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AN ELUTRIATING TUBE FOR THE SPECIFIC GRAVITY SEPARATION OF MINERALS*

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INTRODUCTION

Studies of the isotopic composition of lead in nature require the isolation of relatively pure galena from associated host minerals. Separation techniques based on the use of heavy liquids, sulfide flotation, water superpanning, electromagnetic separations, hand-picking and elutriation have all been utilized on various samples, depending on the properties of the associated minerals. Some of these techniques are time-consuming and require expensive reagents or apparatus, and the use of heavy liquids and sulfide flotation techniques require reagents which may be toxic or chemically corrosive to some metal sulfides. Water elutriation, therefore, seemed particularly attractive and a study was made to adapt or develop suitable apparatus and techniques for ore mineral separations.

Taggart (1945) describes several elutriators which employ rising liquid for size classification of a mineral. Gross, Zimmerley and Probert (1929), of the Bureau of Mines describes a method for sizing ore by elutriation, and Cooke (1937) also of the U. S. Bureau of Mines, reports on a short column hydraulic elutriator for size classification of subsieve sizes. These methods are based on Stokes' law which relates the settling rate of spherical particles of known radius and density through a medium of known viscosity and density. By causing the medium to flow upward, the grains can be given a positive, zero, or negative rate of settling relative to the apparatus. By adjusting this flow closely, sized mineral grains can be fractionated according to their specific gravities.

DESCRIPTION OF ELUTRIATION APPARATUS

An all-glass elutriating tube modified and adapted from models described by H. L. Gibbs (written communication, 1958) and by Taggart (1947) was constructed. The tube assembly with constant-head water supply and receiver flasks for recovery of sinks and floats is shown as figure 1. The elutriator tube may be constructed inexpensively by any glass blower. The increasing cross-sectional areas of the tube were so chosen that the velocity of rising water is reduced approximately 50 per cent with its entry into each larger section. The volume of the tube below

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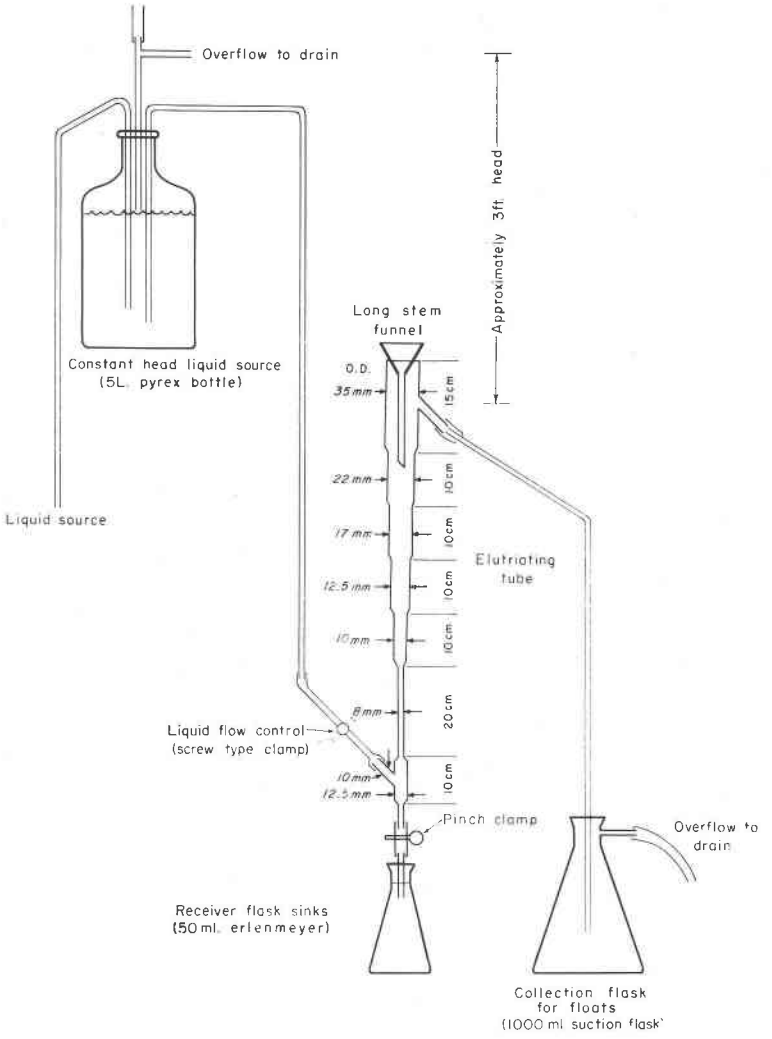

FIG. 1. Schematic diagram of elutriating apparatus.

the overflow outlet is approximately 125 ml. This capacity is designed for a sample load of not more than 10 grams at any one time. The inlet at an enlarged portion near the bottom of the tube was designed to minimize eddy currents in the small-diameter fractionating section. It is essential that the tube be mounted exactly vertical for efficient elutriation. The elutriating water in storage at the start of any mineral separa-

tion is treated with a commercial wetting agent to insure complete wetting of all mineral particles. The amount of wetting agent added is not too critical and may be determined from dilution directions supplied with the reagent used. The long-stem funnel placed in the top of the elutriating tube permits the sample slurry to be introduced below the overflow at a point least subject to lift from rising water.

