MÖSSBAUER SPECTROSCOPIC STUDY OF FIRED SHENQIU METEORITES*

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ABSTRACT

The Shenqiu meteorite was investigated by Mössbauer spectroscopy at room temperature, atomic absorption, X–ray diffraction and scanning electron microscopy. In order to determine fired conditions of the meteorite which occurred during the meteorite fall, Shenqiu meteorite samples were fired in an oxidizing atmosphere and a reducing atmosphere at temperatures up to 1300 °C, respectively. These samples also were fired at 800, 1000 and 1200 °C respectively for different time (up to 24 h).

Keywords: Mössbauer spectroscopy Fired meteorites Phase changes

1 INTRODUCTION

The main sources of information on the cosmo–chemistry of the solar system are meteorites and lunar samples. Meteorites have for a long time interested geochemists in their attempt to reconstruct the early history of the solar system. The most important question regarding these materials is to which thermal processes they have been subjected. Chondrites, by far the most abundant type of meteorites, are characterized by the presence of chondrules, generally spherical bodies up to a few millimeters in diameter, which are composed of silicate, metal and sulphide phases. Mössbauer spectra will be useful in identifying the iron–containing minerals using the fingerprint technique.

2 EXPERIMENTAL PROCEDURE

The samples which were extracted from the Shenqiu (in Henan Province, China) meteorite (14.25 kg), were fired in an oxidizing atmosphere and a reducing atmosphere at temperatures up to 1300 °C. The firing time was 2 h for an oxidizing atmosphere and 15 min for a reducing atmosphere, respectively. The samples were also fired at 800,1000,1200 °C in an oxidizing atmosphere for different time (up to 24 h in steps

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of 6h). The fired samples were quenched extremely rapidly from the highest temperature, so that the final site populations would directly reflect the temperature of formation. A Mössbauer spectrum was taken after each temperature step at room temperature using powder absorbers of about 20 mg/cm^2 and a source of ^{57}Co in palladium. The spectra were also recorded at room temperature for samples from the surface and the interior of the untreated Shenqiu meteorite. The spectra were least–square fitted with a superposition of Lorentzian lines. In order to obtain detailed information, other techniques including X–ray diffraction and scanning electron microscopy, were applied in conjunction with Mössbauer spectroscopy. The results obtained by these techniques were partly listed in this report.

3 RESULTS AND DISCUSSION

3.1 The untreated meteorite

The spectrum of the interior untreated meteorite is shown in Fig.1, and Mössbauer parameters of untreated samples is listed in Table 1. The two lines at 0.01 and 2.23 mm/s are due to Fe^{2+} in the orthopyroxene M2 position, the two lines at –0.34 and 2.54 mm/s are due to Fe^{2+} in olivine[1]. The lines at high velocities are due to troilite (FeS) and kamacite (Fe–Ni alloy). The remainders of meteorite after grinding (difficult to separate mechanically) mainly consist of Fe–Ni alloys.

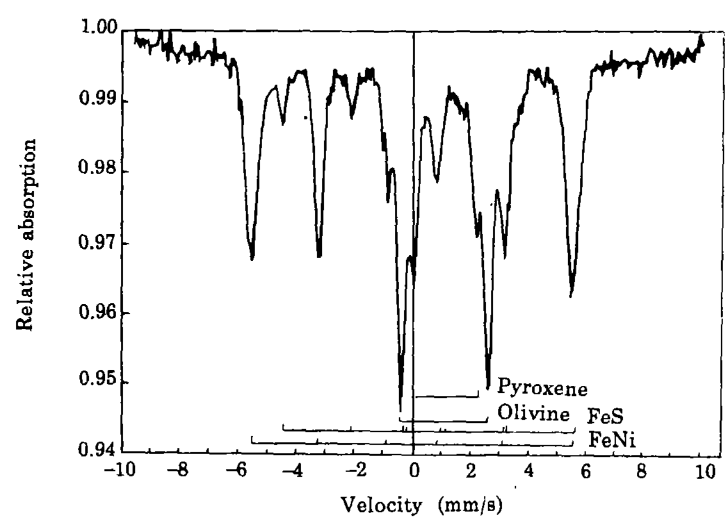

Fig.1 Mössbauer spectrum of the interior of untreated meteorite

The changes which occurred during the meteorite fall and terrestrial weathering result in different parameters of the surface samples. By inspection, it has been seen that the ratio of the olivine area to the pyroxene area is reasonably constant i.e.

$$\text{Area (olivine)}/\text{Area (pyroxene)} = 1.64 \pm 0.04$$

From the Mössbauer spectrum of chemically analysed (using 10% HCl) sample, it is found that no Fe^{2+} is in the M1 orthopyroxene position (i.e. Fe^{2+} preferred the M2 position over the M1 position). According to Sprenkel-Segel, the Shenqiu meteorite can be assigned to equilibrated chondrite[2].

