

# NEUTRON DIFFRACTION STUDY OF $\text{FeCr}_2\text{Se}_4$

KENGO ADACHI, KIYOO SATO and KIYOSHI KOJIMA\*

*Faculty of Engineering, Nagoya University, Nagaya*

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## Abstract

The atomic position and the antiferromagnetic spin structure of  $\text{FeCr}_2\text{Se}_4$ , which has the monoclinic (pseudo hexagonal) structure ( $A=6.23 \text{ \AA}$ ,  $B=3.62 \text{ \AA}$ ,  $C=11.79 \text{ \AA}$  and  $\beta=90^\circ 49'$  at  $293^\circ\text{K}$ ), were determined by means of neutron diffraction. Fe atoms are situated in the layer lattice with ordered vacant sites, while Cr atoms are situated in the layer without vacant sites. The magnetic unit cell is found to be  $2A \times B \times 2C$ . The spin structure of the spins of Fe and Cr atoms was determined as [C]-type defined by Bertaut *et al.*, and the spins orient along near  $[\bar{1}01]$ . The observed magnetic moments are  $3.1 \pm 0.3 \mu_B$  for Cr and  $4.2 \pm 0.3 \mu_B$  for Fe, which correspond to the chromic and the ferrous ion respectively. Some discussions on ionic and magnetic properties of  $\text{MM}'_2\text{Se}_4$  are given.

## § 1 Introduction

In the recent paper<sup>1)</sup>, we have reported the magnetic properties and the phase diagram of the system  $(\text{Fe}_{1-x}\text{Cr}_x)_3\text{Se}_4$  for  $0 \leq x \leq 1$ . From the measurement of the magnetic susceptibility, it has been made clear that the metallic atoms are constituted from di- and tri-valent ions. For the compound,  $\text{FeCr}_2\text{Se}_4$ , corresponding to  $x=2/3$ , a typical antiferromagnetic behavior with the Néel point of  $218^\circ\text{K}$  and the paramagnetic Curie point of  $-650^\circ\text{K}$  have been found as described in reference (1). The observed Curie Weiss constant per mole is determined to be  $C_M=7.0 \pm 0.2$ . This corresponds to the ionic configuration of  $\text{Fe}^{2+}\text{Cr}_2^{3+}\text{Se}_4$ , where the constant is calculated by the formula  $C_M=C(\text{Fe}^{2+})+2C(\text{Cr}^{3+})=6.75$  per mole assuming  $g=2$ .

$\text{FeCr}_2\text{Se}_4$  has a monoclinic structure and belongs to the space group  $C_{2h}^3 - I2/m$  ( $\text{Fe}_3\text{Se}_4$  - type)<sup>2)</sup>, which is regarded as a non-stoichiometric pseudo NiAs structure. The lattice is composed of the metallic layers normal to the  $c$ -axis and the layers with vacancies and without vacancies are stacked successively in alternative manner. In consequence, in order to determine the magnetic structure of  $\text{FeCr}_2\text{Se}_4$ , first of all, it is necessary to know the atomic positions of Cr and Fe in relation to the vacant sites in this crystal. Recently, Andron and Bertaut<sup>3)</sup> have studied the atomic ordering as well as the spin structure for  $\text{NiCr}_2\text{S}_4$  by neutron diffraction, and they have concluded that the Ni atoms are in the layer with vacancies ( $2(c)$ -site), while the Cr atoms are in that without vacancies ( $4(i)$ -site). They have also determined the spin structure and the magnetic moments for each atom, *i.e.*  $2 \mu_B$  for  $\text{Ni}^{2+}$  and  $3 \mu_B$  for  $\text{Cr}^{3+}$  with the moment re-

\* Present address: Matsushita Electric Industrial Co., Ltd., Kadoma, Osaka.

duction of 30%.

For the same purpose mentioned above, the atomic ordering, the spin structure and the magnetic moments, viz. the electronic configuration, of Fe and Cr atoms will be determined by neutron diffraction measurements. The obtained results will be discussed in comparison with the other compounds  $MM'_2Se_4$ .

