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A handbook of chemical manipulation

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Section VIII. The Balance

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SECTION VIII.

THE BALANCE.

93. Of all the instruments the chemist possesses, the balance is perhaps the most important, and requires the greatest amount of care in its use. Its very nature renders it fragile and liable to injury from the slightest carelessness or rough usage. Affected easily by acid or corrosive vapours of all kinds, it ought to be kept in a room adjoining the laboratory, and should never be left with the sash open, or without a vessel of some absorbent substance inside the case.

94. It is quite foreign to the purpose of this work to enter upon the mechanical theory of action of the balance; such a knowledge, although extremely useful, is by no means necessary to enable the operator to use the instrument with perfect ease and success; there are, however, a few things connected with the working of the instrument which are absolutely necessary to be known by the student. In the first place, it ought to be constant in its indications, *i. e.* with the full weight it is intended to carry, it should give the same result in several successive weighings; this, which is too often neglected, is, in fact, the best characteristic of a good balance.

It must also be delicate, that is, readily turned by very small weights, and that, equally with empty pans and with the maximum load.

It is also of great importance that it should be rapid in its action, for there are few things more fatiguing than to work at a slow instrument, and, moreover, it causes a very serious loss of time where many estimations have to be effected.

With regard to the adjustments upon which the above qualities depend, the following points are more especially to be observed.

First, the arms must be of equal length, for, if otherwise, equal weights acting upon levers of unequal length will give unequal indications; that which is at the extremity of the longer arm will appear heavier than the other, and although by the method of double weighing (§ 105) this difficulty is overcome, it is essential to avoid the necessity of an operation requiring so much time.

Secondly, the centre of gravity must be below the fulcrum, otherwise, if equal weights be placed in the pans, and the centre of gravity and the fulcrum coincide, the beam will take any position that may be given it, without any tendency in the index to take a central position on the scale. If, however, the fulcrum be below the centre of gravity, the beam will "overset" with any weight, however small. But although it has been said that the centre of gravity should be below the fulcrum, it is essential that it should not be too much so, for the lower the centre of gravity the greater the stability of the balance, or, in other words, the greater the force required to move the beam, and the less delicate the instrument. Most balances have a contrivance for raising or lowering the centre of gravity, according to the circumstances under which they are to be used, as will be described further on.

In the next place, the centre knife-edge on which the beam rests, and the two knife-edges by which the pans are supported, must be parallel to one another, as otherwise considerable irregularities in the working of the instrument become apparent.

The points of suspension and the working edge of the fulcrum must be all in the same plane, for if the fulcrum is situated below the points of suspension, every addition of weight in the pans will have the effect of raising the centre of gravity, until at last the two points becoming coincident, the beam oversets with a small increment of weight. If, conversely, the points of suspension are situated below the fulcrum, all weights added have the property of depressing the centre of gravity, and therefore of increasing its stability, and also the weight required to move the instrument.

95. It will be seen that several of the properties required in a good balance are somewhat incompatible, and the greatest ingenuity and skill is required in so making the final adjustments, that these points to a certain extent neutralize each other.

96. The first persons in England who made any really important improvements in the balance, so as to render it fit for refined chemical and physical research, were Robinson and Kater; the latter gentleman having undertaken the somewhat difficult matter of adjusting the national standard weights; he engaged Robinson (whose accurate workmanship was well known) to assist him in constructing the necessary instruments, and their united labours succeeded in producing a balance undoubtedly infinitely superior to any that had been made up to that time; in fact, those who possess one of Robinson's instruments may be able to dispense with any other for small weights; but few chemists who have become accustomed to work with the long-armed balances in use in modern laboratories, would willingly use one of Robinson's, especially in organic research, where so much of the glass apparatus is of considerable size, the shortness of the arms of the latter instrument rendering it extremely inconvenient in such cases.

The grand feature in Robinson's balance is the long bearing on which the pans are suspended, instead of the "hook-and-eye" arrangement adopted in most of the instruments brought over to this country from the Continent. A little reflection will show any person, that it is impossible for a hook to take invariably the same position upon a ring with reference to the centre of motion, so that the beam is, for all practical purposes, sometimes longer and sometimes shorter, thereby causing considerable differences in the indications,—differences which sometimes amount to ·01 of a grain, and are quite sufficient to render an instrument unfit for delicate experiments.

