water may boil, but that the latent heat of steam is always greater exactly in the same proportion as its sensible heat is less. Steam raised at 212° under the ordinary pressure of the atmosphere, and steam raised at 180° under half that pressure, contain the same quantity of heat, with this difference, that the one has more latent heat and less sensible heat than the other. It is evident that the same quantity of heat is

requisite for converting a given weight of water into steam, at whatever temperature or under whatever pressure the water may be boiled; and therefore in the steam engine, equal weights of steam at a high pressure and a low pressure are produced by the same quantity of fuel; and whatever the pressure of the steam may be, the consumption of fuel is proportional to the quantity of water converted into vapor. Steam at a high pressure expands as soon as it comes into the air, by which some of its sensible heat becomes latent; and as it naturally has less sensible heat than steam raised under low pressure, its actual temperature is reduced so much that the hand may be plunged into it without injury the instant it issues from the orifice of a boiler.

The elasticity or tension of steam, like that of common air, varies inversely as its volume; that is, when the space it occupies is doubled, its elastic force is reduced one-half. The expansion of steam is indefinite; the smallest quantity of water when reduced to the form of vapor, will occupy many millions of cubic feet; a wonderful illustration of the minuteness of the ultimate particles of matter! The latent heat absorbed in the formation of steam is given out again by its condensation.

Latent Heat

CONVERSATIONS ON CHEMISTRY

Pgs. 33, 118 – 122, 128 – 150

BY JANE MARCET

MRS. B. … we may therefore pass on to the examination of heat, or caloric, with which we are somewhat better acquainted.

Heat and Light may be always distinguished by the different sensations they produce. Light affects the sense of sight. Caloric that of feeling; the one produces Vision, the other the sensation of Heat

Caloric is found to exist in a variety of forms or modifications; and we shall consider it under the two following heads, viz. —

1. FREE or RADIANT CALORIC.

2. COMBINED CALORIC.

The first, free or radiant caloric, is also called heat of temperature: it comprehends all heat which is perceptible to the senses, and affects the thermometer.

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MRS. B. We are now to examine the other modifications of caloric.

CAROLINE. I am very curious to know of what nature they can be; for I have no notion of any kind of heat that is not perceptible to the senses.

MRS. B. In order to enable you to understand them, it will be necessary to enter into some previous explanations.

It has been discovered by modem chemists, that bodies of a different nature, heated to the same temperature, do not contain the same quantity of caloric.

CAROLINE. How could that be ascertained? For you told us that it is impossible to discover the absolute quantity of caloric which bodies contain?

MRS. B. True; but at the same time I said that we were enabled to form a judgment of the proportions which bodies bore to each other in this respect. Thus it is found, that in order to raise the temperature of different bodies the same number of degrees) different quantities of caloric are required for each of them. If, for instance, you place a pound of lead, a pound of chalk, and a pound of milk in a hot oven, they will be gradually heated to the temperature of the oven; but the lead will attain it first, the chalk next, and the milk last.

CAROLINE. That is a natural consequence of their different bulks; the lead, being the smallest body, will be heated soonest, and the milk, which is the largest, will require the longest time.

MRS. B. That explanation will not do; for if the lead be the least in bulk, it offers also the least surface to the caloric; the quantity of heat, therefore, which can enter into it in the same space of time, is proportionally smaller.

EMILY. Why, then, do not the three bodies attain the temperature of the oven at the same time?

MRS. B. It is supposed to be on account of the different capacity of these bodies for caloric.

CAROLINE. What do you mean by the capacity of a body for caloric?

MRS.B. I mean a certain disposition of bodies to require more or less caloric for raising their temperature to any degree of heat. Perhaps the fact may be thus explained: —

Let us put as many marbles into this glass as it will contain, and pour some sand over them — observe how the sand penetrates and lodges between them. We shall now fill another glass with pebbles of various forms — you see that they arrange themselves in a more compact manner than the marbles, which, being globular, can touch each other by a single point only. The pebbles, therefore, will not admit so much sand between them; and consequently one of these glasses will necessarily contain more sand than the other, though both of them be equally full.

