

## A method for performing magnetic mineral separations in a liquid medium

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### Abstract

A method for performing magnetic separations of minerals in a liquid medium with the Franz separator is described. The method is successful for applications where only small sample weights (<200 mg) are available and the sieve size of the particles is small (<53 $\mu$ ).

### Introduction

Early interest in the techniques for separating minerals from powdered rock samples led to the development of laboratory-sized electromagnetic mineral separators based in principle on the much larger equipment used in ore dressing (Hallimond, 1931; Evans, 1939). This early work eventually resulted in the development and commercial production of the Franz Isodynamic Magnetic Separator. Franz separators are routinely used in many laboratories to obtain separates of rock-forming and accessory minerals for various types of analytical work. In terms of separation and recovery, the technique is most successful when large sample weights (>1 g) and relatively coarse-grained materials (>100 $\mu$ ) are used.

However, when the mineral assemblage is fine-grained and only small sample weights are available, two difficulties are encountered. First, fine-grained particles tend to adhere to the standard Franz sample tray, preventing motion through the magnetic field. Second, confinement and recovery of the sample may not be adequately obtained. For work where material balance is important, nearly complete recovery is essential. Confinement is important when loss of some fraction of the sample might be detrimental to the environment, as would be the case for neutron-irradiated samples.

The method reported here was developed specifically to obtain mineral separates for noble-gas analysis from inclusions in the Allende type C3V carbonaceous chondrite. We have found that individual inclusions rarely exceed 100 mg. Fine-grained inclusions often have grain sizes less than 10 $\mu$  (Blander and Fuchs, 1975). Since the method overcomes these difficulties, it may prove useful to others with similar

needs to separate fine-grained minerals in a closed system.

### Experimental procedure

The sample separation and recovery system is shown in Figure 1. Except for centrifuge tubes, screws, and O-rings, the device is made of clear plexiglas to enable direct observation of the separation and recovery process. The essential components of the system are: (1) a sample feed tube; (2) a sample transport and separation channel; (3) extension tubes to allow both filling and removal of a liquid when tilted; (4) exit ports; (5,6) 15.5 mm I.D. rubber O-rings; (7) 15.0 mm O.D. Pyrex centrifuge tubes. The rims of these tubes were thickened and ground flat to insure sealing without breakage; (8) a plate which allows assembly of the centrifuge tubes and O-rings to the exit port block (9).

The fully-assembled system slides between the pole pieces of the electromagnets on our Franz Model L-1 separator. The standard Franz vibrator is attached at point A on the upper end of the sample transport/separation channel (Fig. 1). In our experiments we used 15° side tilt, 25° forward tilt, and distilled water as the liquid medium. Eberhardt *et al.* (1965) and Bochsler *et al.* (1969) made separations with a Franz separator using acetone, but details of their methods were not reported. With the electromagnets and vibrator turned on, a powdered sample is deposited in the feed tube, travels down the transport/separation channel, and enters the centrifuge tubes *via* the exit ports. The feed and extension tubes are stoppered, and the centrifuge tubes are removed, centrifuged, dried, and weighed. Since the weights of the centrifuge tubes are known, the

Table 1. Results for sample CAI F2-5

Fraction	Current (Amps)	Mineralogy	$\frac{I_{\text{Mineral}}}{I_{\text{Spinel}}}$ *	Weight (mg)
1	<0.30	Olivine	4	19.3
		Clinopyroxene	1.7	
		Spinel	1	
		Grossular	<0.13	
		Anorthite	<0.13	
		Perovskite	<0.13	
2	0.30-0.45	Olivine	2	44.7
		Spinel	1	
		Clinopyroxene	0.6	
		Grossular	0.2	
		Perovskite	0.2	
		Anorthite	<0.08	
3	0.45-0.60	Spinel	1	50.9
		Grossular	0.4	
		Olivine	0.3	
		Perovskite	0.2	
		Anorthite	0.1	
		Clinopyroxene	<0.04	
4	>0.60	Spinel	1	18.9
		Grossular	0.3	
		Perovskite	0.2	
		Anorthite	0.1	
		Olivine	<0.03	
		Clinopyroxene	<0.03	
		Total sample weight recovered	133.8	
		Initial sample weight	160.0	

\*Intensity ratios relative to spinel were determined from the densitometer tracings using the most intense x-ray line for each mineral.

weights of the separated mineral fractions can be determined by difference.