Table 1

Room temperature Mössbauer parameters of untreated samples

		SA	SB	IA	IB	RM
Olivine	IS (mm/s)*	1.77	1.14	1.16	1.15	1.31
	QS (mm/s)	2.95	2.94	2.94	2.98	3.20
	Relative area (%)	32	33	33	24	<5
Pyroxene	IS (mm/s)	1.75	1.11	1.15	1.12	1.13
	QS (mm/s)	2.22	2.20	2.26	2.21	2.26
	Relative area (%)	19	20	20	15	<3
Troilite	IS (mm/s)	1.01	0.73	0.71	0.67	
	QS (mm/s)	-0.12	-0.12	-0.15	-0.17	
	H ($\times 10^4$ A/m)	2.51	2.50	2.49	2.49	
	Relative area (%)	21	18	22	13	
Kamacite	IS (mm/s)	0.31	0.01	0.00	0.00	0.02
	QS (mm/s)	-0.01	0.00	0.01	0.02	0.00
	H ($\times 10^4$ A/m)	2.83	2.67	2.71	2.71	2.68
	Relative area (%)	28	29	25	48	92

* IS vs α -Fe SA—Surface A SB—Surface B IA—Interior (1cm) IB—Interior (2cm)
RM—Remainders after grinding

3.2 Firing in a reducing atmosphere

Table 2

Mössbauer areas (% of total) of fired meteorites in a reducing atmosphere

Temperature (°C)	600	800	900	1000	1200	1300
Kamacite	34	38	42	45	52	53
Troilite	23	22	20	18	20	23
Olivine	29	28	27	26	18	16
Pyroxene	14	12	11	11	10	8

Shenqiu meteorite samples are fired in a reducing atmosphere for 15 min at temperatures from 600 to 1300 °C in steps of 100 to 200 °C. Their Mössbauer spectra generally consist of two doublets (olivine and pyroxene) and two six-line components indicating the presence of troilite and kamacite. The different spectral contributions of these fired meteorites are listed in Table 2. It is shown that both the olivine and the pyroxene content decreases for the whole all firing temperature range. The troilite component is nearly constant, but the kamacite component increases from 600 to 1300 °C.

3.3 Firing in an oxidizing atmosphere

Shenqiu meteorite samples are fired in an oxidizing atmosphere for 2 h at temperatures up to 1300 °C. The Mössbauer spectrum at 400 °C consists of two doublets and three sextets. The new six-line component indicates the presence of hematite. It is found that at 800 °C another six-line component appeared, which is proved to be maghematite (γ -Fe_2O_3) by X-ray diffraction patterns. The spectral contributions are listed in Table 3, it is shown that the hematite component increases from 400 to 1000 °C, then decreases and almost disappears at 1300 °C. The components of olivine and pyroxene decrease as the firing temperature increases. The components of troilite and kamacite also decrease as the firing temperature increases, and are almost disappeared at 900 °C. The γ -Fe_2O_3 component appears at 800 °C, and increases up to 1200 °C. A Fe^{3+} component is found at 1300 °C. When the disordering starts, a temperature above the "equilibrium" temperature has been reached. Hence, it is possible to determine the "equilibrium" temperature from our firing results.

Table 3

Mössbauer areas (% of total) of fired meteorites in an oxidizing atmosphere for 2h

Temperature (°C)	400	500	600	700	800	900	1000	1100	1200	1300
α -Fe_2O_3	<5	20	28	36	44	65	73	51	<5	–
γ -Fe_2O_3	–	–	–	–	<5	10	15	41	87	75
Kamacite	35	25	22	19	14	<3	–	–	–	–
Troilite	16	14	12	11	8	<2	–	–	–	–
Olivine	28	26	24	22	19	12	8			
Olivine + pyroxene								<8	<8	<3
Pyroxene	16	15	14	12	10	8	4			
Fe^{3+}	–	–	–	–	–	–	–	–	–	22

3.4 Firing at 800 °C in an oxidizing atmosphere

Shenqiu meteorite samples are fired at 800 °C in an oxidizing atmosphere up to 24 h in steps of 4 h or 6 h. The Mössbauer spectrum after 2 h indicates the presence of hematite, maghematite, troilite, kamacite, olivine and pyroxene. The spectral contributions are listed in Table 4. They show that the components of hematite and maghematite increase up to 24h, and that the components of troilite and kamacite are almost disappeared after 12 h. The components of olivine and pyroxene decrease after 2 h.

3.5 Firing at 1000 °C in an oxidizing atmosphere

Shenqiu meteorite samples are fired at 1000 °C in an oxidizing atmosphere up to 24 h in steps of 4 h or 6 h. The Mössbauer spectrum after 2 h indicates the presence of hematite, maghematite, olivine and pyroxene. The spectral contributions are listed in Table 4, they show that the hematite component decreases and the maghematite component increases up to 24 h respectively. The components of olivine and pyroxene decrease after 2 h.

3.6 Firing at 1200 °C in an oxidizing atmosphere

Shenqiu meteorite samples are fired at 1200 °C in an oxidizing atmosphere up to 24 h in steps of 4 h or 6 h. The Mössbauer spectrum after 2 h indicates the presence of hematite, maghematite, troilite, kamacite, olivine and pyroxene. The spectral contributions are listed in Table 3. They show that the component of maghematite

Table 4

Mössbauer areas (% of total) of fired meteorites at 800,1000, 1200 °C for different time

	α -Fe_2O_3	γ -Fe_2O_3	Kamacite	Troilite	Olivine	Pyroxene
Time (h)			800 °C			
2	44	5	14	8	19	10
6	52	6	10	8	16	8
12	72	7	–	–	14	7
18	75	8	–	–	11	6
24	80	8	–	–	8	4
Time (h)			1000 °C			
2	73	15	–	–	8	4
6	65	23	–	–	8	4
12	61	30	–	–	6	3
18	56	38	–	–	(6)*	
24	57	39	–	–	(4)	
Time (h)			1200 °C			
2	<5	87	–	–	(8)	
6	–	93	–	–	(7)	
12	–	95	–	–	(5)	
18	–	97	–	–	(3)	
24	–	100	–	–	(–)	

* ( )—Total area of olivine and pyroxene

increases up to 24 h. The component of hematite is almost disappeared after 6 h. The components of olivine and pyroxene decrease.

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