CAROLINE. This I understand perfectly. The marbles and the pebbles represent two bodies of different kinds, and the sand the caloric contained in them; and it appears very plain, from this comparison, that one body may admit of more caloric between its particles than another.

MRS. B. You can no longer be surprised, therefore, that bodies of a different capacity for caloric should require different proportions of that fluid to raise their temperatures equally.

EMILY. But I do not conceive why the body which contains the most caloric should not be of the highest temperature; that is to say, feel hot in proportion to the quantity of caloric it contains.

MRS. B. The caloric that is employed in filling the capacity of a body is not free caloric, but is imprisoned as it were in the body, and is therefore imperceptible; for we can feel only the caloric which the body parts with, and not that which it retains.

CAROLINE. It appears to me very extraordinary that heat should be confined in a body in such a manner as to be imperceptible.

MRS. B. If you lay your hand on a hot body, you feel only the caloric which leaves it and enters your hand; for it is impossible that you should be sensible of that which remains in the body. The thermometer, in the same manner, is affected only by the free caloric which a body transmits to it, and not at all by that which it does not part with.

CAROLINE. I begin to understand it; but I confess that the idea of insensible heat is so new and strange to me, that it requires some time to render it familiar.

MRS. B. Call it insensible caloric, and the difficulty will appear much less formidable. It is indeed a sort of contradiction to call it heat, when it is so situated as to be incapable of producing that sensation. Yet this modification of caloric is commonly called SPECIFIC HEAT.

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MRS. B. … Now let us proceed to latent heat.

CAROLINE. And pray what kind of heat is that?

MRS. B. It is another modification of combined caloric, which is so analogous to specific heat, that some chemists make no distinction between them. We call latent heat that portion of insensible caloric which is employed in changing the state of bodies; that is to say, in converting solids into liquids, or liquids into vapour. When a body changes its state from solid to liquid, or from liquid to vapour, its expansion occasions a sudden and considerable increase of capacity for heat, in consequence of which It immaculately absorbs a quantity of caloric which becomes fixed In the body it has transformed; and as it is perfectly concealed from our senses it has obtained the name of latent heat.

CAROLINE. I think It would be much more correct to call this modification latent caloric instead of latent heat since It does not excite the sensation of heat.

MRS. B. This modification of heat was discovered and named by Dr. Black long before the French chemists Introduced the term caloric. But you are not to suppose that the nature of heat is altered by being variously modified: for if latent and specific heat do not excite the same sensations as free caloric, it is merely owing to their being in a state of confinement, which prevents them from acting upon our organs; and, consequently, as soon as they are extricated from the body in which they are Imprisoned, they return to their state of free caloric.

EMILY. But I do not yet clearly see in what respect latent heat differs from specific heat, for they are both of them imprisoned and concealed in bodies.

MRS. B. Specific heat Is that which is employed in filling the capacity of a body for caloric, in the state in which this body actually exists: while latent heat is that which is employed only in effecting a change of state, that is, in converting bodies from a solid to a liquid, or from a liquid to an aeriform state.

I shall now show you an experiment, which I hope will give you a clear idea of what is understood by latent heat.

The snow which you see in this phial has been cooled by certain chemical means (which I cannot well explain to you at present) to five or six degrees below the freezing point, as you will find indicated by the thermometer which is placed in it. We shall expose it to the heat of a lamp, and you will see the thermometer gradually rise till it reaches the freezing point –

EMILY. It does, — but here it stops, Mrs. B., and yet the lamp burns just as well as before. Why is not its heat communicated to the thermometer?

CAROLINE. And the snow begins to melt; therefore it must be rising above the freezing point.

MRS. B. The heat no longer affects the thermometer, because it is wholly employed in converting the ice into water. As the ice melts, the caloric becomes latent in the new-formed liquid, and, therefore, cannot raise its temperature; and the thermometer will consequently remain stationary till the whole of the ice be melted.

