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| Title | Fundamental studies on zinc ferrite |
| Author(s) | Hirakoso, Keinosuke; Watanabe, katsuya; Baba, Riichi et al. |
| Citation | Memoirs of the Faculty of Engineering, Hokkaido University, 10(1), 39-57 |
| Issue Date | 1955-09-30 |
| Doc URL | https://hdl.handle.net/2115/37792 |
| Type | departmental bulletin paper |
| File Information | 10(1)_39-58.pdf |

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# Fundamental Studies on Zinc Ferrite

By

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(Received June 30, 1955)

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**Abstract**

In connection with the hydrometallurgy of zinc the problem of zinc ferrite has great importance for the improvement of leaching extraction of zinc. It has been mentioned by many authors, but further details have not been reported.

In this research some results were obtained from leaching tests with various

strengths of sulphuric acid for the roasted samples at various temperatures. The measurement of intensity of saturation magnetization was carried out for the samples at various temperatures and at various combination ratios of $Fe_2O_3$/ZnO. In these experiments the maximum point of intensity of saturation magnetization was obtained from the sample whose ratio of $Fe_2O_3$/ZnO was 1.4. By the diffraction lines from the Norelco X-ray spectrometer it could be comfirmed that only a zinc ferrite is formed as a compound of ZnO and $Fe_2O_3$, i. e., $ZnO \cdot Fe_2O_3$. From the results of the measurement of lattice constant and the leaching test it was found that the zinc ferrite does not form solid solution with ZnO. The point of minimum lattice constant was found to correspond with the point of maximum intensity of saturation magnetization.

The solid solution corresponding to minimum lattice constant is considered to be a limited solution in the system of $ZnO \cdot Fe_2O_3$ and $Fe_2O_3$.

Concerning the deterioration of intensity of saturation magnetization in the range over the point of limited solid solution, the conclusion was reached that the deterioration of intensity of saturation magnetization is caused by the dilution of excessive $\alpha$-$Fe_2O_3$ and also by the formation of solid solution of $\gamma$-$Fe_2O_3$ in $ZnO \cdot Fe_2O_3$, having less solubility than that of the point of limited solid solution.

The relations among lattice constant, intensity of saturation magnetization and amount of dissolved $\gamma$-$Fe_2O_3$ are each described by linear functions.

## I. Introduction

It is well known that when zinc sulphide ore is roasted in oxidizing atmosphere at high temperature, zinc ferrite, hardly soluble in dilute sulphuric acid, is formed and the extraction of zinc is consequently impeded in the wet process.

In the Tainton process,[1] the roasted ore is separated by magnetic separator into two portions, non-magnetic (zinc oxide) and magnetic (zinc ferrite). To obtain still higher extraction in this process, the ferrite portion is dissolved in strong sulphuric acid until the strength of the acid is somewhat reduced and then neutralization is completed with the oxide portion which is free from zinc ferrite.

There has been considerable recent development of theories on magnetic properties of ferrite, so called ferrimagnetism.[2]

In respect to the zinc ferrite it is pointed out that the normal zinc ferrite, $ZnO \cdot Fe_2O_3$, is a normal spinel type and non-magnetic substance. The intensity of magnetization of zinc ferrite depends upon the formation of solid solution of $ZnO \cdot Fe_2O_3$ and $Fe_2O_3$. The slight

solubility of ZnO[3] and the greater solubility of $Fe_2O_3$ in $ZnO \cdot Fe_2O_3$ have been reported. Moreover it is recorded that $ZnO \cdot Fe_2O_3$ is formed even from 500°C[4] and the maximum intensity of magnetization is obtained in the composition of $2ZnO \cdot 3Fe_2O_3$.[5]

The purpose of this paper is to ascertain further details of these data on the zinc ferrite, such as the behaviour of its dissolution in various strengths of sulphuric acid, the effect of dissolved $\gamma$-$Fe_2O_3$ on the intensity of magnetization and lattice constant with special reference to the solubility of ZnO and $Fe_2O_3$ into $ZnO \cdot Fe_2O_3$.

## II. Experimental Procedure

### a. Preparation of Specimens

In this experiment pure zinc oxide on the market is used. Ferric oxide is prepared by calcining ferric hydroxide at about 700°C, precipitated from ferric sulphate solution by ammonia.

For the preparation of specimens, theoretical amount of zinc and ferric oxide is exactly weighed and well mixed in an agate mortar. This mixture is pressed in a cylinder (1 cm diameter) to form uniform-shaped tablets at the pressure of 6.4 tons per square cm.