## § 2 Experimental Results

### 1. Determination of atomic positions

#### a) Sample preparation and X-ray diffraction

Powdered sample  $FeCr_2Se_4$  was prepared in evacuated dual silica ampouls by the following procedure making use of Fe (99.99%), Cr (99.99%) and Se (99.999%). The weighted composite materials were set at 400°C for one day, at 500 to 600°C for 3 days, then cooled to room temperature, and crushed and mixed in argon atmosphere in order to avoid oxidation. The mixture was, then, heated at 800 to 900°C for 3 days, 1000 to 1050°C for 3 days, then cooled slowly to room temperature. The powdered sample with 100 to 200 mesh was prepared for the diffraction experiments.

$Fe_3Se_4$  type structure was confirmed by X-ray diffraction, and the lattice parameters were found as  $A (\sim\sqrt{3}a) = 6.23 \text{ \AA}$ ,  $B (\sim a) = 3.62 \text{ \AA}$ ,  $C (\sim 2c) = 11.79 \text{ \AA}$ , and  $\beta = 90^\circ 49'$  ( $a$  and  $c$  are those for the NiAs structure), which agree with the result obtained in ref. (2). From the intensity analysis, there was not observed any distinct preferred orientation for the powdered sample.

#### b) Neutron diffraction above Néel temperature

In order to determine the atomic positions of Cr and Fe in the crystal, the

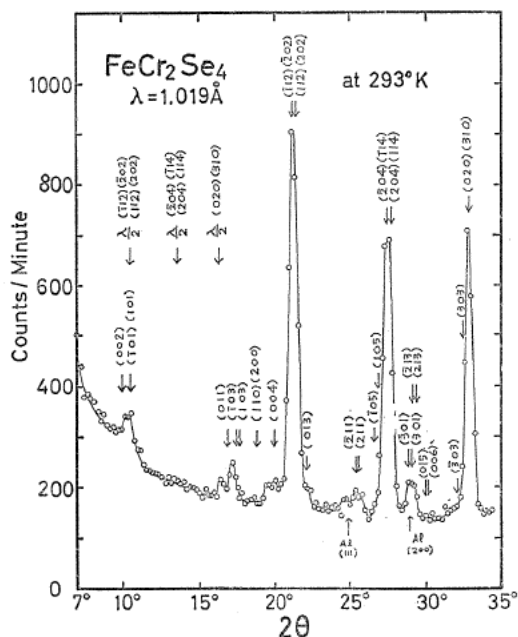


FIG. 1. Neutron diffraction pattern of  $FeCr_2Se_4$  at 293°K.

neutron diffraction at room temperature ( $T_N=218^\circ\text{K}$ )<sup>1)</sup> was carried out. Because of the difference of nuclear coherent scattering amplitudes for Cr ( $0.35 \times 10^{-12}$  cm) and Fe ( $0.96 \times 10^{-12}$  cm), the position can be determined easily. In Fig. 1, the diffraction pattern at  $293^\circ\text{K}$  is shown, where the neutron wave length of  $\lambda=1.019 \text{ \AA}$  has been used. All the diffraction lines can be explained by nuclear indices ( $hkl$ ) with the lattice parameters indicated above. The observed diffraction intensities were compared with the following five possible models of atomic arrangement which are illustrated in Fig. 2. In the figure, only the metallic sites of the chemical unit cell are shown, where the sublattices,  $\alpha_1$  and  $\alpha_2$  ( $2(c)$ -site) are in the layer with ordered vacant sites, while,  $\beta_1$  and  $\beta_2$  ( $2(i)$ -site) are in the layer without vacancies.

- Model (1), all the lattice points are randomly occupied by Fe and Cr;  
 Model (2), the  $\alpha_1$  and  $\alpha_2$  are occupied by Fe only, while the  $\beta_1$  and  $\beta_2$  are occupied by Cr;  
 Model (3), the  $\alpha_1$  and  $\alpha_2$  are occupied by Cr only, while the  $\beta_1$  and  $\beta_2$  are occupied by Fe and extra Cr at random;  
 Model (4), the  $\alpha_1$  and  $\alpha_2$  are occupied by Cr only, while, for the  $\beta_1$  and  $\beta_2$  sites, just above and below the vacant sites are occupied by Cr and Fe respectively;  
 Model (5), the  $\alpha_1$ ,  $\alpha_2$  and  $\beta_2$  are occupied by Cr only, while  $\beta_1$  are occupied by Fe only.

