A new type of specific gravity balance.

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A RAPID and accurate method of determining the density of a mineral has long been sought for by mineralogists and gemmologists. The hydrostatic method gives a high degree of accuracy, but has the drawback that each estimation occupies about a quarter of an hour so that if some ten to twenty specimens have to be investigated the time taken will be considerable. The use of heavy fluids is rapid, but for finer distinctions a large number of fluids is required and they tend, either from evaporation or chemical change, to become variable, while the Westphal balance is only reliable for fairly large portions of the mineral. Several attempts therefore have been made to develop a balance which will give a direct reading. Most of these such as the Kratschner balance have been based upon Leonardo da Vinci's principle of the bent lever, but generally have not been sufficiently delicate or accurate for small specimens. After a considerable number of experimental trials I have been able to produce a model which within one or two minutes will give a reading sufficiently accurate for all diagnostic purposes, although it might not meet the requirements of a research worker.

The instrument (figs. 1 and 2) differs from an ordinary balance in the two important particulars, that the arms instead of moving only a few degrees have to describe an arc of 90°, and the position of the centre of gravity has to be altered.

The balance consists of a central pinion or axle A to which two arms B are attached extending 32 mm. from the centre and terminating at each end in grooved quarter circles C around which pass silk threads suspending the pans D and counter weight E, so that the length of lever supporting the point of suspension remains constant through an angle of 90°; attached also to the axle is a relatively long pendulum with a screw thread cut in its lower part on which the pendulum weight F can be moved up or down. To the upper end of the pendulum bar is screwed a counter weight G. It was found that this unit must be of the lightest weight possible combined with rigidity or a high modulus of elasticity so that it would not bend. After many experiments, with brass, steel, and duralumin, perspex was used with entirely satisfactory results. The axle has a strip of safety-razor blade H running through it and fixed at an angle of 45° with the vertical. Its free ends are supported on either side in short lengths of glass tubing so that the balance rotates round the edges almost entirely free of friction. From the left arm are suspended two light pans D united by a thin tantalum wire. Below the lower one is a beaker standing on a brass stage which can be rapidly raised or lowered by means of an excentric wheel. When the stage is lowered the lower pan is above the level of the fluid in the beaker, but when it is raised the pan is entirely submerged. To the right arm is suspended the counter weight E which consists of a hollow duralumin tube the top of which can be unscrewed. It contains lead filings which can be added to or removed to gain an accurate balance. The pendulum moves across a scale doubly graduated, the lower scale giving a reading of the weight up to 5 carats and the upper giving the specific gravity.

Unlike an ordinary balance it is essential that the centre of gravity of the balance arms and their appendages be below the point of suspension or the whole equilibrium is disturbed. This point of suspension has a definite position which is given by the following equation. The length of the balance arm multiplied by the highest weight to be measured on the scale equals the weight of pans, balance arms, and counter weight multiplied by the height of the point of suspension above the centre of gravity. In fig. 2.3, L is the length of the balance arm, and x the height of point of suspension above the centre of gravity; W is the weight of the pans, balance arms, and counter weight, and the highest weight to be measured is 6 carats. Then $Wx = 6L$. Since W and L are easily measured, x can readily be obtained. With the pendulum unit absent and 6 carats in the scale the balance will then swing round until the centre of gravity and the point of suspension are in a horizontal line. In this position the system is, however, unstable, for, whether the centre of gravity moves farther up or down, the moments around the point of suspension will be decreased. Therefore only $\frac{5}{6}$ of the scale, i.e. 5 carats are used, and a stop is placed above so that the pendulum cannot swing far round. It is clear that the point of suspension will only be a short distance above the centre of gravity; in my own model it was 2·25 mm., and it is inversely proportional to the weight of the perspex unit and its appendages. It is for this reason that the unit must be as light as possible or one would be unable to measure and drill accurately the canal for the insertion of the razor blade strip.