CAROLINE. Now It is all melted^ and the thermometer begins to rise again.

MRS. B. Because, the conversion of the ice into water being completed, the caloric no longer becomes latent; and therefore the heat which the water now receives raises its temperature, as you find the thermometer indicates.

EMILY. But I do not think that the thermometer rises so quickly in the water as it did in the ice, previous to its beginning to melt, though the lamp bums equally well?

MRS. B. That is owing to the different specific heat of ice and water. The capacity of water for caloric being greater than that of ice, more heat is required to raise its temperature, and therefore the thermometer rises slower in the water than it did in the ice.

EMILY. True: you said that a solid body always increased its capacity for heat by becoming fluid; and this is an instance of it.

MRS. B. Yes; and the latent heat is that which is absorbed, in consequence of the greater capacity which the water has for heat, in comparison to ice. But we must attend to our experiment The water begins to boil, and the thermometer is again stationary. It is now your tum Caroline, to explain the phenomena.

CAROLINE. It is wonderfully curious! The caloric is now busy in changing the water into steam, in which it hides itself, and becomes insensible to the touch. This is another example of latent heat producing a change of form. At first it converted a solid body into a liquid, and now it turns the liquid into vapour.

MRS. B. You see, my dear, how easily you have become acquainted with these modifications of insensible heat, which at first appeared so unintelligible. If, now, we were to reverse these changes, and condense the vapour into water, and the water into ice, the latent heat would re-appear entirely in the form of free caloric.

EMILY. Pray do let us see the effect of latent heat returning to its free state.

MRS. B. For this purpose, we need simply conduct the vapour through a tube into a vessel of cold water, where it will part with its latent heat and return to its liquid form.

EMILY. How rapidly the steam heats the water!

MRS. B. That is because It does not merely Impart its free caloric to the water^ but likewise its latent heat. This method of heating liquids has been turned to advantage in several economical establishments. Steam-kitchens are constructed upon the same principle; the steam being conveyed through a pipe into the several vessels which contain the provisions to be dressed, where it communicates to them its latent caloric, and returns to the state of water. Count Rumford made great use of this principle in many of his fire-places: his grand maxim was to avoid all unnecessary waste of caloric, for which purpose he confined the heat in such a manner that not a particle of it could unnecessarily escape; and while he economised the free caloric, he took care also to turn the latent heat to advantage. It is thus that he was enabled to produce a degree of heat superior to that which Is obtained in common fire-places, though he employed less fuel.

EMILY. When the advantages of such contrivances are so clear and plain, I cannot understand why they are not universally used.

MRS. B. A long time is always required before innovations however useful, can be reconciled with the prejudices of the vulgar.

EMILY. What a pity it is that there should be a prejudice against new inventions: how much more rapidly the world would improve, if such useful discoveries were immediately and universally adopted!

MRS. B. Among the variety of novelties attempted to be introduced, I believe, my dear, that there are as many, the adoption of which would be prejudicial to society, as there are of those which would be beneficial to it. The well-informed, though by no means exempt from error, have an unquestionable advantage over the ignorant, in judging what is likely or not to prove serviceable; and therefore we find the former more ready to adopt such discoveries as promise to be really advantageous, than the latter, who, having no other test of the value of a novelty but time and experience, at first oppose its introduction. The well-informed, however, are frequently disappointed in their most sanguine expectations, and the prejudices of the vulgar, though they often retard the progress of knowledge, yet sometimes prevent the propagation of error.

The most important use to which we apply steam is the steam-engine: its prodigious advantage in the arts renders it an object of such universal interest, that I think it will be worth your while to bestow a little attention upon it; but as it would interrupt our present subject, we will defer it till we have concluded the history of caloric. To return, therefore, to latent heat; we have converted steam into water, and are now to change water into ice, in order to render the latent heat sensible, as it escapes from the water on its becoming solid. For this purpose, we must produce a degree of cold which will make water freeze.

