assumption. J. J. Thomson subsequently considers the case of χ being a function of T as well as of v (p. 100). But he does not in this case make $\frac{\partial Q}{T}$ a complete differential.

I think that in the general case we must regard χ as a function of the unconstrainable coordinates, and as varying from one configuration to another, through which the system passes in the same stationary motion with constant v. When v becomes $v + \partial v$ we do work in two ways. Firstly, we alter the value of χ for each configuration, doing thereby on the whole an amount of work equal to $\overline{\frac{d\chi}{dv}}\partial v$. Secondly, we alter the comparative frequency of different values of χ in the stationary motion. This is essential; for without this the system would not be in stationary motion with the altered values of T and v. I think J. J. Thomson had this in his mind when he made χ a function of T as well as v (p. 100).

Let, then, $f dx_1 \ldots dx_n$ or $f d\sigma$ denote the frequency of the configuration $x_1 \ldots x_n$, so that

$$\bar{\chi} = \int f\chi d\sigma, \quad \overline{\frac{d\chi}{dv}} = \int f\frac{d\chi}{dv}d\sigma,$$

and

$$\partial\bar{\chi} = \int f\partial\chi d\sigma + \int\chi\partial(fd\sigma)$$

$\partial d\sigma$ referring to variation of the limits of integration

$$= \int\chi\partial(fd\sigma) + \overline{\frac{d\chi}{dv}}dv.$$

and so

$$\partial\bar{\chi} - \overline{\frac{d\chi}{dv}}\partial v = \int\chi\partial(fd\sigma)$$

and

$$\frac{\partial Q}{T} = 2N\partial\log(iT) + \frac{1}{T}\int\chi\partial(fd\sigma).$$

Now how to make

$$\frac{1}{T}\int\chi\partial(fd\sigma),$$

or

$$\int\frac{\chi}{T}\partial(fd\sigma),$$

a complete differential?

If

$$B = \int f(\log f - 1)d\sigma$$

(Boltzmann's minimum function),

$$\int\log f\partial(fd\sigma) = \partial B + N\partial\log v,$$

and is a complete differential.

Hence one solution, and probably the only general solution, of the problem is obtained by making log Cf proportional to $\frac{\chi}{T}$, or

$$f = C\epsilon^{-c\frac{\chi}{T}},$$

where c is numerical. That gives

$$\frac{\partial Q}{T} = 2N\partial\log(iT) - \frac{1}{c}\partial B - \frac{N}{c}\partial\log v.$$

Since $2iT$ is the Action of the system during the definite time i, we see that the second law stands in a certain relation to the principle of least Action. But I think the complete treatment of it must be based on the virial equation. And it may be regarded as the law of the variation of B when T and the controllable coordinates vary.

S. H. BURBURY.

THE LOSS OF H.M.S. "VICTORIA."[1]

III.

LAST week we discussed the opinions expressed by the Board of Admiralty, in their Minute of the 30th of October, upon certain points that relate to the construction and stability of the *Victoria;* but the remainder was left for consideration in the present concluding article.

The value of an armour-belt at the ends for resisting damage.—Their lordships say "the fact that the *Victoria* was not armour-belted to the bow had no influence upon the final result of the collision. No armour-belt could have prevented the ripping open of the bottom below water by the ram-bow of the *Camperdown*, and the flooding of the compartments to which water could find access through the breach." Mr. White argues strongly against the assertion, which he states has been made, that if a strong armour-belt had existed at the place where the blow was struck, the damage might have been greatly reduced and the ship kept afloat. He considers that all the most important compartments which were flooded in the *Victoria* must have been thrown open to the sea under the conditions of the collision, even if there had been such a belt. "The breach in the side might have been different in form and possibly less extensive, especially above water; but it must in any case have been of large extent, and have admitted very large quantities of water in a short time." Mr. White proceeds to argue that the extent to which the *Camperdown* penetrated into the interior of the *Victoria* was not altogether a disadvantage, as the *Camperdown's* bow thus became virtually locked in the protective deck of the *Victoria*, till the relative forward movement of the latter ship was destroyed and the tearing action of her spur upon the side of the *Victoria* was thereby prevented. "Under the assumed condition of a non-penetrable armour-belt, this relative forward movement and tearing action must have taken place." But the Admiralty cannot admit the assumption of impenetrability. Reference is made to cases of collision, such as those between *Vanguard* and *Iron Duke*, and between *Grosser Kurfürst* and *Konig Wilhelm*, which prove, in Mr. White's opinion, that "the existence of an armour-belt is no sufficient safeguard against injuries resulting from serious collision."