The pendulum weight *F* is an inverted T-shaped piece of metal which is drilled and a screw thread cut to fit the screw on the lower end of the pendulum. It is made of a convenient size and the edge milled for ease of turning. It is placed in a convenient spot on the lower end of the pendulum which is then balanced on a knife edge placed at the point

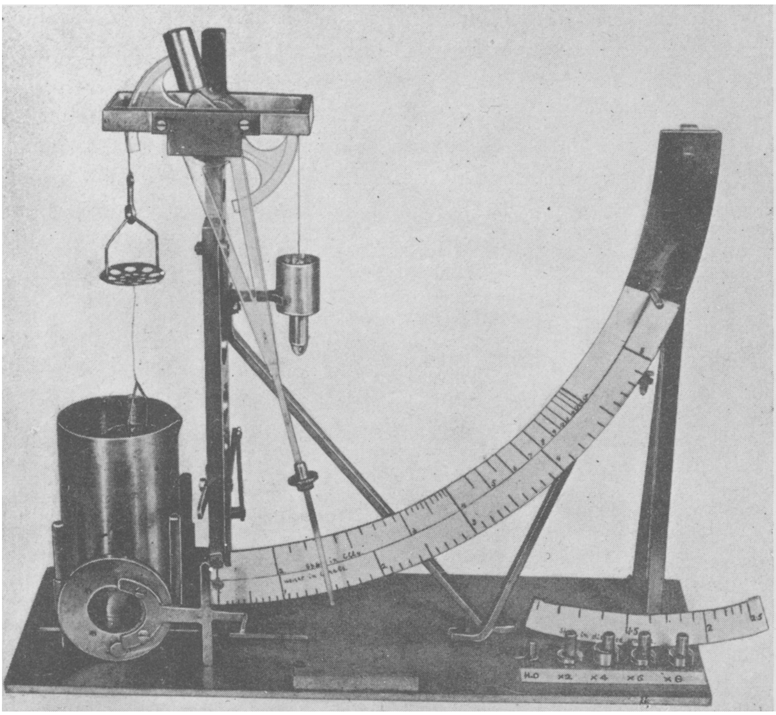

Fig. 1. A new type of specific gravity balance. The upper scale gives sp. gr. 2–15, using carbon tetrachloride. The lower scale gives weights 1–5 carats. The smaller supplementary scale gives sp. gr. 1–2·5, using water.

of suspension of the balance arm; the counter balance *G* being cut to give an accurate balance; its weight can be roughly estimated by taking moments around the point of suspension, but the final adjustment has to be made experimentally.

The correct balance of the pans and wire with their counter weight *E* is found by weighing them against one another on a balance, lead filings being added to or removed from the counter weight as required. The pendulum is then permanently fixed to the axle with a cement made of perspex dissolved in chloroform (fig. 2.4). With the lower pan in the fluid (carbon tetrachloride is used as it is easily obtainable and has a low surface tension) a 5-carat weight placed in the upper pan should make the pendulum swing round and come to rest at a point representing five-sixths of the quarter circle, i.e. 75° from the vertical; this may require

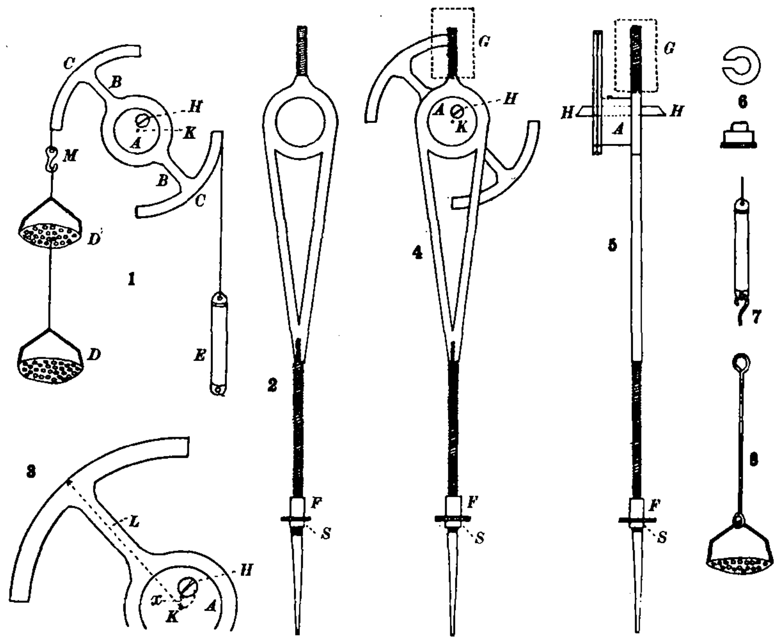

FIG. 2. Parts of the specific gravity balance, (1) arms, pans, and counter weight; (2) pendulum; (3) razor-edge pivot of arms and pendulum; (4) assembled perspex unit, front view; (5) same, side view; (6–8) accessories.

a slight adjustment of the height of the pendulum weight *F*. When this is correctly adjusted the stop *S* is screwed up to it and then permanently fixed with perspex cement, so that when the pendulum weight is screwed down to it the pendulum will always be vertical and register 0° when the pans are empty and 5 carats when that weight is placed in the upper pan. It is now only necessary to calibrate the two scales.

