CHEMICAL BALANCE.

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CHEMICAL BALANCE.

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CHEMICAL BALANCE.

The balance is an instrument by means of which we ascertain the mass of bodies in grains, grams, or any other units of mass. We have many mechanical contrivances by the use of which we determine the heavier of two bodies, or the ratio of their weights, among which we mention the following as being the most extensively and approximately successfully employed: spring balances, chain balances, lever balances, tortion balance, and hydrostatic weighing machine. We will concern ourselves only with the lever balance, which, thruout this discussion, will be designated by the term balance.

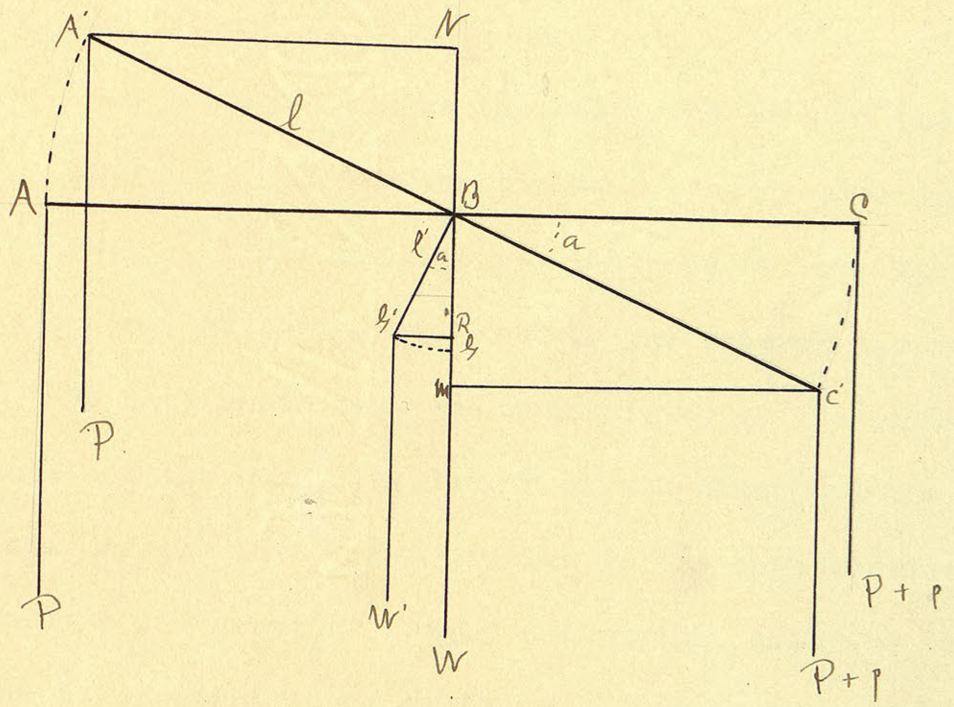
The balance of primitive days consisted simply of a straight beam, supported at the middle and flattened at the ends upon which were placed the objects to be weighed. Subsequently scale pans were attached and, finally, an enterprising tradesman conceived the notion of using in one pan an object or set of objects as a counterpoise. From this idea has developed our "set of weights." The weights first used were common objects, such as rocks and pebbles of a convenient size. We still retain the name "stone" (28 pounds) in one of our old English systems of weights.

The balance is used more extensively than any other weighing machine. When the lever is balanced at the center the apparatus is designated as a true balance; when supported at some other point than the center, a false balance. The latter form is used almost exclusively in the determination of weights when only an approximately accurate result is required. The steelyard, and common truck or stationary scales are well known examples of the false balance.

The true balance is used in all weighings when any considerable degree of accuracy is required, such as physical experiments, chemical analyses, etc. "In its simplest and most scientific form, the balance consists of a horizontal lever, having its fulcrum (which is a knife edge) just above the center of gravity of the whole balance and carrying two pans, suspended as delicately as possible (preferably from knife edges) at equal distances on the right and left of the fulcrum. It also carries a tongue pointer or index (a slender rod) rigidly attached to the middle og the beam or lever and extending vertically up or down. Except in coarse balances, there is a divided scale, over which the end of the tongue moves in the oscillations of the balance. All delicate balances are protected from currents of air by glass cases, and they have contrivances for steadying the pans", also a lever which raises the beam from its central knife edge support, the lever being operated by means of a milled head outside the case.

GENERAL THEORY OF THE BALANCE.