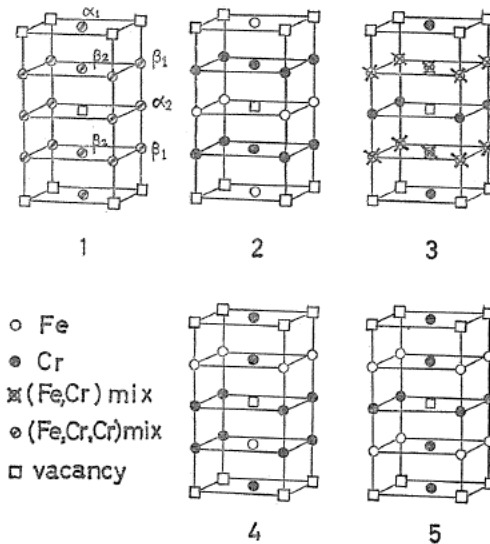


FIG. 2. Possible five models for the atomic arrangement of Fe and Cr atoms.

It is noted for Model (5) that a new superlattice reflection will be found, since a different extinction rule is applied. The calculated intensities for each model and the observed ones are shown in Table I together with the reliable factor  $R$ . In the calculation of diffraction intensity, we have neglected the small amount of atomic displacements of the metal and selenium atoms and assumed

TABLE I. The observed and calculated nuclear intensities of neutron diffraction at 293°K (above Néel point).  $I_{\text{cal}}$ 's are due to the calculation for five models of atomic arrangement (Fig. 2), and  $R$  is the reliable factor

$hkl$	$I_{\text{cal.}}$ for each model										$I_{\text{obs.}}$
	(1)		(2)		(3)		(4)		(5)		
	$I$	$\Sigma I$	$I$	$\Sigma I$	$I$	$\Sigma I$	$I$	$\Sigma I$	$I$	$\Sigma I$	
002	90		17		256		246		245		462
$\bar{1}01$	80	248	219	451	31	318	115	473	30	304	
101	78		215		31		112		29		
011	62	120	136	296	24	46	90	173	23	44	275
$\bar{1}03$	29		81		11		42		11		
103	29		79		11		41		10		
110	3	4	3	4	3	4	3	4	3	4	0
200	1		1		1		1		1		
004	275	275	255	255	265	265	250	250	254	254	277
$\bar{2}02$	882	3900	498	3521	1043	3974	987	3760	1000	3807	3368
$\bar{1}12$	857		1370		585		553		560		
112	1742		983		2060		1949		1973		
202	419		670		286		271		274		
013	37	37	103	103	15	15	54	54	14	14	121
$\bar{2}11$	29	57	78	156	11	22	41	82	10	20	235
211	28		78		11		41		10		
$\bar{1}05$	13	2884	36	2715	5	2754	19	2634	5	2638	2563
105	13		35		5		19		4		
$\bar{2}04$	482		446		463		438		444		
$\bar{1}14$	960		888		922		872		883		
114	947		876		909		860		871		
204	469		434		450		426		431		
$\bar{3}01$	11	66	31	183	4	25	16	95	4	24	390
301	11		31		4		16		4		
$\bar{2}13$	22		61		9		32		8		
213	22		60		8		31		8		
015	21	31	57	85	8	303	30	309	8	291	0
006	10		28		295		279		283		
$\bar{3}03$	9	2376	25	2232	4	2273	13	2169	3	2176	2308
303	9		25		4		13		3		
020	789		730		758		717		726		
310	1569		1452		1507		1426		1444		
					$\Sigma I_{\text{super}}$		419				*
$R(\%)$	19.13		8.28		22.08		15.70		24.60		

\* Any superreflections corresponding to Model (5) can not be observed.

the perfect ordering of vacant site. So, it is considered that the  $R$ -factors obtained here may be overestimated. From the table, the Model (2) with  $R=8.28\%$  is the most reliable atomic arrangement. Thus, it is concluded that in  $\text{FeCr}_2\text{Se}_4$ , the layers with vacant sites are occupied by Fe only, while those without vacant site are occupied by Cr, which corresponds to the same situation of atomic arrangement for  $\text{NiCr}_2\text{S}_4$ .