CAROLINE. That must be very difficult to accomplish in this warm room.

MRS. B. Not so difficult as you think. There are certain chemical mixtures which produce a rapid change from the solid to the fluid state, or the reverse, in the substances combined, in consequence of which change latent heat is either extricated or absorbed.

EMILY. I do not quite understand you.

MRS. B. This snow and salt, which you see me mix together, are melting rapidly; heat, therefore, must be absorbed by the mixture, and cold produced.

CAROLINE. It feels even colder than Ice, and yet the snow is melted. This is very extraordinary.

MRS. B. The cause of the intense cold of the mixture is to be attributed to the change of a solid to a fluid state. The union of the snow and salt produces a new arrangement of their particles, in consequence of which they become liquid; and the quantity of caloric, required to effect this change, is seized upon by the mixture wherever it can be obtained. The eagerness of the mixture for caloric, during its liquefaction, is such, that it converts part of its own free caloric into latent heat, and it is thus that its temperature is lowered.

EMILY. Whatever you put in this mixture, therefore, would freeze?

MRS. B. Yes: at least any fluid that is susceptible of freezing at that temperature. I have prepared this mixture of salt and snow for the purpose of freezing the water from which you are desirous of seeing the latent heat escape. I have put a thermometer in the glass of water that is to be frozen, in order that you may see how it cools.

CAROLINE. The thermometer descends, but the heat which the water is now losing is its free, not its latent, heat.

MRS. B. Certainly: it does not part with its latent heat till it changes its state and is converted into ice.

EMILY. But how IS this, Mrs. B.? The thermometer has fallen below the freezing pointy and yet the water is not frozen?

MRS. B. That is often the case previous to the freezing of water when it is in a state of complete rest. Now it begins to congeal, and you may observe that the thermometer again rises to the freezing point.

CAROLINE. It appears to me very strange that the thermometer should rise the very moment that the water freezes; for it seems to imply that the water was colder before it froze than when in the act of freezing.

MRS. B. It is so; and after our long dissertation on this circumstance I did not think it would appear so surprising to you. Reflect a little, and I think you will discover the reason of it.

CAROLINE. It must be, no doubt, the extrication of latent heat, at the instant the water freezes, which raises the temperature.

MRS. B. Certainly: and if you now examine the thermometer, you will find that its rise was but temporary, and lasted only during the disengagement of the latent heat. Now that all the water is frozen it falls again, and will continue to fall till the ice and mixture are of an equal temperature.

EMILY. And can you show us any experiments in which liquids, by being mixed, become solid, and disengage latent heat?

MRS. B. Yes, several: but you are not yet sufficiently advanced to understand them well. I shall, however, show you one, which affords a striking instance of the fact. The fluid which you see in this phial consists of a quantity of a certain salt called muriate of lime, dissolved in water. Now, if I pour into it a few drops of this other fluid, called sulphuric acid the whole, or very nearly the whole, will be instantaneously converted into a solid mass.

EMILY. How white it turns! I feel the latent heat escaping; for the bottle is warm, and the fluid is changed to a solid white substance like chalk I

CAROLINE. You mean, Emily, that you feel the free caloric, which was latent in the mixture ; for you know that you cannot feel it in a latent state. But pray what is that white vapour which ascends ?

MRS. B. You are not yet enough of a chemist to understand that. — But take care, Caroline; do not approach too near it for it has a very pungent smell.

I shall show you another instance similar to that of the water, which you observed to become warmer as it froze. I have in this phial a solution of a salt called sulphate of soda or Glauber's salt, made very strong, and corked up when it was hot, and kept without agitation till it became cold. Now, when I take out the cork and let the air fall upon it, (for, being closed while boiling, there was a vacuum in the upper part,) observe that the salt will suddenly crystallise.

CAROLINE. Surprising I how beautifully the needles of salt have shot through the whole phial!

MRS. B. Yes, it is very remarkable; — but pray do not forget the object of the experiment. Feel how warm the phial has become by the conversion of part of the liquid into a solid.