A difference of weights in the pans produces a difference in the angle which the beam makes with the horizontal. This difference in angle produced by a given difference in the weights is what is meant by the sensibility of the balance. The conditions which affect this sensibility may be determined as follows. Let ABC be the beam of the balance, and W its weight, and each arm l units in length, the beam moving about the point B.



When the center of gravity is above the point B, the equilibrium of the balance is unstable and a slight addition of weight to either pan would cause it to turn upside down. Should the center of gravity be at B, the equilibrium would be indifferent and the beam would remain at rest in any position. Therefore the center of gravity must be below B, say at a distance l' at point G. Suspend weights P p from C, and P from A. The greater weight at C causes the balance to turn through a certain angle a, and, by the principle of the lever we obtain the following equation of equilibrium:

$$(P+p)C'M = W\,G'\,R + P \cdot A'N$$

$$(P+p) \cdot l\ \cos a = W \cdot l' \sin a + P \cdot l \cos a$$

$$pl \cdot \cos a = Wl' \sin a$$

or $$\tan a = \frac{pl}{W \cdot l'}$$

Hence the sensibility, or the amount of the angle a, depends on p, l, W, and l', and we readily see that:

(1.) The longer the beam, the greater the sensibility.

(2.) The lighter the beam, the greater the sensibility.

(3.) The smaller the distance between the point of suspension and the center of gravity, the greater the sensibility.

We have shown that the sensibility of the balance depends on the weight of the beam, the length of its arms, and the position of its center of gravity. The problem in the construction of the beam is to secure the greatest length and rigidty with the least weight. The beam is constructed of aluminum and rests by a fine agate or hardened steel knife edge upon an agate or hardened steel plane. The pans are also suspended by knife edges and planes of similar construction. The sensibility of balances vary ordinarily with the amount of the load. This is usually due to the deflection of the beam which causes the position of the center of gravity to vary. This defect is partially remedied by means of a "gravity bob", an adjustable weight above the point of support which may be raised or lowered as the amount of load on the beam requires. It is advantageous to make use of the gravity bob only when there is iniformity in the mass of the objects to be weighed. For ordinary miscellaneous weighing it is advisable to plot a"sensibility curve," by means of which interpolations in weighing may be made.

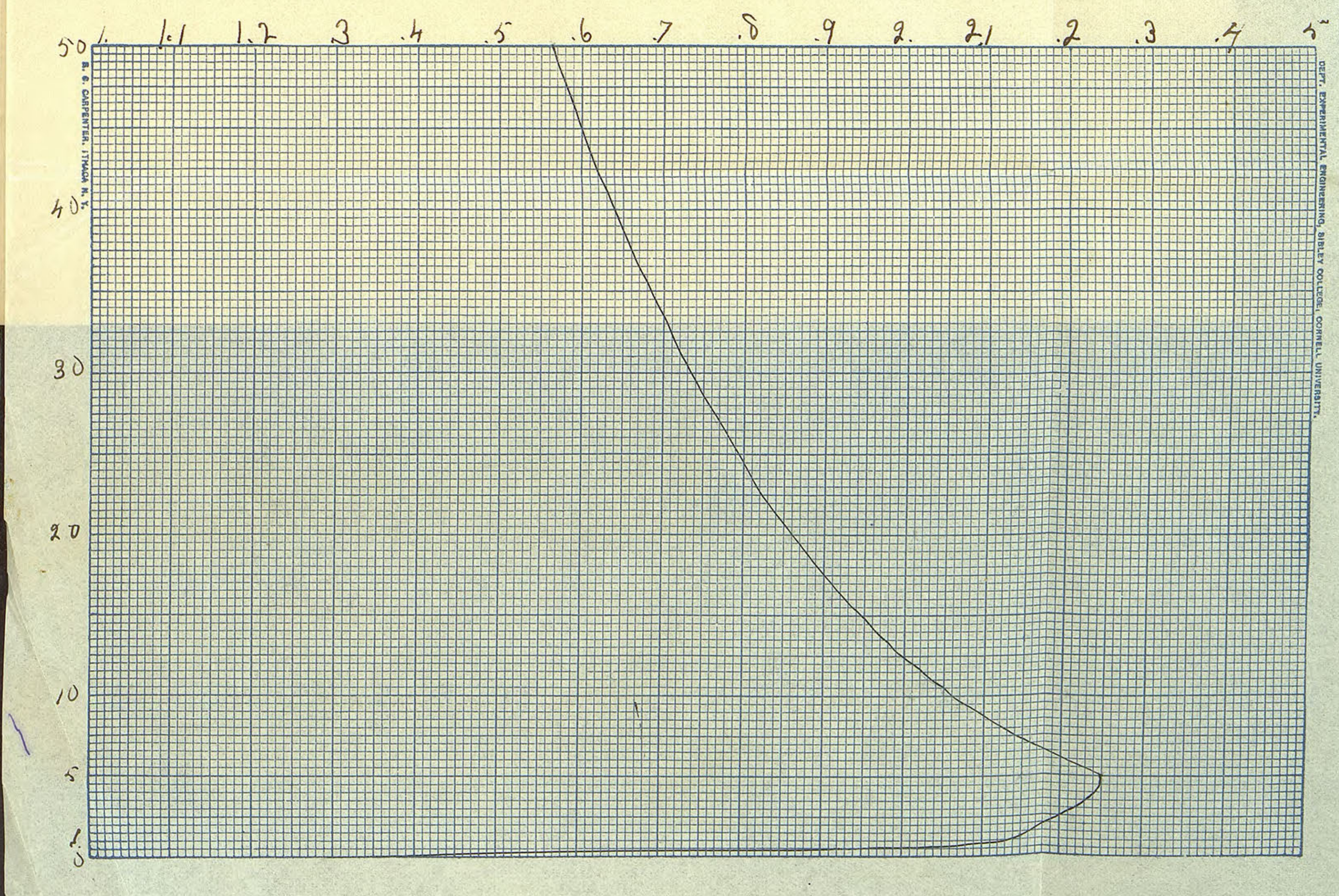
This is found as follows: Note on the graduated scale the exact position at which the pointer would come to rest when the pans are swinging empty. Place a weight of one mg. in the right hand pan and again note the point about which the pointer oscillates. Instead of swinging about the same point as before, which we may call 10, the central division of the scale, it now swings about another point, let us say 8. A weight of one mg. produced a deviation of two divisions on the scale. This shows that the balance is sensitive to the extent of two divisions per milligram when the pans contain little or no load. This fact may be recorded by means of a dot on co-ordinate paper, the ordinates representing the load and the abscissas the sensitiveness. Next place in each scale pan a weight of 10 g., determine the point about which the pointer swings, add one mg. to the right hand pan and again note the central point of oscillation. Calculate the sensitiveness and record it as before.