## 2. Determination of spin structure

Considering the atomic arrangement obtained above, the spin structure below the Néel temperature is determined. The diffraction pattern at 78°K is shown in Fig. 3. Several distinct magnetic reflections are observed and the antiferromagnetic unit cell is determined to be  $2A \times B \times 2C$ , where  $A'=2A=12.40 \text{ \AA}$ ,  $B'=$

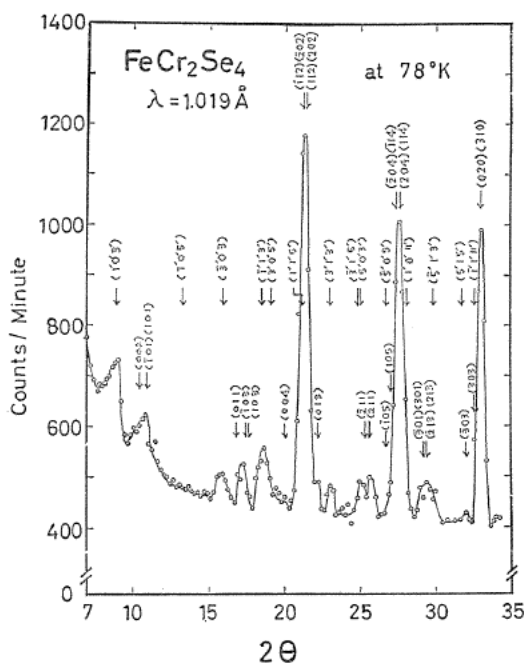


FIG. 3. Neutron diffraction pattern of  $\text{FeCr}_2\text{Se}_4$  at  $78^\circ\text{K}$ :  $(hkl)$  is the indices of nuclear reflections;  $(h'k'l')$  is those of magnetic reflections, where the indices are indicated by magnetic unit cell  $2A \times B \times 2C$ .

$B=3.61 \text{ \AA}$ ,  $C'=2C=23.48 \text{ \AA}$  and  $\beta=90^\circ 49'$  are given at  $78^\circ\text{K}$ . Hereafter, the index of magnetic reflections is written by  $(h'k'l')$  for the magnetic cell.

According to the classification of the spin structures reported by Bertaut *et al.*<sup>4)</sup> for  $\text{Cr}_3\text{X}_4$  ( $X=\text{S}, \text{Se}$  and  $\text{Te}$ ), the four antiferromagnetic models\* [A], [B], [C] and [D] can be applied to our results.

The comparison with observed and calculated reflection angles for these models is presented in Table II. As shown in the table, the observed reflection angles agree better with the calculated ones for the models [C] and [D] rather than those for [A] and [B].

Now, let us determine the magnetic structure, the spin direction and the moment length from the observed intensities.

It is noted that the magnetic reflection  $(\bar{1}'0'5')$  has not been observed within errors as seen in Fig. 3. Consequently, this result requires the antiferromagnetic

\* The extinction rule for all the models is given by

$$h' \text{ or } l' = \text{even,}$$

and the condition of the appearance of reflection is,

$$h'+l' = \begin{cases} 4n+2, & k = \text{even} \\ 4n, & k = \text{odd} \end{cases} \text{ for [A] and [B],}$$

$$h'+l' = \begin{cases} 4n, & k = \text{even} \\ 4n+2, & k = \text{odd} \end{cases} \text{ for [C] and [D],}$$

where  $n=0, \pm 1, \pm 2, \pm 3, \dots$

TABLE II. The observed and calculated magnetic reflection angles for the  $\text{FeCr}_2\text{Se}_4$  at  $78^\circ\text{K}$ 

$h' k' l'$	A, B		$h' k' l'$	C, D		$2\theta_{\text{obs}}$
	$2\theta_{\text{cal}}$	$\Delta 2\theta^*$		$2\theta_{\text{cal}}$	$\Delta 2\theta^*$	
$\bar{1}' 0' 3'$	8.76	0.14	$1' 0' 3'$	8.90	0	8.90
$3' 0' 3'$	16.14	0.24	$\bar{3}' 0' 3'$	15.94	0.04	15.9
$1' 1' 3'$	(18.60)	0.05	$\bar{1}' 1' 3'$	(18.54)	0.01	18.7
$\bar{3}' 0' 5'$	18.65** (18.76)		$3' 0' 5'$	18.71** (19.04)		
$3' 1' 3'$	22.86	0.14	$3' 1' 3'$	23.00	0	23.0

$$* \Delta 2\theta = |(2\theta)_{\text{cal}} - (2\theta)_{\text{obs}}|$$

\*\* Since in observed pattern these two reflections are overlapped (single peak), the  $2\theta_{\text{cal}}$  was obtained basis on the weighted average of the calculated intensity as shown in Table III.

