$MgSO_4.7H_2O$ and $MgCl_2.6H_2O$ respectively; the point E, which corresponds to the point C in Fig. 1, represents a solution saturated simultaneously with regard to $MgCl_2.6H_2O$ and the hydrate $4MgSO_4.5H_2O$. The broken curve joining A and E has reference to solutions which are saturated with one or other of the hydrates of magnesium sulphate, but not with magnesium chloride.

If a solution containing equivalent quantities of these two salts and represented by the point a is evaporated at 25° C., then, as in the cases already considered, separation of salt, viz. $MgSO_4.7H_2O$, will take place when the index point moving along O a reaches the curve C A.

As the concentration of the magnesium chloride in the solution increases, we move along the curve A C until at the point C this concentration has attained such a magnitude that the transition temperature $MgSO_4.7H_2O \rightarrow MgSO_4.6H_2O$ has been lowered from 47° C. to 25° C. The separated $MgSO_4.7H_2O$ in contact with the solution is now transformed into $MgSO_4.6H_2O$, and by further evaporation the index point moves along the curve C D, a further quantity of $MgSO_4.6H_2O$ crystallising out. At D the system undergoes a similar change to that which took place at C; $MgSO_4.5H_2O$ crystallises out and the $MgSO_4.6H_2O$ now disappears. Further changes of like character (not indicated in the diagram) are experienced as the magnesium chloride concentration increases, whereby $MgSO_4.4H_2O$ and $MgSO_4.2H_2O$ appear successively. At the point E the hydrate $4MgSO_4.5H_2O$ displaces the dihydrate and the solution then becomes saturated also with regard to $MgCl_2.6H_2O$. These two salts now crystallise out together until the solution completely disappears; the point E represents the crystallisation end point of all solutions containing the sulphate and chloride of magnesium. As before, the arrows indicate the course of the crystallisation for any given solution.

The above crystallisation phenomena may be regarded as typical for solutions containing two salts with a common ion.

The phenomena are much more complex if the solution contains four different ions, as in a solution of the chlorides and sulphates of magnesium and potassium. The four simple salts and their various hydrates, as well as several double salts, may in general crystallise out from such a solution. The course of crystallisation of the solution referred to has been carefully worked out by van 't Hoff, Meyerhoffer and their pupils. The phase rule serves as a safe and sure guiding principle; solubility determinations and measurements of the vapour pressures of solutions supply the data which, when graphically represented in a suitable manner, enable us to follow the various phases of the crystallisation process with almost the same ease as in the simpler cases. The diagram representing the various saturated solutions formed by the system composed of water and the sulphates and chlorides of magnesium and potassium has been tested by a qualitative and quantitative study of the products of isothermal evaporation, and the course of crystallisation is found to agree perfectly with that indicated by the motion of the index point on the diagram. In this short article it is not possible to treat of this more complicated case in detail; suffice it to say that all solutions containing the above-mentioned salts deposit in the last stage of crystallisation a mixture of carnallite, $MgCl_2.6H_2O$ and $4MgSO_4.5H_2O$.

The above sketch gives some idea of the preliminary work in connection with the problem of explaining, on a physico-chemical basis, the formation of the oceanic salt deposits. It indicates the initial stages of the synthetic method pursued by van 't Hoff in his treatment of this highly interesting problem.

H. M. DAWSON.

BOOMERANGS.[1]

BOOMERANGS may be studied for their anthropological interest as examples of primitive art,[2] or for the manner in which they illustrate dynamical principles.[3] But there is extraordinary fascination in making and throwing them, and in watching the remarkable and always graceful curves described in their flight; accordingly, my chief object in the following paper has been to diminish the practical difficulties of the subject by giving some of the results of ten years' experimental acquaintance with it.

The Australian weapons vary enormously in shape and size, while the skill of the natives in throwing them is great in some districts and very small in others. The marvellous flights that were described by former travellers are but rarely seen to-day, and although it is undeniable that many a native can make a boomerang go 80 metres away before returning to his feet, I know of only one trustworthy account of a much more sensational throw.[1] In this the boomerang described five circles in the air, travelling to a distance of about 90 metres from the thrower and rising to a height of 45 metres.