To use the instrument the pendulum weight is screwed down to the stop, and the beaker raised so that the lower pan is submerged. The pendulum will now register 0°. The mineral is placed in the upper pan when the pendulum will swing up to give the correct weight. The pendulum weight is now screwed up and as this is done the pendulum will swing up the scale so that it can be made to stop exactly opposite the 5-carat mark. Thus whatever the weight of the specimen (under 5 carats) it is made to measure 5 unknown units. The pendulum is moved back to 0°, the beaker lowered, the mineral removed from the upper to the lower pan, the beaker raised, and the pendulum freed. When it comes to rest it will give an accurate reading of the density on the upper scale.

Since the weight of fluid displaced is always a given proportion of the weight of the mineral it will be seen that if the weight is always given as 5 units, which with each specimen will have different values, the specific gravity will always be given in its correct position on the scale, e.g. if a mineral of sp. gr. 2 is weighed in water it will lose half of its weight whatever that may be, so that if its weight be given as 5 units of some sort, its specific gravity will be at a point corresponding to 2·5 on the weight scale. If its sp. gr. is 4 it will lose $\frac{1}{4}$ of its weight so that the sp. gr. of 4 will be opposite the 3·75 on the weight scale. The principle of the instrument is then, that after the weight in carats has been recorded the pendulum weight is raised so that the value of the unit of weight is altered until the specimen weighs exactly 5 of these units.

As described above the limit of weight of the specimen to be investigated is 0–5 carats, the lower practical limit is however 1 carat. If for instance a specimen of $\frac{1}{2}$ carat is being investigated the weight will be correctly given, but when the pendulum weight is screwed up so that the pendulum moves to the 5-carat mark each major division of the scale will equal $\frac{1}{10}$ carat and the smaller divisions $\frac{1}{100}$ carat. With such a delicacy the resistance of the fluid on the pan and specimen will cause considerable inertia and the pendulum will move so sluggishly that the recording of the specific gravity is unreliable. With such small specimens the use of heavy fluids is still the most satisfactory method. In the upper limits the 5-carat range will cover the greater number of gemmological specimens, but some of them and many mineralogical specimens will be of greater weight. Four extra graduated weights are therefore provided. They are slipped on to the pendulum weight (fig. 2.6) and are such that when in position the recording on the weight scale has to be multiplied by 2, 4, 6, 8 respectively so that in each case the limit of weight will be 10, 20, 30, and 40 carats. Naturally the larger the weight added the less delicate will be the recording; the specific gravity scale will, of course, remain unchanged. The only factor that is altered is the unit of weight.

The specific gravity of the fluid used, carbon tetrachloride, is 1·6. Certain substances, of which the most important to the gemmologist are opal, amber, tortoiseshell, jet, vegetable ivory, and the plastic imitations (bakelite, erinoid, and celluloid), have a specific gravity less than this and would float off the pan. In such cases the beaker must be filled with distilled water instead of carbon tetrachloride. Immersed in it the lower pan will weigh more than when immersed in carbon tetrachloride. A small extra counter weight in the form of a wire hook is hung on the lower ring of the duralumin counter weight (fig. 2.7) and will give a correct balance, the weight scale will then remain correct. The specific gravity scale will, however, differ considerably, for the proportion of the weight lost in water will be less, a small extra specific gravity scale registering up to 2·5 is therefore provided which will slip over the lower part of the upper scale.

For the use of those who simply require a rapid method of estimating the weight, a single pan (fig. 2.8) is made which hangs on the hook *M* (fig. 2.1) instead of the double pan and accurately balances the counter weight. The beaker is removed, the specimen placed in the pan, and the pendulum released when it will swing over and give a correct reading of the weight thus avoiding trial with several weights as in an ordinary balance.

The instrument is being manufactured for me by Messrs. Rayner and Keeler of 100 New Bond Street, London, W. 1.