spins of Fe and Cr atoms to lie nearly in the normal direction to the  $(\bar{1}' 0' 5')$  plane. This direction is close to the  $[\bar{1} 0 1]$  direction for the original lattice. Then, making use of the  $q$ -values for  $(h' k' l')$  reflections of each model, the spin structure as well as the magnetic moments per Fe and Cr atom is estimated. Here, the magnetic form factor of  $\text{Cr}^{3+}(S=3/2)$  for  $\text{Cr}_2\text{O}_3$  and  $\text{CrSb}^{5)}$  and that of  $\text{Fe}^{2+}(S=2)$  for  $\text{KFeF}_6^{6)}$  have been used, where the influence of temperature factor of the nuclear reflections is neglected for below and above the Néel point. The calculated and observed intensities of magnetic reflections are given in Table III for each model: [A], [B], [C] and [D]. As shown in the table, since the models, [B] and [D] can not explain the observed magnetic intensities for  $(\bar{1}' 0' 3')$  or  $(1' 0' 3')$ ;  $(3' 0' 3')$  or  $(\bar{3}' 0' 3')$ ;  $(1' 1' 3')$  or  $(\bar{1}' 1' 3')$ ;  $(\bar{3}' 0' 5')$  or  $(3' 0' 5')$  and  $(\bar{1}' 1' 5')$  or  $(1' 1' 5')$  respectively, the models, [A] and [C] fit better than [B] and [D], and further the reliable factor of  $R=18\%$  for [C] is smaller than that of [A] ( $R=20\%$ ).

On the other hand, as has been shown in Table II, the models, [C] and [D] were better as for the reflection angles. Consequently, our experimental result can be well explained by model [C]. Thus, it is possible to conclude that  $\text{FeCr}_2\text{Se}_4$  has [C]-type antiferromagnetic structure with the most probable spin direction of the polar angle  $22^\circ$  in the  $A'-C'$  plane, which is shown in Fig. 4. In this structure, the respective plus and minus spins of Fe and Cr lie in the  $(\bar{1}' 0' 1')$  plane, and the propagation vector of antiferromagnetic arrangement is given as  $[\bar{1}/2' 0' \bar{1}/2']$  direction, *i.e.*  $\square \text{Cr}^{3+}(\uparrow) \text{Fe}^{2+}(\downarrow) \text{Cr}^{3+}(\uparrow) \square \text{Cr}^{3+}(\downarrow) \text{Fe}^{2+}(\uparrow) \text{Cr}^{3+}(\downarrow), \dots$ , along the direction ( $\square$  is vacant site).

The magnetic moments have been determined from the calculated and observed intensities in Table III, and the magnetic form factors cited above. The moments are estimated to be  $3.1 \pm 0.3 \mu_B$  per Cr and  $4.2 \pm 0.3 \mu_B$  per Fe, showing the ionic constitutions of  $\text{Cr}^{3+}$  and  $\text{Fe}^{2+}$  ions. Though the errors due to the some simplifications of the calculation, that is, the assumption of the perfect ordering of vacant site, neglect of the small displacement of atoms from the normal site in NiAs structure and the neglect of the temperature factor, can be considered, these

TABLE III. The observed and calculated magnetic intensities of  $\text{FeCr}_2\text{Se}_4$  where the magnetic form factors of  $\text{Cr}^{3+5}$  as well as  $\text{Fe}^{2+6}$  and the spin direction perpendicular to  $(1'0'5')$  plane for models [A] and [B], and to  $(\bar{1}'0'5')$  for model [C] and [D] are taken into account respectively