97. As an example, we will quote an instance frequently occurring in organic chemistry: where mixtures of organic acids or alkaloids are under examination, it is usual to convert the former into silver, and the latter into platinum salts, and by crystallization to separate them from impurities; it often happens that the crops obtained do not exceed 1 or 2 grains in weight, and yet that the quantity of silver or platinum in the salt has to be estimated with precision: if, now, the balance is liable to a variation

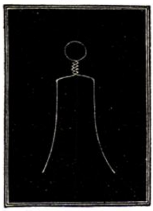
of ·01 grain, we see that ·5, or 1 per cent. error, is immediately incurred by this means alone; in circumstances like this it is necessary to work upon much larger quantities than if a more perfect instrument were at hand.

The error caused by the hook-ends renders it imperative therefore in refined investigations to use an instrument having long bearings at the extremities of the beam; as by this method of construction a uniform result is invariably obtained.

98. In an active laboratory of research there should be at least three balances: one to carry from $1\frac{1}{2}$ to 2 pounds, and with that load to turn with ·02 of a grain; another for organic and other delicate estimations to carry 1000 grains, and with that load to indicate ·002 of a grain; and a third, for assaying, to work with very small weights, say 30 to 40 grains at the outside, and to turn rapidly and distinctly with ·001 of a grain.

99. The first of these is, perhaps, the most valuable and generally useful instrument. The beam is very long (18 inches), and is divided into ten parts, in order to dispense with the hundredths of a grain weight by using a "rider," which consists of a small weight of the form and size represented in fig. 65; it is constructed of gold- or silver-gilt wire, and weighs 0·1 grain in the pan; and when placed on the beam at the different numbers, it indicates any weight from ·01 to ·09 grain, and renders unnecessary the use of such small and fragile weights as those of that value.

Fig. 65.



A balance of this kind enables us to use weighed instead of measured quantities in the examination of mineral waters, a method decidedly to be preferred where practicable; it, moreover, renders the operator to a great degree independent of the necessity of using vessels of extreme thinness in analytical operations, a moderate weight not affecting the sensibility of the instrument: this property is of great assistance in physico-chemical investigations, where the increase of weight of potash, chloride-of-calcium, and sulphuric-acid tubes, has to be determined with precision.

100. When at rest, the knife-edges are not in contact with the working planes, but by turning the handle in front of the case, from right to left, the supports for the arms descend and leave the points of support on their planes, and in a state of freedom for oscillation.

101. The second balance may have several forms given to it, or rather to its working parts, according as the purchaser is guided by inclination or economy.

The more perfect instruments are made in such a manner that the pans are prevented from oscillating when the beam is at rest; but by turning the milled head, the pans are first released and then the beam. The contrivance, by means of which the eccentrics (which move the supports for the beam and pans) perform their office*, is extremely ingenious and simple; the description of it is, however, foreign to this work, and must be ascertained by inspection. Some balances, on the other hand, are so arranged that the beam itself is raised from the supports, and the pans are not provided with any steadying appliances.

An apparatus for moving the rider without the necessity of opening the case, is also a great assistance in delicate weighings.

102. It will be observed that in chemical balances the index points downwards instead of upwards; and while to the unpractised person this may seem a matter of little importance, it is in fact of the greatest assistance imaginable to the operator, where many and accurate weighings are to be performed. It can scarcely be believed until experienced, how much fatigue is occasioned by the necessity for raising the eyes from the pans to the index, even if we disregard the inconvenience of having the lantern so tall, as must necessarily be the case when so constructed.

103. The next balance which claims our attention is that for assaying purposes. Mr. Oertling has improved it in such a manner as to give increased rapidity of action and constancy of indication; the details of its construction, and the reasons which

* Invented by L. Oertling of Store Street, Bedford Square, London, to whom the author is indebted for the opportunities of minutely inspecting the details of his beautiful instruments, and also for a balance of great precision and delicacy.

led to the peculiarities of the contrivances, will not be dwelt upon; but it is necessary to inform the student of the main features, in order that the great advantages which it possesses may be appreciated.