For present purposes it will be convenient to consider two types of implements. The first (Fig. 1) is about 80 cm. in length, measured along the curve, is bent (at B) almost to a right angle, and has the cross section shown in Fig. 2. It is about

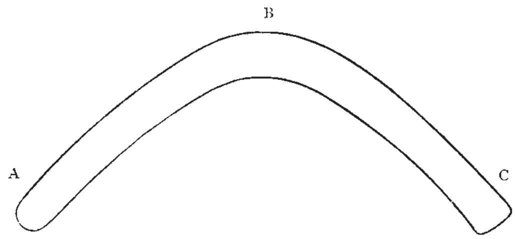

FIG. 2.

FIG. 1.

6·5 cm. wide and 1 cm. thick in the centre at B, and the dimensions of the cross section diminish slightly towards the ends A and C; the weight is about 230 grams. The arms are twisted from the plane ABC after the manner of the sails of a windmill, being rotated through 2° or 3° in the direction of a right-handed screw about the lines BA, BC as axes. This deviation from the plane is subsequently referred to as the "twist," and the peculiarity that, as seen in the cross section of Fig. 2, one face is more rounded than the other, is called the "rounding."

Boomerangs of the second type (Fig. 3) are about 70 cm. long and 7 cm. wide, and have a cross section similar to that of Fig. 2. The "twist" is in the opposite direction, involving a left-handed rotation of about 3°; the axes of rotation are now DE, FE instead of ED, EF.

Returning Flights.—An implement of the first type is held with the more rounded side to the left and the concave edge

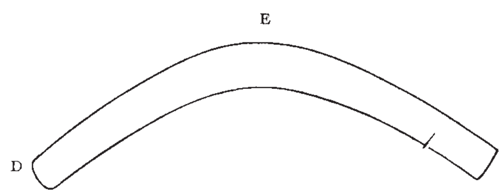

FIG. 3.

forwards. It is thrown, with plane vertical, in a horizontal direction and as much rotation as possible is given to it. The plane of rotation does not remain parallel to its original direction, but has an angular velocity (1) about the direction of translation, and (2) about a line in its plane perpendicular to this.

The effect of (2) is that the path curls to the left; while owing to (1) the plane of rotation inclines over to the right (*i.e.* rotates in the direction of the hands of a clock facing the thrower) and its inclination to the vertical becomes comparable with 30° in two seconds. The angular velocity (2) will now imply that the path bends upwards as well as horizontally round to the left.

When the boomerang has described a nearly complete circle its pace has diminished, and it falls to the ground near the thrower. (See Figs. 4, 5, in which projections on a horizontal and on a vertical plane are given; the direction of the axis of rotation is indicated by giving the projections of a line of

[1] This paper is here published by permission of the editors of the *Physikalische Zeitschrift*, for which it was originally written. A German translation has appeared in that journal, and from its publishers the accompanying illustrations have been obtained.

[2] "The Native Tribes of Central Australia," by B. Spencer and F. J. Gillen (1899), Ch. xix.

[3] E. O. Erdmann, *Ann. d. Phys. u. Chemie.*, vol. cxxxvii. p. 1 (1869); E. Gerlach, *Zeitschr. d. D. Vereins z. Förd. d. Luftschifffahrt*, Heft 3 (1886); G. T. Walker, London *Phil. Trans.*, vol. cxc. p. 23 (1897).

[1] Mr. A. W. Howitt, NATURE, July 20, 1876.

constant length measured along it. The scale of these diagrams is about 1:1000).

The angular velocity (1) is increased by an increase of twist and by an increase of rounding; it also increases when cos θ increases, where θ is the inclination of the plane of rotation to the horizontal. The curling to the left (2) is increased by an increase of twist, or of cos θ, and, in general, by an increase of rounding.