Continue with loads of 20, 30, 40, 50, 75, and 100 g. Next draw the curve thru these points. This curve will be more or less irregular, depending upon the rigidity of the beam and the fineness of the adjustments.

The following observations were made on an Eimer and Amend balance in the physical laboratory:

WEIGHTS.	SENSITIVENESS IN SCALE DIVISIONS per mg.
Pans empty	1.29
1 g	2.15
5 g	2.25
10 g	2.05
20 g	1.86
30 g	1.79
40 g	1.64
50 g	1.56

From these results the following curve was obtained.



MANIPULATION OF THE BALANCE.

In order that the sensitiveness of the balance be not decreased by the knife edges becoming dull, the pans and beam should be relieved from the knife edge support at all times except when an observation is actually being taken. It is of the utmost importance that they should be thus supported while being loaded or unloaded or when the balance is likely to be jarred in any manner. Before weighing with a balance, the case should be accurately leveled, and firmly supported upon a stand or table free from the trmors of the floor. All particles of dust should be removed from the scale pans and knife edges with a camel's hair brush. The beam, on being released, should come to rest with the pointer near the central division of the scale. In balancing a load the weights should be handled by means of pincers.

The object to be weighed is placed in the left hand pan and the weights in the other. The reason for so placing the object and weights is simply for convenience in handling the weights. For the purpose of economizing time, place a large weight in the right hand pan, release the beam and observe the movement of the pointer. If it moves quickly to the left the weight is too large and must be replaced by a smaller one. The beam is again released and the indications of the pointer observed. Perhaps it swings tothe right. Since we have tested the weights successively, beginning with the larg largest, we know that the weight now on the pan is the largest one that can be used in balancing the load on the pan. Proceed in the same way to determine which is the next largest necessary until the load is balanced. It seldom occurs that the pointer comes to rest at the zero point, nor is it possible to bring it to this position withany combination of weights in the set. To remedy this, most balances are provided with a centigram weight, called the "rider", which can be placed at different positions on the graduated beam.