The objections that have been made to leaving so much of the ends of some of our first-class battleships unprotected by armour, have been mainly in connection with their defence against gun-fire. The gun is, and appears likely for some time to be, the weapon of attack which a battleship must be designed primarily to resist. The attack of the ram can often be evaded by speed or skilful handling; and that of the torpedo by watchfulness, tactical resource, and smart conduct on the part of the officers in command. The real defence against rams and torpedoes lies at present much more in the judgment and skill with which a ship can be safeguarded or manœuvred by her officers, than in her own intrinsic power of resistance.

At the same time, it is obviously desirable that everything possible should be done to increase the amount of resistance that can be offered by a ship's hull to attack from ram or torpedo. The Admiralty say that an armour-belt would have no influence upon the final result of ramming. This statement is based upon two assumptions: (1) that "under a blow of such energy as was delivered on the *Victoria* the strongest armoured side ever constructed must have yielded and been driven in. Its water-tightness and that of the bulkheads, &c., within it adjacent to the place where the blow was struck, must have been destroyed, and the ultimate result (as regards the admission of water) would have been practically as serious under the same conditions of open water-tight doors, &c. as that which actually occurred in the *Victoria*"; and (2) that if the *Camperdown's* bow had been prevented by an armour-belt from penetrating to so great a depth as was stated into the side of the *Victoria*, her spur would have torn away much more of the bottom plating than it actually did.

The truth of both these assumptions appears very

[1] Continued from p. 127.

questionable. With regard to the first, it is pointed out that the ram-bow of the *Iron Duke* drove the armour of the *Vanguard* bodily inwards more than a foot. The armour of the *Vanguard* was, however, only 6 to 8 inches thick, while the force of the blow with which she was struck is said to have been two-thirds of that delivered to the *Victoria*. The armour at the point where the *Victoria* was struck would have been 15 or 16 inches thick if she had been fitted with an armour-belt, while the energy of the blow delivered to her is stated to have been "about the muzzle energy of a 12-inch 45-ton B.L.R. gun, the estimated perforation of its projectile being about $22\frac{1}{2}$ inches of wrought-iron armour." The armour of the *Victoria* was not, however, of wrought iron, but of iron faced with steel, on the "compound" principle, which offers much greater resistance to penetration than wrought iron.

Seeing that the depth of the armour-belt would be 7 to 8 feet, and its thickness 15 or 16 inches: and that the projectile referred to, whose energy is about equal to that of the blow delivered to the *Victoria*, only succeeds in penetrating the plate by concentrating its whole effect upon an area 12 inches in diameter, it does not appear that the armour ought to suffer much from a blow distributed over so much greater an area. The armour of the *Vanguard* was driven in because the supports in its rear were not strong enough to resist the blow. In our present ships the top of the armour-belt comes against the edge of a protective deck, which is $2\frac{1}{2}$ or 3 inches thick, and could well be supported and connected to it in such a manner as to effectually resist being driven inwards; and it appears to be mainly a question of fitting a similar bearing at the bottom of the armour, in connection with the armour-shelf, to furnish sufficient resistance at the lower edge. Such an arrangement for supporting the armour would not be difficult to devise; and it does not appear impossible to thus construct an armour-belt, in a ship like the *Victoria*, that would resist being driven in by such a blow as she received; and would do so without necessarily causing the water-tightness of the bulkheads, &c. adjacent to the place where the blow was struck, to be destroyed by the shock of the collision. The fact is that armour-belts have usually been arranged exclusively for keeping out projectiles from guns, and not with the view of resisting ramming. Had the latter been regarded as an important function for armour-plating to perform, the lower edge of armour, which would receive the first force of the blow in many cases, would have been supported in the rear better than it now is, and probably somewhat in the manner indicated.