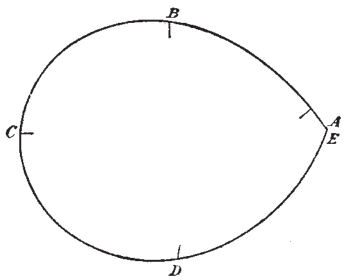

FIG. 4.—Plan.

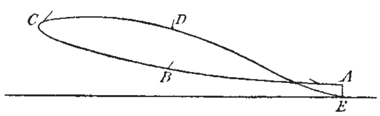

FIG. 5.—Elevation through C A.

If it be desired that the boomerang should describe a second circle in front of the thrower (Figs. 6, 7), it must be thrown much harder, so that when one circle has been described it may still have sufficient forward velocity. When the projectile has described the first circle and is over the thrower's head, the axis of rotation must point in an upward direction in front of him; if it pointed behind him the subsequent path would be behind his back, and a figure of eight (Figs. 8, 9) would become possible. For a path with a second loop in front of the thrower

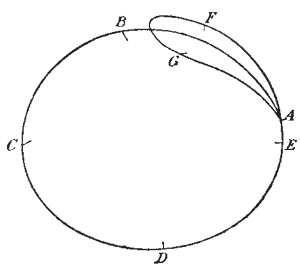

FIG. 6.—Plan.

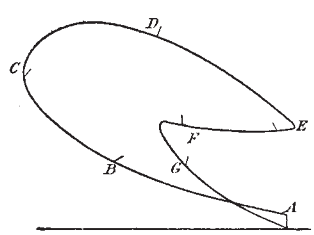

FIG. 7.—Elevation through C E.

he should accordingly choose a boomerang with much twist and much rounding, and throw it with his body leaning over to the left, so that the angle θ between the axis of rotation and the vertical may be slightly in excess of a right angle. The increased twist will mean that the first circle has a smaller circumference and that there will be more pace left after it has been described; and the increased rounding will keep the plane of rotation from becoming horizontal too soon.

For a figure of eight we should require less rounding, or we might give more spin in throwing, and aim a little uphill with θ rather less than a right angle. There are so many elements capable of variation that nothing but experience can teach how to get the best results with any particular boomerang.

The most complex path that the author has succeeded in

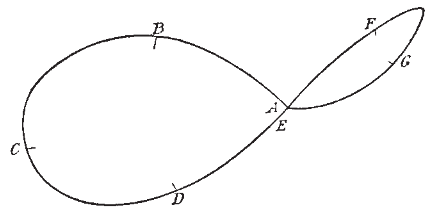

FIG. 8.—Plan.

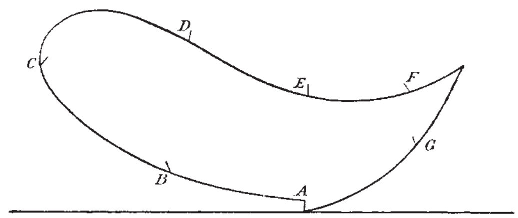

FIG. 9.—Elevation through C A G.

effecting is that of Figs. 10 and 11. But it is certain that these fall far short of what is done by skilful natives of Australia.

If the angle between the arms is increased and the twist and rounding unaltered, the angular velocity (1) is increased, and it becomes easier to make a second loop behind than in front. If the angle exceeds 150°, the angular velocity of the first kind is so large that it is very hard to get a return at all.

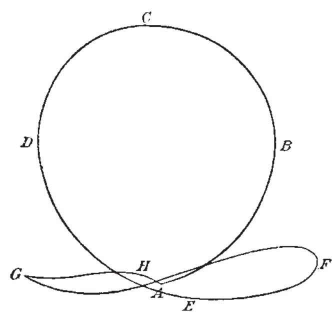

FIG. 10.—Plan.