EMILY. Quite warm, indeed I This is a most curious instance of the disengagement of latent heat.

MRS. B. The slaking of lime is another remarkable example of the extrication of latent heat. Have you never observed how quicklime smokes when water is poured upon it, and how much heat it produces?

CAROLINE. Yes; but I do not understand what change of state takes place in the lime that occasions its giving out latent heat; for the quicklime, which is solid, is (if I recollect right) reduced to powder by this operation, and is, therefore, rather expanded than condensed.

MRS. B. It is from the water, not the lime, that the latent heat is set free. The water incorporates with, and becomes solid in, the lime; in consequence of which the heat, which kept it in a liquid state, is disengaged, and escapes in a sensible form.

CAROLINE. I always thought that the heat originated in the lime. It seems very strange that water, and cold water too, should contain so much heat.

EMILY. The water, then, must exist in a state of ice in the lime, since it parts with the heat which kept it liquid.

MRS. B. It cannot properly be called ice, since ice implies a degree of cold, at least equal to the freezing point. Yet, as water, in combining with lime, gives out more heat than in freezing, it must be in a state of still greater solidity in the lime than it is in the form of ice; and you may have observed that it does not moisten or liquefy the lime in the smallest degree.

EMILY. But, Mrs. B., the smoke that rises is white: if it were only pure caloric which escaped, we might feel, but could not see it.

MRS. B. This white vapour is formed by some of the particles of lime, in a state of fine dust, which are carried off by the caloric.

EMILY. In all changes of state, then, a body either absorbs or disengages latent heat?

MRS. B. You cannot exactly say absorbs latent heat, as the heat becomes latent only on being confined in the body; but you may say, generally, that bodies, in passing from a solid to a liquid form, or from the liquid state to that of vapour, absorb heat; and that when the reverse takes place, heat is disengaged. You will however perceive, as we proceed, that this general rule is liable to many exceptions arising from chemical action. In the explosion of gunpowder, for instance, several solid substances suddenly assume a gaseous form, and nevertheless considerable heat is disengaged.

EMILY. We can now, I think, account for the experiment you showed us of the ether boiling, and the water freezing in vacuo, at the same temperature.

MRS. B. Let me hear how you explain it.

EMILY. The latent heat, which the water gave out In freezing, was immediately absorbed by the ether, during its conversion into vapour; and, therefore, from a latent state in one liquid, it passed into a latent state in the other.

MRS. B. But this only partly accounts for the result of the experiment: it remains to be explained why the temperature of the ether, while in a state of ebullition, is brought down to the freezing temperature of the water. — It is because the ether, during its evaporation, reduces its own temperature, in the same proportion as that of the water, by converting its free caloric into latent heat; so that, though one liquid boils, and the other freezes, their temperatures remain in equilibrium.

EMILY. But why does not water, as well as ether, reduce its own temperature by evaporating?

MRS. B. It does, though much less rapidly than ether. Thus, for instance, you may often have observed, in the heat of summer, how much any particular spot may be cooled by watering, though the water used for that purpose be as warm as the air itself. Indeed, so much cold may be produced by the mere evaporation of water, that the inhabitants of India avail themselves of this mode of procuring ice. During the cool of the night, and in situations most exposed to the night-breeze, they succeed in causing water to freeze, though the temperature of the air be as high as 60 degrees. The water is put into shallow earthen trays, so as to expose an extensive surface to the process of evaporation, and in the morning it is found covered with a thin cake of ice, which is collected in sufficient quantity to be used for purposes of luxury.

EMILY. Does not the radiation of heat, which during the night takes place from the water, tend to increase the cold produced by its evaporation?