The second assumption upon which the opinion that an armour-belt would have been useless is based is that, by preventing the *Camperdown* from penetrating so far as she did into the interior of the *Victoria*, there would have been serious tearing of the bottom abaft the breach as the ships got clear of each other. In support of this it is stated that the bow of the *Konig Wilhelm* tore open the bottom of the *Grosser Kurfürst* for some distance abaft the first breach, owing to the speed with which the latter vessel tried to cross ahead of her. This tearing action would depend very much, however, upon whether the point of the ram would have penetrated far enough into the bottom below the armour-belt to keep the ships together for a sufficient time, and it is quite likely that it would. Anyhow, it is impossible to say what depth of penetration would be necessary for this purpose, especially as the ram bows of ships by which a British vessel might be attacked are very different in length and form; and it seems a doubtful process of reasoning which leads to the result that the great depth to which the side of the *Victoria* was penetrated might not have been considerably reduced with advantage.

But the objections that have been made to leaving so great a length at the ends of a battleship without armour are not, as we have said, with reference to their being rammed, but because of the damage to which they are thus exposed by gun-fire. The results of the Admiralty calculations show that the effect of gun-fire upon the unarmoured ends of such ships as the *Victoria* might be very serious. We are informed by Mr. White that the *Victoria*, as she was at the time of the collision, would change her trim 3 feet by the bow in consequence of 110 tons loss of buoyancy above the protective deck. It follows, therefore, that if the whole of the compartments above the protective deck were penetrated so as to admit water, there would be a loss of buoyancy sufficient to change her trim fully 5 feet by the head. The change of trim and extra mean immersion thus caused by the loss of buoyancy would bring the top of the armour-belt close to the water-line at its fore end; and the slightest inclination would then be sufficient to immerse the fore end of the armour-belt on its inclined side. Perforation of the thin side plating at this point above the armour would thus admit water into the ship over the top of the armour-belt, and lead to a growing loss of buoyancy and stability, both transverse and longitudinal, which would soon place the vessel in a perilous position. The destruction of such a ship does not thus appear very difficult by the large rapid-firing guns that are carried in cruisers and in the secondary batteries of battleships. These guns, firing twelve to twenty projectiles of 6 inches and $4\frac{3}{4}$ inches diameter, per minute could be aimed with great precision at the water-line of a ship, and would very soon cause the whole of the thin partitions in the unarmoured ends to be penetrated through and through, and admit water freely into the whole of the compartments. If the vessel thus attacked were steaming ahead, at the slowest speed possible, the additional water that would thus be forced in would greatly increase the change of trim, and it would only be necessary to follow up the process of aiming at the water-line along the fore end, and over the top, of the armour-belt in order to soon disable or sink her.

The foregoing considerations may suffice to show that we see no sufficient grounds for believing the Admiralty to be right in the assertion that the absence of an armour-belt at the bow had no influence upon the final result of the collision in the case of the *Victoria*; still less that an armour-belt could not be made more effective than it now is against the attack of a ram; and still less, again, that an armour-belt of sufficient length to furnish all the buoyancy and stability necessary for safety would not afford a most powerful protection to a battleship against the destructive effects of the present rapid gun-fire.