$h'k'l'$	$2\theta_{\text{cal}}$	A		B		$h'k'l'$	$2\theta_{\text{cal}}$	C		D		$I_{\text{obs}}$
		$I_A$	$\Sigma I_A$	$I_B$	$\Sigma I_B$			$I_C$	$\Sigma I_C$	$I_D$	$\Sigma I_D$	
$\bar{1}'0'3'$	8.76	892	892	0		$1'0'3'$	8.90	860	860	0		826
$1'0'5'$	13.40	0		0		$\bar{1}'0'5'$	13.26	0	0	0		0
$3'0'1'$	14.34	0		404	404	$3'0'1'$	14.44	0	0	401	401	
$3'0'3'$	16.14	130	130	0		$3'0'3'$	15.94	141	141	0		206
$\bar{1}'1'1'$	17.14	1	1	510	510	$1'1'1'$	17.16	1	1	509	509	
$\bar{1}'0'7'$	18.04	0		75	75	$1'0'7'$	18.20	0	0	74	74	
$1'1'3'$	18.60	311		0		$\bar{1}'1'3'$	18.54	316		0		632
$3'0'5'$	18.76	171	482	0		$3'0'5'$	19.04	162	478	0		
$\bar{1}'1'5'$	21.10	207	207	0		$1'1'5'$	21.16	204	204	0		260
$3'1'1'$	21.84	1	1	208	208	$3'1'1'$	21.80	0	0	211		
$3'0'7'$	22.74	0		10		$3'0'7'$	22.40	0	0	11		
$3'1'3'$	22.86	200	200	1	13	$\bar{1}'0'9'$	22.96	0	0	2	225	206
$1'0'9'$	23.10	0		2		$3'1'3'$	23.00	195	195	1		
$5'0'1'$	23.90	0		68		$5'0'1'$	23.84	0	0	70		
$1'1'7'$	24.54	0		71	139	$\bar{1}'1'7'$	24.40	0	0	73	143	
$5'0'3'$	24.80	75		0		$5'0'3'$	25.00	72		0		123
$3'1'5'$	25.16	78	153	0		$3'1'5'$	24.96	82	154	0		
$3'0'9'$	26.54	0		37	37	$5'0'5'$	26.74	25		0		
$5'0'5'$	27.04	23		0		$3'0'9'$	26.90	0	37	36	36	
$3'1'7'$	27.84	0	35	79		$1'0'11'$	28.06	12		12		105
$\bar{1}'0'11'$	27.96	12		0	126	$3'1'7'$	28.10	0		76	125	
$\bar{1}'1'9'$	28.30	0		47		$1'1'9'$	28.40	0		49		
$5'1'1'$	29.00	0		76		$5'1'1'$	29.06	0		76		
$5'0'7'$	29.40	0		35	111	$5'0'7'$	29.80	0		33	109	
$5'1'3'$	30.00	49	49	0		$5'1'3'$	29.84	70	70	0		60
$3'0'11'$	31.36	0		0		$3'0'11'$	30.96	0	0	0		
$5'1'5'$	31.46	54	54	0	16	$3'1'9'$	31.30	0	51	19	19	95
$3'1'9'$	31.60	0		16		$5'1'5'$	31.74	51		0		
$1'1'11'$	32.66	13	13	0		$\bar{1}'1'11'$	32.56	13	13	0		13

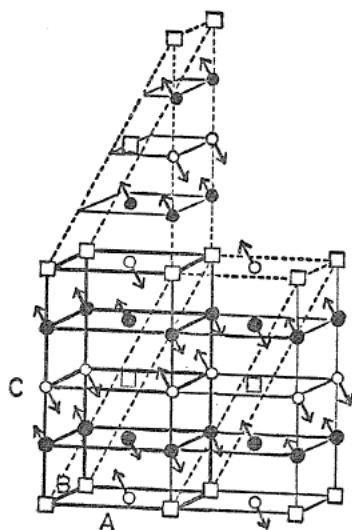


FIG. 4. The magnetic structure of  $\text{FeCr}_2\text{Se}_4$ :  $\circ$  is  $\text{Fe}^{2+}$  ion,  $\bullet$  is  $\text{Cr}^{3+}$  ion and  $\square$  is vacant site; the arrows indicate the spin direction nearly parallel to  $[\bar{1}01]$  direction with the spins  $3\mu_B$  for  $\text{Cr}^{3+}$  and  $4\mu_B$  for  $\text{Fe}^{2+}$ .

results agree well with those which have been obtained by our recent magnetic measurements in this substance<sup>1)</sup>.