Our test samples consisted of fine-grained Allende inclusions, hand-picked under a binocular microscope. These samples were crushed, ground in acetone, and sieved to pass through a  $53\mu$  screen. Mineral separates were characterized by X-ray diffraction using Debye-Scherrer powder cameras. An aliquot of each fraction was exposed to  $\text{CuK}\alpha$  X-rays for 12 hours. Densitometer tracings of the films were obtained on a Perkin-Elmer PDS Microdensitometer interfaced to a PDP 11 computer.

## Results

The results for sample CAI F2-5 are representative of the samples we have studied and are summarized in Table 1, including mineralogy, relative peak intensities, current settings, and weights for each of the four separated fractions. The mineralogy of the Allende inclusions consists of spinel, forsteritic olivine, grossular, and clinopyroxene (Ca-rich) as major phases, with minor amounts of anorthite and perovskite. Our separates typically have olivine and clinopyroxene concentrated in the highest magnetic fraction and spinel, grossular, perovskite, and anorthite concentrated in the lowest magnetic fraction. The extent to which separation of minerals has been achieved is evident from the changes in the spinel-

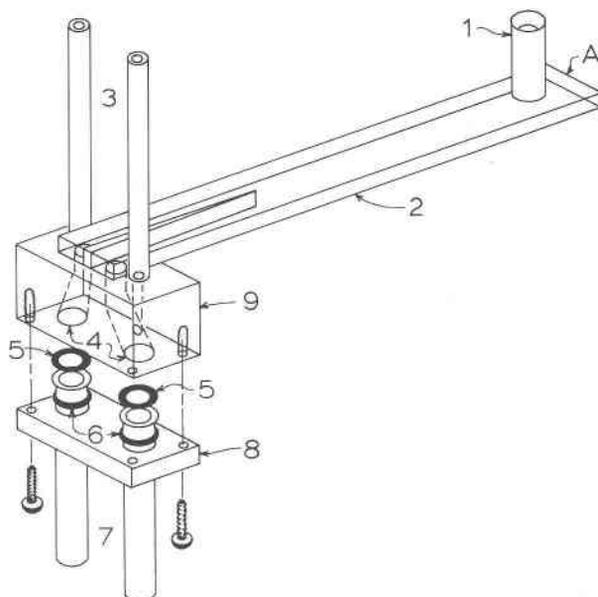


Fig. 1. The experimental device for obtaining mineral separates in a liquid medium (see text for explanation).

normalized intensities of the strongest X-ray line of each mineral (Table 1). Incomplete separation is apparent from these data, especially for olivine and spinel. Factors contributing to incomplete separation are: (1) Incomplete disaggregation of the fine-grained samples; inclusions of spinel in olivine are common and nearly impossible to separate. (2) Cohesion of mineral particles in the liquid. (3) Possible interference from small air bubbles adhering to the grains.

Recycling the sample material may improve the separation, but the percentage of unrecovered mate-

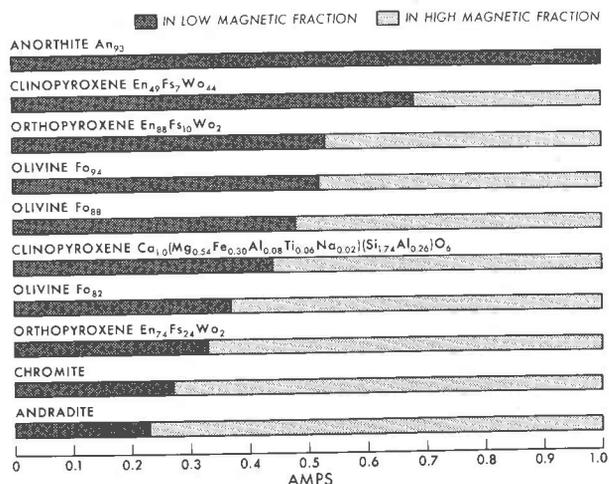


Fig. 2. Experimentally determined current settings for separation of pure mineral phases in distilled water.

rial is likely to be higher. We recovered 84 percent of the starting material for sample CAI F2-5 in three runs through the separator. The loss is primarily due to material remaining in suspension in the liquid.

To obtain more definitive data on the current settings (in amps) at which minerals may be separated, we determined the current settings at which pure mineral phases will leave the low magnetic fraction and enter the high magnetic fraction. The results are shown in Figure 2 and are comparable to those published by Rosenblum (1958) for the normal separation procedure with dry grains. Data for the Allende sample CAI F2-5 (Table 1) are generally consistent with the current settings determined for olivine, clinopyroxene, and anorthite (Fig. 2).

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