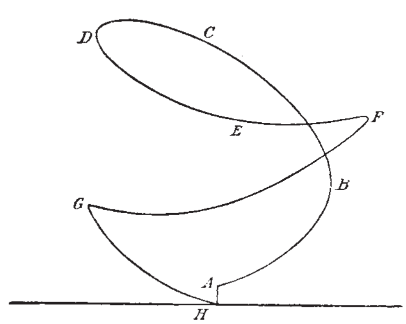

FIG. 11.—Elevation through G F.

When the twist is left-handed and the angle large we have a specimen of the second type (Fig. 3), and it must be thrown with the more rounded side uppermost and the plane of rotation inclined at between 30° and 60° to the horizontal (*i.e.* $30° < \theta < 60°$); the angle of projection (*i.e.* inclination to the horizon of the initial velocity of translation) must be comparable with 45°.

The uphill path is nearly straight until the forward velocity becomes small; the projectile then returns along a track close to that of the ascent (Figs. 12 and 13).

Non-returning flights.—A good boomerang of the second type will travel an immense distance in a nearly straight line if properly thrown. The motion should resemble that of an aëroplane or flying machine; the plane of rotation must remain nearly horizontal though slightly uphill, and the trajectory must be flat. There will thus be an upward pressure of air on the under surface of the implement, and the force of gravity will be counteracted as long as there is sufficient forward velocity. The boomerang is thrown very slightly uphill, the angle of projection not being greater than 12°; the rounded side is uppermost and θ is initially 30°. The plane of rotation soon appears to the thrower to become approximately horizontal, and it remains so during the flight; the projectile rises to a height of about 12m. from the ground and travels in a nearly straight path until its forward velocity is almost exhausted; it then strikes the earth at a distance of about 130 metres from the thrower.

It will be seen that the angular velocity (1) is at first small and positive, and that it subsequently disappears; the angular velocity (2) is small throughout. These results are due to the left-handed twist and the rounding.

Considerable accuracy both in making and in throwing is necessary if the best results are to be obtained. If the plane of rotation slopes downward to one side, the boomerang will slide down in the inclined plane of rotation; thus the path will be bent and materially shortened. The correct relation has to be found between the twist, the rounding, the angle between the arms of

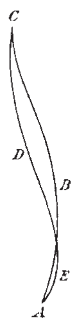

FIG. 12.—Plan.

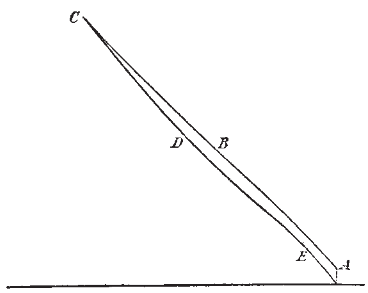

FIG. 13.—Elevation through A C.

the boomerang, the density of its material, and the amounts and directions of its initial linear and angular velocities. An illustration of this is afforded by the first specimen of this type that I have made; it travels further against the wind than with it. In the former case the boomerang keeps quite low, scarcely rising higher than 6 metres, and, being retarded very little by frictional resistance, travels about 125 metres; in the latter case the body spends its energy in running uphill to a height of about 15 metres, and falls to the ground at a distance of about 90 metres.

It is rather difficult to give sufficient spin to keep the motion stable through a long flight, and I have found it advantageous to wind round the wood about 60 grammes weight of copper wire in three equal portions, of which one is in the middle and one near each end. This materially increases the moment of inertia about the centre of gravity without interfering seriously with other details. I have thrown a loaded boomerang of this type 167 metres, and my range with a spherical ball of half the weight is only 63 metres.

Mode of manufacture.—A block of straight-grained ash about 90 cm. long, 7 cm. (or 7·5 cm.) thick, and of width not less than 7 cm. is taken. The block is soaked in steam, bent to the requisite shape and held in this shape until cool and dry. It is then sawn into strips 1·3 cm. thick. After sufficient time has lapsed for the wood to be seasoned, each strip is trimmed into a boomerang, the most useful tool in general being a spokeshave. It is very important that the outer edge, at any rate in the neighbourhood of the bend, should follow the grain of the wood. When the projectile falls hard upon one end the stress near the centre is very severe, and any point at which the direction of the grain meets the convex edge obliquely is likely to develop a split and ultimately a breakage.