### § 3 Discussion and Conclusion

Recently, so many compounds  $(MM'_2)X_4$  ( $X = \text{Se}$  and  $\text{S}$ ) with  $\text{Fe}_3\text{Se}_4$  type crystal structure have been found<sup>2)</sup>, and the electrical and magnetic properties have been studied for some compounds.

It is noted, however, from the magnetic and neutron diffraction studies, that the ionic constitution is not always applicable for the compounds containing some 3d-transition metals. For example,  $\text{Ni}_3\text{Se}_4$ <sup>3)</sup> (extrapolated to  $x=1$  for  $(\text{Fe}_{1-x}\text{Ni}_x)_3\text{Se}_4$ ) and  $\text{Co}_3\text{Se}_4$ <sup>4)</sup> have temperature independent susceptibilities suggesting that they have no localized magnetic moments. On the other hand, from the recent neutron diffraction studies on the antiferromagnetic  $\text{NiCr}_2\text{S}_4$ <sup>5)</sup> and the ferrimagnetic  $\text{Fe}_3\text{Se}_4$ <sup>3)</sup> the considerable reduction of the magnetic moment has been found, that is, 30% reduction of the moments for  $2\mu_B(\text{Ni}^{2+})$  and  $3\mu_B(\text{Cr}^{3+})$  in  $\text{NiCr}_2\text{S}_4$ , and 60% for  $5\mu_B(\text{Fe}^{3+})$  and 20% for  $4\mu_B(\text{Fe}^{2+})$  in  $\text{Fe}_3\text{Se}_4$ <sup>\*</sup>. Also, in the recent magnetic investigation for the antiferromagnetic substances<sup>10)</sup>  $\text{FeM}'_2\text{X}_4$  ( $M' = \text{Ti}, \text{V}$  and  $X = \text{S}, \text{Se}$ ), it has been concluded that Ti and V have not localized moment but di-valent  $\text{Fe}^{2+}$  ( $4\mu_B$ ) has the moment with about 15% of reduction by means of the susceptibility measurements.

In  $\text{FeCr}_2\text{Se}_4$ , however, the considerable reduction of magnetic moment can not be observed by the present and the previous studies on neutron diffraction and magnetic measurement<sup>1)</sup>. So, we can conclude that the electronic constitution of this substance is given to be  $(\text{Fe}^{2+}\text{Cr}^{3+}\square)_3\text{Se}_4$ , in which Hunt's rule is satisfied for the metallic ions. So many problems for the group of compounds  $\text{MM}'_2\text{X}_4$ , such as the origin of exchange interaction (spin structure), the mechanisms of moment reduction and delocalization, and the electronic structure, are remained. In order to give the solutions to the problems, it is necessary to do magnetic and neutron diffraction measurements for the other compounds  $\text{MM}'_2\text{Se}_4$  and to measure the conduction properties for the single crystal.

In conclusion, the following results have been determined by neutron diffraction of  $\text{FeCr}_2\text{Se}_4$ .

(1) The atomic positions of Fe and Cr in the crystal were determined; Fe atoms are in the layer with vacant sites (2(c)-site) and Cr atoms in that without vacancies (4(i)-site).

(2) The magnetic unit cell is given to be  $2A \times B \times 2C$  and the spin structure is determined as [C]-type defined by Bertaut *et al.*<sup>4)</sup> and the spins orient nearly  $[\bar{1}01]$  direction.

(3) The magnetic moments are determined as,  $3\mu_B$  for  $\text{Cr}^{3+}$  ion and  $4\mu_B$  for  $\text{Fe}^{2+}$  ion, in accordance with the result of magnetic susceptibility<sup>1)</sup>. In the substance  $\text{FeCr}_2\text{Se}_4$ , the ionic constitution is profitable.

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\* In our recent study<sup>1)9)</sup> on the high temperature magnetic susceptibility of  $\text{Fe}_3\text{Se}_4$ , however, the ionic constitution of di- and tri-valent irons ( $\text{Fe}^{2+} + \text{Fe}_2^{3+}\text{Se}_4^{2-}$ ) has been supported.



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#### *Note added in proof:*

One of the author heard that neutron diffraction study of  $\text{FeCr}_2\text{Se}_4$  has been reported recently by Bertaut's group at Grenoble (France), and nearly the same results were obtained.