The sufficiency of the stability possessed by the ship.—The Admiralty say "the capsizing of the *Victoria*, under the special circumstances described, does not suggest any insufficiency of stability in the design of that vessel. The provision made was ample for all requirements. When fully laden and in sea-going trim the metacentric height was 5 feet, stability reached its maximum at an angle of $34\frac{1}{2}$ degrees to the vertical, and the range of stability was $67\frac{1}{2}$ degrees." It will be observed that it is only the stability that would be possessed when the hull of the ship is absolutely intact that is here spoken of; and it is doubtless sufficient for that condition, and would enable the vessel to take considerable quantities of water on board without danger. This is not a point, however, which has great practical importance in connection with actual fighting requirements. In order to judge of the sufficiency of the stability under ordinary fighting conditions it is necessary to know what it would be when the thinly-plated ends and compartments outside the armour-belt are penetrated by projectiles. This is a factor of such great importance to the problem, as to make the bare information with regard to the stability in the intact condition comparatively valueless. Whether the provision of stability was ample, in the *Victoria*, for all requirements, as the Admiralty assert, or is ample in existing ships of similar type, depends almost entirely, as regards the fighting requirements of a first-class battleship, upon what it is when the thinly-plated ends are penetrated. It is quite certain that damage to the ends would soon make demands upon the stability, which necessitate the provision of a large reserve in the intact condition for drawing upon, and that this reserve should be sufficient to cover not merely the heeling effect of water held over to one side by longitudinal partitions, but also the reduction of stability due to loss of buoyancy in compartments that are opened up to the sea, and the effect of speed of ship upon the quantity of water that might be admitted, and the position into which it might be forced. There is no necessity to look far in order to see that the stability could thus be seriously reduced very early in an action, and might soon become insufficient to enable the ship to be handled and fought as she should be, if not to place her in absolute peril.

The steps that should be taken "to prevent the recurrence, under similar circumstances, of the conditions which, after the collision, resulted in the loss of the ship."—The Admiralty considers that the only step requisite is to issue regulations to the fleet which will ensure "that, under special circumstances, and particularly when there is risk of collision, doors, hatches, &c. shall be kept closed as far as possible, and men stationed at any that are necessarily left open"; also, "that under certain conditions arising out of collision or under-water attack, the gun-ports and other openings in the upper structure shall be closed before water can enter and endanger the stability of the ship." Now, everyone acquainted with the Admiralty and the Navy must know perfectly well that this really leaves matters as they were. Officers in command of H.M. ships are quite aware that water-tight doors, hatches, &c. require to be worked in the manner described; but the difficulty is to do it, in any emergency that may arise, so as to be effective for the purpose. The great number of water-tight doors, the difficulty of properly securing some of them, and the necessity that exists for many to be frequently open in order to carry on the ordinary work of the ship, makes it practically impossible to ensure that safety can always be relied upon by such precautions. It is true that the *Victoria* would, in all probability, not have been lost if all the water-tight doors and hatches in the fore part of the vessel had been closed; but it does not therefore follow that a similar disaster can be prevented in future merely by an order from the Admiralty directing that all such doors, &c. are to be closed in future in sufficient time to keep water from passing out of one compartment into another.

We would recommend that the number of water-tight doors in the various compartments be reduced; that no door which is essential to efficient water-tight sub-division, and is ever required to be left open without attendance, be fastened merely by clips; that all doors which are relied upon for safety should be capable of being closed either by a satisfactory self-acting arrangement, or by appliances for working them from a deck at a safe height above water. We would also call attention to the danger of making the safety of a ship depend upon the complete closing of a large number of small compartments. The only arrangement that can be relied upon is one of subdivision into a series of main compartments, formed by bulkheads that are carried to a deck that is high above the water-line, which will be perforated as little as possible by doors, or by pipes, &c. below water. Such an arrangement as that in the *Victoria*, where the efficiency of some of the divisional bulkheads, which appear to have formed part of the system of water-tight subdivision, depended upon the closing of scuttles in a water-tight deck only 3 feet above water, at which the bulkheads stopped, is manifestly untrustworthy; and it is impossible for the Admiralty to remedy its defects by promulgating orders to make it work.