It is better to cut the material to its final twisted shape rather than to impart the twist by another steaming and bending. Considerable care is required in the process, for the removal of a layer of wood a millimetre thick in such a way as to increase or diminish the twist will cause a marked difference in the flight. It will be found to facilitate throwing to cut that end of the boomerang which is held in the hand to the somewhat square form shown at the right hand of Figs. 1 and 3.

There is some difficulty in avoiding warping, for boomerangs are less likely to get broken if thrown when the ground is damp and soft, and under these circumstances the moisture is likely to be absorbed by the wood. It is of great advantage, therefore, to make the surface of the implements very smooth with fine glass-paper and to saturate them with linseed oil. The additional density thereby produced is also of service in that it diminishes the effect of the frictional resistance of the air.

I have used artificially bent oak as a material, but have not found it as heavy or as strong as ash. Oak branches that are naturally bent are not hard to procure, but boomerangs made from them are liable to break at places where there are knots or irregularities in the grain of the wood.

Evolution.—Boomerangs of every variety of shape are still to be found in Australia, and it appears impossible to get direct historical evidence as to the nature of the successive stages of development. But if speculation be allowed, the following series may be suggested.

First we should have a clumsy kind of wooden sword, curved, but without rounding or twist, and with one end roughened to form a handle; when the intended victim was out of reach it would be natural to throw the weapon, and at short ranges it would be extremely effective. Bad workmanship would involve the frequent production of implements of which one side was more rounded than the other, and it would soon be found that these missiles, when thrown with the rounded side uppermost, travelled much further and straighter than the former.

Boomerangs of this character vary in length from 50 to 110 cm., and in weight from 200 grammes to 1250. They are, for the most part, twisted in a manner that seems quite fortuitous, and form the enormous majority of the present native implements. Light specimens with a slight left-handed twist may have a fairly straight trajectory of 100 metres, and may return if aimed much uphill, especially when thrown against a wind. Those which are bent through a large enough angle and happen to be twisted (either by carelessness in manufacture or by subsequent warping [1]) after the manner of a right-handed screw are returning boomerangs of the first type. In many of these the twist is so large as to be conspicuous, and when once the connection between the form and the return flight has been noticed, the process of development is complete.

GILBERT T. WALKER.

THE INTERNATIONAL SEISMOLOGICAL CONFERENCE AT STRASSBURG.

IN 1895 the late Dr. Rebeur-Paschwitz proposed, with the approval of Prof. Milne and other seismologists, to form an international seismological union. Although, unfortunately, he did not live to carry the project into execution, the microseismic survey of the world has since then been actively pushed on by Prof. Milne, the observatories using the Milne horizontal pendulums now numbering about forty. Meanwhile, the project of Rebeur-Paschwitz was taken up by Prof. Gerland, and, thanks to his active exertions, the first international seismological conference was finally held at Strassburg on April 11–13. The total number of the members who attended the conference was thirty-five, as follows:—*Austria-Hungary* (Prof. Belar, Prof. Exner, Prof. von Kövesligethy, Hofrath Konkoly, Prof. Láska, Prof. Schafarzik); *Belgium* (Prof. Langrange); *Denmark* (Lieutenant-Colonel Harboe); *Germany* (Dr. Ebell, Dr. Ehrismann, Prof. Futterer, Prof. Gerland, Prof. Günther, Dr. Hecker, Prof. Helmert, Herr Jaehnike, Prof. Kobold, Geheimrath Lewald, Prof. Leutz, Prof. Rudolph, Dr. Polis, Prof. Schmidt, Dr. Schütt, Prof. Straubel, Dr. Tetens, Prof. Wagner, Prof. Weigand, Prof. Wiechert); *Italy* (Dr. Oddone); *Japan*

1 This may be illustrated by the fact that when the author first made boomerangs he was only aware of the need for rounding; but the first two specimens that he constructed happened to have right-handed twist and returned admirably.