The old assay balances were constructed with hook-and-eye ends; this arrangement, as we have before said, entirely precluded any constancy in its results; and yet the long bearings or knife-edges at the ends make the beam so heavy as to materially interfere with the delicacy of the instrument. To obviate this, Mr. Oertling has constructed the ends of the best assay balance in such a manner that the support for the pans rests upon two points which work, one in a small cup and the other in a groove; and as the two points lie nearly half an inch from each other, a constancy as great as in instruments with the long bearing, is obtained; by this means the beam may be made of such extreme lightness that great rapidity of action is ensured.

This balance can be made so small as to be carried about in the pocket, and that without losing any of its valuable qualities; and the artist above alluded to has constructed them so small as to go into a case 8 inches long by $2\frac{1}{2}$ high, and 2 inches wide.

104. It is necessary, in weighing, to attend to one or two points which materially assist in ensuring rapidity and accuracy. In the first place, the beams of delicate balances oscillate for a very long time, so that if it were necessary to wait until the index was at rest, weighing accurately would be an exceedingly tedious operation; but a very little consideration will show us that if we simply adjust the weights until the movements of the index on each side the zero of the scale are equal, we shall obtain a result even more accurate than by waiting until it is stationary, because, while oscillating, we are sure that no resistance is offered through the beam "sticking." In the next place, it is essential to try the weights in a regular order; thus it will be seen that in instruments intended for chemical use, they are numbered 1000, 600, 300, 200, 100, 60, 30, 20, 10, 6, 3, 2, 1, ·6, ·3, ·2, ·1, ·06, ·03, ·02, ·01. Suppose, therefore, the substance or instrument being weighed requires 1740 grains to counterpoise it, 1000 is tried,—too light;

1600, still too light; 1900, too heavy; 1800, still too heavy; 1700, too light; 1760, too heavy; 1730, too light; 1750, too heavy; 1740, right. Now, although this takes some time to describe, it will be found in practice, that, by adopting this method, a result is obtained in less than half the time that would be required by using the weights at random.

105. Weights should never be added or removed while the beam is oscillating; it should be invariably brought to a state of rest before making any alteration.

If the beam be a little longer on one side than the other, the substance on the longer end of the lever appears heavier than the true weight; but if one pan is invariably used for the weights and the other for the "substance," the errors, being all of the same value, do not affect the results of analyses made with it, as the quantities obtained are not necessarily of one particular standard so that they are truly proportional.

But if an error of this kind be suspected, it is easy to determine the fact thus:—place a substance in one pan and accurately counterpoise it; now change its position from one pan to the other; if the equilibrium is undisturbed, the arms are of equal length; but if the reverse happens, and the *absolute* weight is required, we must adopt the method of double weighing, said to be invented by Borda, which is thus performed: place anything the weight of which is to be obtained, in one pan, and counterpoise it; then remove the substance and replace it by weights; now as things equal to the same are equal to each other, the weights express the true value of the substance, for they exercised the same amount of force upon the beam.

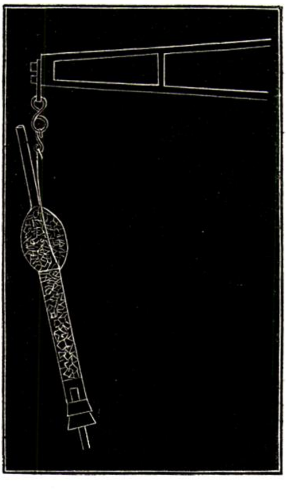
106. For the reasons stated, we should therefore always use the same pan for the weights; and it will be found by far the more convenient method to keep the right-hand one for this purpose, as otherwise the hand has to be used across in adjusting the weights, and has further to move, a matter of more importance than would appear to any one inexperienced in these matters. Each of the different forms of balance should be provided with levelling screws

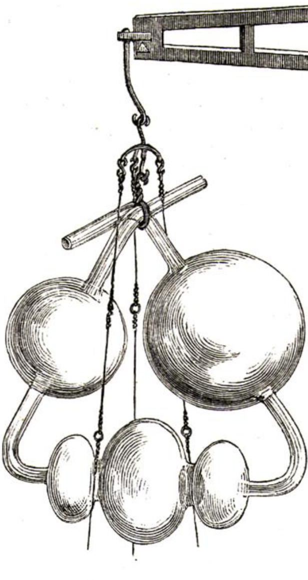
and a spirit-level, with which the instrument should be carefully adjusted before use. It not unfrequently happens that what would otherwise be the most convenient position in a laboratory for the balance, is rendered apparently unsuitable, from the fact that, the source of light being behind it, the motions of the index are rendered comparatively indistinct. This may readily be obviated by adjusting a small mirror to such an angle as to throw the light upon the graduated ivory scale.