So far as other ships of the type of the *Victoria* are concerned, the Admiralty does not see that the necessity for any improvement is indicated. We consider, however, as the foregoing remarks show, that the result of the ramming of the *Victoria* points clearly to the necessity of making the armour-belts longer in such ships if the armour is to be made really effective. This would increase the power of resistance to gun-fire, while the belts might be so fitted as to reduce the injuries likely to be caused by ramming. Water-tight flats at a small height above water, and thin bulkheads above water, are of little good against rapid gun-fire. Vessels with short armour-belts, such as the *Victoria* and others of her type, might, as has been pointed out, be destroyed by rapid gun-fire without any penetration of their armour; so that their defensive power is not measured by the resistance to penetration of the armour they carry. They thus belong more to the type that are called protected ships than to that of armour-clads; and it would probably be more correct to classify them as such. Their names now figure in the list of first-class battleships, and make our Navy appear stronger in this class of ships than it really is. If they were classed according to their real fighting value, the necessity for adding to the number of battleships would appear stronger than it now does to those who cannot judge the relative merits of ships.

Another lesson taught by the *Victoria* disaster appears to be that the officers of such ships should be more fully instructed with regard to the probable effects of various kinds of injury than they now appear to be. It is quite certain that the officers of the *Victoria* never imagined that the ship could sink so rapidly as she did, even with many of the water-tight doors open, or that her safety depended, to the extent it did, upon the absolute closing of so many small compartments. They require to be advised, and to obtain some experience as to the best mode of treatment under different conditions of damage. Would the captains of the ships with short armour-belts all know, for instance, whether it would be better or not to admit water into the ends before going into action? Has it been decided that it would be better to thus admit water, and prevent changes of trim as the thin ends become perforated by projectiles, or to keep water out as long as possible, and to submit to changes of trim and of heeling to one side or the other as the various compartments were opened up? The effect of loose water in the ends might be very objectionable if the speed of the ship were changing, or if she were rolling to any extent; but it would exist as soon as the ends became damaged; and it is clear that the presence of a large body of water in the long unarmoured ends of some of these ships would be a great source of difficulty in keeping speed and in manœuvring.

The general result of the Admiralty investigation, and of the judgment based upon it, is that there is no fault to be found with any single point connected with the construction and arrangements of the *Victoria*, or other ships of her type, for which those who conducted the investigations, or pronounce the judgment, could be held responsible; but that the whole blame is due to the one cause with which no one at the Admiralty could be in any way connected, viz. the failure to close all the water-tight doors, hatches, &c. in time to prevent the disaster. In saying this we do not wish to cast any doubt upon the accuracy of the calculations which have been made, or upon the desire of the Admiralty to arrive at a fair decision upon the questions raised. It is impossible for persons who are deeply interested in these questions, and in the results of the investigation, to divest themselves of all feeling and bias, and to judge their own ideas and work from an absolutely impartial standpoint. It would probably happen in any inquiry, that if one of the parties implicated were allowed to draw up the judgment, the result would not be unfavourable to itself. Most people appear satisfied, however, that this course should be taken when the question involved is that of the efficiency of the battleships upon which the defence of the British Empire would mainly depend in the event of war.

FRANCIS ELGAR.

THE NEW LABORATORIES OF THE INSTITUTE OF CHEMISTRY.

AT length the members of the Institute of Chemistry may feel entitled to cry with Proteus, "Time is the nurse and breeder of all good," for now the object, kept steadily in view through evil report and good, though there was mighty little of the latter, has been achieved, and the Institute of Chemistry finds itself in the possession of a house with offices, council chamber, examination rooms, laboratories for examination, and everything handsome about it.

The successive councils are to be congratulated on the firmness with which they have resisted the numerous and persistent attempts which have been made by a somewhat important body of members to force the Institute into becoming a publishing and paper-producing body, thus adding another to the already too numerous chemical journals.

The Institute was not founded for this purpose; but the fact was forgotten again and again by those who were apparently unable to resist the temptation to spend the gradually accumulating funds of the Institute on "doing something," no matter what, but preferably holding meetings and printing a journal. The councils, however, proved wiser than some of their constituents, and held to the true view of their function, namely, that they were an examining and qualifying body.