Operation of the Apparatus

Not more than 10 grams of crushed sample, which has carefully been sieved to uniform particle size, is mixed into a slurry with water containing a wetting agent. The slurried sample is quickly transferred to the elutriating tube by means of a small stream of water from a wash bottle. The upward flow of water is adjusted so that those minerals having the highest specific gravities are suspended above the bottom fractionating section. After 2 or 3 minutes of fractionation the rate of flow is decreased so that those mineral grains having the highest specific gravities slowly drop from the bottom fractionating section into the receiver flask. Visual observations are used to determine the desired fraction of the sample. The receiver flask can be removed at any time by applying a pinch clamp to the rubber connection used to attach the receiver flask to the elutriating tube. A new receiver flask, filled with water, may then be attached to the elutriating tube. This permits small fractions of mineral separates to be removed at will and observed by a hand lens or binocular microscope. Adjustment of the water flow by the screw clamp gives decreasingly slower water velocities and thereby separation by sinking of minerals of decreasing specific gravity.

In our work most minerals have been separated as described above, but it is also possible to collect the minerals from the top overflow by increasing the velocity of flow. Those minerals of lowest specific gravity and such other minerals as micas which may have large surface areas in relation to their diameters may be more easily collected as floats. Biotite has been satisfactorily separated from samples both as floats and as residue after removal of all minerals which sank prior to the biotite.

A short time spent with the elutriator will permit one to determine the best procedure to follow for the specific separations being made. Sometimes a few mineral particles having lower specific gravities than the mineral being separated may be mechanically carried down with the sinks. An additional pass of this mineral concentrate through the column will remove these minerals with lower specific gravity. Maximum recovery of a desired mineral may also be best obtained by means of an initial separation for removal of the bulk of the impurities and followed

by a second elutriation to recover the concentrated mineral. Should the initial elutriating conditions not prove satisfactory, no part of the sample need be lost as both the sinks and floats are easily recovered.

Satisfactory mineral separations have been accomplished on a wide range of particle sizes, providing that each closely sized fraction is elutriated separately, and that the grains are not mineralogically composite. Galena separates of better than 95 per cent purity were obtained easily from seven different size fractions, between 40 and 200 mesh, from a specimen containing galena, gahnite, biotite, and quartz.

By using sized one-gram samples each of quartz, pyrite, and galena, it was possible to keep essentially all of a given mineral in any two adjacent sections of the elutriating tube. No differences in this respect were observed between samples sized to -40 $+60$, -60 $+80$, or -80 $+100$ mesh.

Qualitative comparisons between water elutriation and other mineral separations techniques are difficult to evaluate. Not only the purity of the separate but also its percentage recovery must be considered. Sepparations of galena from pyrite, difficult and time consuming by sulfide flotation and water super panning, were readily made by elutriation. A synthetic mixture containing equal amounts of pyrite and galena sized to -100 $+120$ mesh yielded 81 per cent of the galena with a purity visually estimated at better than 95 per cent, and almost complete recovery of pyrite, of similar purity, was made from an ore composed primarily of quartz and pyrite. Free gold also was easily separated from host material.

Extension and Adaptations

An elutriating tube similar in design to the one described but proportionally larger, should prove advantageous for mineral separations of larger samples. The larger tube would also be especially suited for fine-grained materials which settle slowly and therefore require only a minimum flow of rising water. Although water has much to recommend it, other liquids or gases might be adapted as the elutriating medium. Gaudin and others (1930) proposed the use of acetone as an elutriating medium; this was investigated and found satisfactory. Its lower specific gravity and viscosity together with its wetting properties would recommend it for some specific mineral separations.

Sizing by elutriation is common practice, and the elutriating tube described permits easy particle sizing of material of uniform density and shape. Water elutriation also makes field separations possible as a field reconnaissance tool in heavy minerals exploration.

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USING THE MICROSCOPE FOR SPECIFIC GRAVITY DETERMINATION OF MINUTE MINERAL GRAINS

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The determination of the specific gravity of the larger pieces of solid materials is comparatively easy and is accurately performed by means of the various balances now in common use. The system of comparing the specific gravity of an unknown solid with that of calibrated heavy liquids is also very useful for quick determinations of their relative specific gravities. The approximation to the actual specific gravity of the unknown by this method depends upon the variation in the specific gravities between the individual liquids in the set. The actual specific gravity of a solid can, of course, be determined by adjusting the density of the liquid to equal that of the solid. This state is obtained when the latter merely swims about in the liquid for its movement is then determined by convection currents rather than by any differences in specific gravities.

The application of the heavy liquid technique for specific gravity determination can be done with considerable facility by means of a petrographic microscope or any microscope which permits tilting the stage and tube to 60 degrees or preferably more. A sample of the material is prepared by crushing a fragment of the specimen, allowing some of the pieces to be several times larger than the majority of the smaller ones. A microscope slide is made from the crushed material in the same manner as in preparing a specimen for the index of refraction determination. After covering the grains with a cover glass a liquid of known specific gravity is placed between the slide and the cover glass. The slide is then placed on the microscope stage and the stage is then tilted to 60 degrees or more. Upon rotation of the stage one will observe that the smaller