107. In organic researches, it is necessary to ascertain the increase of weight of tubes which are of a more bulky kind than those in general use in the other branches of the science; the ordinary chloride-of-calcium tubes, and Liebig's potash bulbs will serve as an illustration. As the point sought to be ascertained is

Fig. 67.

Fig. 66.





merely the increase of weight before and after certain operations, and as the absolute weight is of no consequence, one of the pans may be removed, and the chloride-of-calcium or potash tube may be attached by a steel hook immediately to the ring of the wire which is used to support the pans; by this arrangement the tubes appear lighter than they really are, to an extent equal to the weight of the pan, as in fig. 66. Another method, fig. 67, is still more generally adopted, and is convenient, as it prevents the necessity for removing the pan. The planes which rest on the knife-edges in balances of the kind represented in the figure, have square apertures or notches which enable them to take the position shown.

It is scarcely necessary to mention, that in performing the weighing it is only requisite to counterpoise the chloride-of-calcium and potash tubes, and the hooks which suspend them; and, after the operation, to weigh again, taking care that the circumstances are exactly similar, that is to say, that the hooks are not changed. In order to perform this with facility, each chloride-of-calcium tube is provided with a little brass belt and long link, to which the hook may be easily attached. The potash tube (fig. 67) has an arrangement which is easily seen by reference to the engraving. It is quite unnecessary to have a pan with a notch cut in it, such as is frequently supplied with the balance for this purpose.

108. Care must of course be taken in using apparatus which occupies so much space, that no part of it touches the beam or lantern of the balance. There are a few special cases in which precautions are required in weighing; in the first place, it is inadmissible to put any substance or vessel into the balance-pan unless quite cold, as considerable errors become manifest by such a procedure (§ 84). It has also been said that deliquescent substances are in many cases advantageously weighed by first counterpoising the liquid, or a portion of it, in which they are to be dissolved, and then ascertaining the increase of weight. If this be impracticable, it is necessary to perform the operation in a well-closed vessel; and if the substance has been recently ignited to expel water or other volatile matters, the platinum crucible in which the ignition was effected should be cooled under circum-

stances which prevent the possibility of any moisture being absorbed during that process. The lid of the crucible must fit accurately, and if it be inconvenient to place it under a bell-glass, over sulphuric acid, during the refrigeration, it should be cooled as directed in § 84. If the crucible is of porcelain, it would of course be fractured by too sudden cooling; the vessel should therefore be placed under a dry bell-glass, upon a triangle of thin wire, so that it is only touched by the metal at very small points; by this means the danger of fracture is greatly lessened.

109. There are many substances which give off corrosive vapours, and if weighed in the balance-case would cause any instrument of ordinary construction great injury; to do away with this inconvenience, many balances have all the working parts of agate. This is an excellent contrivance, and perfectly effects the purpose intended; but it is advisable in such cases to have a good pair of ordinary scales, and where minute accuracy is not desired, to substitute them for the delicate balance.

110. In weighing gases, in the operation of taking their density, it is necessary, from their small weight, to use vessels of considerable size, which therefore lose in weight an amount equal to that of their bulk of air. But this loss, being the same in all the weighings, has no influence upon the result, provided the temperature and pressure of the atmosphere has not altered during the experiment. If it has, an error is introduced, the amount of which it is difficult to calculate; but if we balance the globe in which the gas is to be weighed by another exactly resembling it, an accurate result may be obtained, because any change of density in the air affects the globe containing the gas and its counterpoise equally. We shall allude to this again further on.

If two vessels of the same capacity cannot be procured, the smaller must have a closed tube attached to it, the bulk of which, plus that of the globe to which it is attached, must equal that of the larger one.