The manner of weighing as described above is very tedius and also inaccurate, as friction always tends to bring the pointer to rest slightly to the right or left of its true zero point, or position of equilibrium. The position at which the pointer would eventually come to rest is determined expeditiously and accurately by observing successive turning points and taking the average. To avoid mistakes the following rule is adopted: "observe any odd number of consecutive turning points; find the averageof those on the right and the average of those on the left; add these averages algebraically, and divide by two." The reason for taking an odd number of turning points is onvious if we examine a simple case. Suppose we had observed three turning points, two on the right and one one the left of the center of equilibrium. Friction produced by atmospheric resistance and other causes, tends to decrease the amplitude of each vibration. The turning point of the first right swing is further to the right of the center of vibration than the second right swing, and the turning point of the left swing is at a shorter distance from this center than the first right and farther than the second right swing. Assuming that the amplitude of the vibrations decrease at a uniform rate, the mean of the two right swings will obviously be as far to the right of this central point as the turning point of the left swing is to the left. The average of these means will be the center of vibration. It is customary to take five observations; three on one side and two on the other.

Much time is also saved in weighing by interpolation. This operation is performed as follows: The zero point is noted when there is no load upon the scale pans. The center of swing is observed when the object to be weighed is nearly balanced. From our sensibility curve we ascertain the amount of variation in scale divisions produced by a weight of one mg. corresponding to the approximate weight of the object to be weighed. We now divide the difference between the zero point and the center of vibration of the weights now on the balance by the variation produced by the one mg. weight as given in our curve. The quotient is the amount in milligrams that is necessary to balance the object. Whether this amount should be added to, or subtracted from the weights in the scale pan depends upon whether the pointer comes to rest on the right or left of the zero point. If on the right, the weights being in the right hand pan, the weights are too light and the amount must be added. If to the left it must be subtracted.

Suppose the value for the zero has been determined to be 9.5. The approximate weight of the object on the pan is 25.06 g. We have this weight in the right hand scale pan, and the center of oscillation is determined as 10.75 .

The sensibility curve shows for a load of 25 g. a sensitiveness of 2.5 .

$$\frac{10.75 - 9.5}{2.5} = .5 \quad .5$$

25.06 g. + .5mg. = 25.065g., which is the weight of the object.

ERRORS IN WEIGHING.

Even with the most sensitive and delicately constructed balances, it is impossible to obtain absolute accuracy in weighing. Some of the most obvious sources of error are: inequality in length of the arms of the balance (see discussion of "Ratio of the Arms of the Balance), impossibility of securing an absolutely accurate set of weights, friction of the supports, etc. If the load and weights are of different specific gravities, the buoyant force of the air will make an appreciable difference unless the weighing is performed in a vacuum. The objects in each scale pan should be at the same temperature as a warm body is somewhat lightened on account of the upward currents of air which it produces. The door of the case should always be closed during observations, to shut off air currents.

The glass case should never be rubbed with silk, as this generates electricity about the various parts, which may also be a source of error.

RATIO OF THE ARMS OF THE BALANCE.

Weighings are ordinarily made on the assumption that the arms of the balance are of equal length. That they should be exactly equal is almost an impossibility. The ratio of the arms may be determined as follows: Let R be the length of the right and L the length of the left arm. Place a body whose mass is A in the right pan and let B represent the apparent mass, as given by the weight in the left pan, necessary to establish an equilibrium. Then place the body with mass A in the left pan and designate the apparent mass by C. Then by the principle of the lever

$$AR = BL$$
$$CR = AL$$
$$CR^2 = BL^2$$
$$R/L = \sqrt{B/C}$$
$$= 1 + \frac{B - C}{2C} \quad \text{(nearly)}$$

Make the different determinations with weights of 10g., 20g., and 50g..

Weight of object in	left pan	.........9.9984 g.
" " " "	right "	.........10.00066
" " " "	left "	.........19.9968
" " " "	right "	.........20.00112
" " " "	left "	.........49.993
" " " "	right "	.........50.00483

(1) $\frac{R}{L} = 1 + \frac{10.00066 - 9.9984}{19.9968} =$ 1.000118

(2) $\frac{R}{L} = 1 + \frac{20.00112 - 19.9968}{39.986} =$ 1.000108

(3) $\frac{R}{L} = 1 + \frac{5000485 - 49.993}{99.986} =$ 10001183

When the rationis given, to find the true weight, multiply the weight of the object in the left pan by the ratio of R to L.

The error caused by inequality in the length of the arms of a balance is eliminated in the following methods:

1. By double weighing. Weigh the body first in the right hand pan and then in the left hand pan. The geometrical (arithmetical if the difference is slight) mean will be the exact weight of the body.

2. By Taring. The body being on one pan is balanced by loading the other pan. Then remove the body and place weights in its place until the same equilibrium is again established. The weights put on give the weight of the body.