Upwards of twenty years ago the passage of the Food and Drugs Act led to a series of appointments of public analysts that taken in the mass were little short of scandalous. The chemical profession had no corporate existence; it had never been consulted in the matter of drafting the Act, and the Government of the day, though having eminent chemists at command, never asked any advice. County and borough, corporation and vestry, were required to appoint "analytical chemists," and, left to their own sweet will in making the selection, with results that can be more easily imagined than described. It was this that literally forced the then small number of men who were practising chemistry professionally, to organise themselves with a view, not of undoing the mischief already done, for that was irreparable, but of gradually supplying a body of men whose qualifications were vouched for by a searching examination.

These examinations, at first held in town and at a number of provincial centres, have gradually concentrated in London, and the increasing number of examinees at length warned the council that the time had come when the Institute must be able to examine under its own roof.

The presidency of Dr. Tilden has been signalised by the carrying through of this project. After a prolonged search, suitable premises were found at No. 30 Bloomsbury Square, and the lease purchased. The House Committee, consisting of the President and Treasurer, with Prof. J. M. Thomson and Mr. R. J. Friswell, immediately set about planning the laboratory, the architectural work being placed in the hands of Mr. H. V. Lanchester.

The immediately surrounding property being residential, it was of great importance to prevent any nuisance from the escape of fumes, and the committee, in view of the almost universal failure of most of the fume apparatus in existing laboratories, placed themselves in the hands of one of their members whose experience as a chemical manufacturer led him to adopt the novel expedient of treating the laboratory as an acid factory, and scrubbing and burning the fumes, the latter by means of a specially constructed furnace, which also causes the draught by which the fumes are removed. So far this arrangement appears to work well, and it will no doubt be watched with interest by future builders of laboratories.

When the premises were taken over they consisted of a house of 36 feet frontage and 45 feet depth. Behind this lay a space of 60 feet by 36 feet, partly covered by an old building, once no doubt a stable, and partly occupied by an area and a built-out basement kitchen, which had a very large chimney, built independently of the house chimneys, and about 95 feet high and 18 inches square. The old building being removed, there remained an area of 34 by 36 feet for the principal laboratory, while the basement kitchen could be easily converted into a combustion laboratory, and its tall chimney—a factory shaft on a small scale—utilised for ventilating the fume cupboards and working benches.

The house faces nearly due west, and this permitted the laboratory to be lighted entirely from the north. As it was not possible to erect a lofty roof, it was decided to divide it into three gables, each having one side of glass, the other, turned towards the south, slated and matchboarded inside. These unglazed sides rise at an angle of 40°, and are so prolonged that the glazed sides, rising at an angle of 60°, meet them at an angle of 80°, and the entrance of direct sunlight is thus prevented, and, except for a very short time in the middle of the day, at midsummer. The main laboratory, 35 × 32 feet, is fitted with thirty-two working benches, and a desk for the examiner; two fume chambers and one bench of muffles being arranged at each end. It is lined throughout with white glazed bricks, the floor is of 2-inch pitchpine, and the working benches are of the same wood with mahogany edges, and tops saturated with high melting paraffin wax. Each bench has the necessary reagent shelves, seven drawers, and ample space with shelves beneath for the storage of large apparatus. It is also provided with two gas-cocks, a low-pressure water-cock, another for the supply of a condenser, and one high-pressure cock for a Sprengel filter pump. The sinks are circular, of salt-glazed stoneware, and so arranged that each supplies accommodation for four benches. Under each bench, below the floor level, runs an 8-inch Doulton pipe (which gives off 3-inch branches to each bench), and connects with a 12-inch main which runs along the front wall and descends to the level of the combustion laboratory floor, where it enters a salt-glazed stoneware tower packed with coke, and provided with a water shower. Passing up this, which is 2ft. 6in. diameter and 13ft. 6in. high, the washed fume is carried by another 12-inch pipe to the ground level again, and enters the ashpit of a furnace 4ft. × 1ft., which has fire-brick doors closing air-tight against planed cast-iron rims. Separate 8-inch pipes communicating with the 12-inch main go to each fume cupboard, and when the furnace is alight a most powerful draught, amounting to about 12,000 cubic feet of air per hour, is drawn from the benches and fume cupboards.

The stone muffle benches are each provided with a