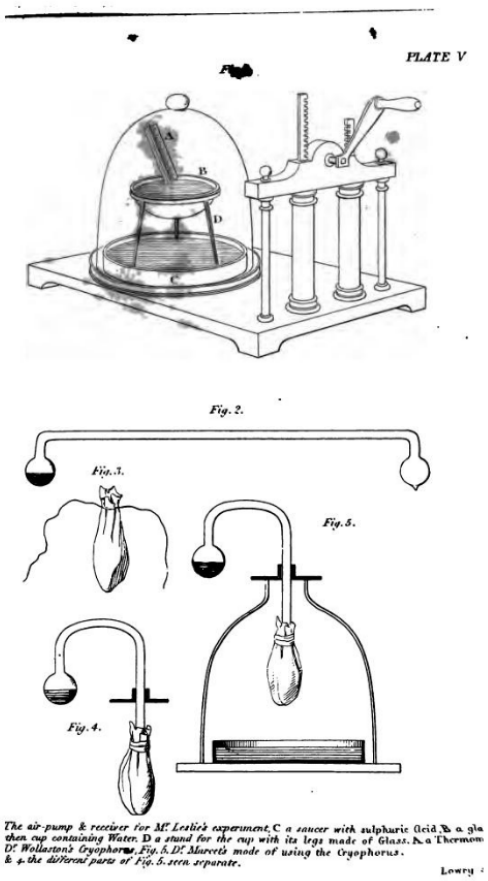
MRS. B. I have no doubt that it does, particularly if the sky be perfectly clear, as is generally the case in those tropical climates.

CAROLINE. How delicious It must be to drink iced water in so hot a climate! But, Mrs. B., could we not try that experiment?

MBS. B. If we were in the country, I have no doubt but that we should be able to freeze water, by the same means, and under similar circumstances: but we can do it immediately, upon a small scale, even in this room, in which the thermometer stands at 70 degrees. We have only to place some water in a little cup under the receiver of the air-pump (Plate V. fig. 1.), and exhaust the air from it. What will be the consequence, Caroline?

CABOLINE. Of course the water will evaporate more quickly when there is no longer any atmospheric pressure on its surface: but will this be sufficient to make the water freeze?

MBS. B. Probably not, because the vapour will not be carried off fast enough; but this will be accomplished without difficulty if we introduce into the receiver (fig. 1.), in a saucer, or any other large shallow vessel, some strong sulphuric acid, a substance which has a great attraction for water, whether in the form of vapour or that of liquid. This attraction is such, that the acid will instantly absorb the moisture as it rises from the water, so as to make room for the formation of fresh vapour; this will of course hasten the process, and the cold produced from the rapid evaporation of the water will in a few minutes, be sufficient to freeze its surface. We shall now exhaust the air from the receiver.



EMILY. Thousands of small bubbles already arise through the water from the internal surface of the cup: what is the reason of this?

MBS. B. These are bubbles of air which were partly attached to the vessel, and partly diffused in the water itself; and they expand and rise in consequence of the atmospheric pressure being removed.

CABOLINE. See, Mrs. B.; the thermometer in the cup is sinking fast; it has already descended to 40 degrees!

EMILY. The water seems now and then violently agitated on the surface, as if it were boiling; and yet the thermometer is descending fast!

MBS. B. You may call it boiling, if you please, for this appearance is, as well as boiling, owing to the rapid formation of vapour; and it takes place from the surface, for it is only when heat is applied to the bottom of the vessel that the vapour is formed there. — Now crystals of ice are actually shooting all over the surface of the water.

CAROLINE. How beautiful it is! The surface is now entirely frozen, — but the thermometer remains at 32 degrees.

MRS. B. And so it will, conformably with the doctrine of latent heat, until the whole of the water be frozen; but it will then again begin to descend lower and lower, in consequence of the evaporation

which goes on from the surface of the ice. The above experiment was first devised by Professor Leslie, of Edinburgh.

EMILY. It is indeed a most interesting one; but it would be still more striking if no sulphuric acid were required.

MRS. B. I will show you a freezing instrument, contrived by Dr. Wollaston, upon the same principle as Mr. Leslie's experiment, by which water may be frozen merely by its own evaporation, without the assistance of sulphuric acid.

This tube, you see (Plate V. fig. 2.), is terminated at each extremity by a bulb, both of which are internally exhausted of air, but one of them is half full of water, which is consequently always much disposed to evaporate. This evaporation, however, does not proceed sufficiently fast to freeze the water; unless the empty bulb be cooled by some artificial means, so as to condense quickly the vapour which rises from the water: the process is thus so much promoted as to cause the water to freeze in the other bulb. Dr. Wollaston has called this instrument Cryophorus.

CAROLINE. So that cold here performs the same part which the sulphuric acid did in Mr. Leslie's experiment?

MRS. B. Exactly so; but let us try the experiment.

EMILY. How will you cool the instrument? You have neither ice nor snow.

MRS. B. True; but we have other means of effecting this. You recollect what intense cold can be produced by the evaporation of ether in an exhausted receiver. We shall enclose the bulb in this little bag of fine flannel (Plate V. fig. 3.), then soak it in ether, and introduce it into the receiver of the air-pump. (Fig. 5.) For this purpose, we shall find it more convenient to use a cryophorus of this shape (fig. 4.), as its elongated bulb passes easily through a brass plate which closes the top of the receiver. If we now exhaust the receiver quickly, you will see, in less than a minute, the water freeze in the other bulb, out of the receiver.

EMILY. The bulb already looks quite dim; small drops of water are condensing on its surface, and now crystals of ice shoot all over the water. This is, indeed, a very curious experiment!

MRS. B. By a similar method, even quicksilver may be frozen. — But we cannot at present indulge in any further digression.

Having advanced so far on the subject of heat, I may now give you an account of the calorimeter, an instrument invented by Lavoisier, upon the principles just explained, for the purpose of estimating the specific heat of bodies. It consists of a vessel, the inner surface of which is lined with ice, so as to form a sort of hollow globe of ice, in the midst of which the body, whose specific heat is to be ascertained, is placed. The ice absorbs caloric from this body, till it has brought it down to the freezing point; this caloric converts into water a certain portion of the ice which runs out through an aperture at the bottom of the machine; and the quantity of ice changed to water is a test of the quantity of caloric which the body has given out in descending from a certain temperature to the freezing point.

CAROLINE. In this apparatus, I suppose, the milk, chalk, and lead would melt different quantities of ice, in proportion to their different capacities for caloric?

MRS. B. Certainly; and thence we are able to ascertain, with precision, their respective capacities for heat. But the calorimeter affords us no more idea of the absolute quantity of heat contained in a body, than the thermometer does: for though by means of it we extricate both the free and combined caloric, yet we extricate them only to a certain degree, which is the freezing point: and we know not how much they contain of either below that point.

EMILY. According to the theory of latent heat, it appears to me that the weather should be warm when it freezes, and cold in a thaw: for latent heat is liberated from every substance that freezes, and such a large supply of caloric must warm the atmosphere; whilst, during a thaw, that very quantity of free heat must be taken from the atmosphere in order to melt the ice, and return to a latent state in the bodies which it thaws.

MRS. B. Your observation is very natural; but consider that in a frost the atmosphere is so much colder than the earth, that all the caloric which it takes from the freezing bodies is insufficient to raise its temperature above the freezing point: otherwise the frost must cease. Yet if the quantity of latent heat extricated does not destroy the frost, it serves to moderate the suddenness of the change of temperature of the atmosphere, at the commencement both of frost and of a thaw. In the first instance, its extrication diminishes the severity of the cold, and, in the latter, its absorption moderates the warmth occasioned by a thaw: it even sometimes produces a discernible chill, at the breaking up of a frost.

CAROLINE. But what are the general causes that produce those sudden changes in the weather, especially from hot to cold, which we often experience?

MRS. B. This question would lead us into meteorological discussions, to which I am by no means competent. One circumstance, however, we can easily understand. When the air has passed over cold countries, it will probably arrive here at a temperature much below our own; and then it must absorb heat from every object it meets with, which will produce a general fall of temperature.

I think I have now concluded all the observations I have to make to you on heat.