The zinc blende from Ōe mine, Hokkaido, and pyrite from Osaruzawa mine, Akita prefecture, are used as sulphide ore samples. Pure crystals of these ores are picked out carefully and ground, mixed and pressed as the oxide specimens.

The details regarding these specimens are listed in Table 1.

### b. Methods of Leaching and Analysing

After heat treatment at given temperature, the sample is leached with various strengths of sulphuric acid (5%, 10% and 20%) at about 96°C for 30 min. The leaching temperature (96°C) is maintained by setting the sample beaker in a boiling water bath.

Determination of zinc and iron in the leached solution is carried out by the volumetric titration method.

Free ZnO in each sample is determined by leaching with ammoniacal ammonium chloride solution at room temperature for about 24 hours. The component of the samples are checked by chemical analysis.

### c. Measurement of Intensity of Saturation Magnetization

Some of these samples are examined as to their magnetic properties. The apparatus for measuring of intensity of saturation magnetiza-

TABLE 1.

| Specimens No. | Component $Fe_2O_3$/ZnO Mol. | Heat treatment |
|---|---|---|
| A—1 | 1 | 530°C |
| A—2 | " | 550°C |
| A—3 | " | 700°C |
| A—4 | " | 800°C 2 hours and cooled in air. |
| A—5 | " | 900°C |
| A—6 | " | 1000°C |
| A—7 | " | 1100°C |
| B—1 | ZnO | |
| B—2 | $Fe_2O_3$ | |
| B—3 | 1/3 | |
| B—4 | 1/2 | 1050°C, 30 min. and cooled in air. |
| B—5 | 2/3 | |
| B—6 | 1 | 1100°C, 2 hours and cooled in air; treatment repeated 3 times. |
| B—7 | 3/2 | |
| B—8 | 2 | 1050 °C, 30 min. and cooled in air. |
| B—9 | 3 | |
| | ($FeS_2$/ZnS Mol.) | |
| C—1 | 2 | |
| C—2 | 3 | 1150°C, 30 min. and cooled in air. |
| C—3 | 4 | |
| C—4 | 6 | |
| D—1 | 0.81 | |
| D—2 | 0.89 | |
| D—3 | 1.01 | 1100°C, 2 hours and cooled in air; treatment repeated 3 times. |
| D—4 | 1.57 | |
| D—5 | 1.94 | |
| D—6 | 3.00 | |
| E—1 | 2 | 900°C |
| E—2 | " | 950°C |
| E—3 | " | 1000°C |
| E—4 | " | 1100°C 2 hours and cooled in air. |
| E—5 | " | 1150°C |
| E—6 | " | 1250°C |
| F—1 | 1.02 | |
| F—2 | 1.03 | |
| F—3 | 1.1 | 1000°C, 3 hours and cooled in air; treatment repeated once. |
| F—4 | 1.2 | |

| | | |
|---|---|---|
| F—5 | 1.3 | |
| F—6 | 1.4 | |
| F—7 | 1.5 | |
| F—8 | 2 | |
| F—9 | 3 | |
| G—1 | 0.8 | 1100°C, 2 hours and cooled in air; treatment repeated 2 times. After the treatment the specimens are heated at 1150°C for 2 hours and cooled in the furnace to 1100°C and then annealed at the same temperature for 2 hours and cooled in air. |
| G—2 | 1.05 | |
| G—3 | 1.1 | |
| G—4 | 1.15 | |
| G—5 | 1.2 | |
| G—6 | 1.3 | |
| G—7 | 1.4 | |
| G—8 | 2 | |
| G—9 | 3 | |
| G—10 | 4 | |
| G—11 | 6 | |
| H—1 | 1 | 1150°C, 3 hours and cooled in air; treatment repeated once. |
| H—2 | 1.03 | |
| H—3 | 1.1 | |
| H—4 | 1.2 | |
| H—5 | 1.3 | |
| H—6 | 1.4 | |
| H—7 | 1.5 | |
| H—8 | 2 | |
| I—1 | 0.7 | 1400°C, 2 hours and cooled in water. |
| I—2 | " | " air. |
| I—3 | " | 1250°C, " water. |
| I—4 | " | " air. |
| I—5 | " | (I-1) is annealed at 1100°C for 2 hours and cooled in water. |
| I—6 | " | Same as (B-6). |

tion is shown in Fig. 1. The sample basket (weight of a sample is about 20 mg.) is hung in a magnetic field which is varied from 1500 to 2500 gausses; then magnetic balance is slanted by the intensity of magnetization of the sample. Balancing is made by the compensator, which consists of two solenoids, outside and inside. The current of the former solenoid is constantly fixed, and that of the latter is varried according to the magnetic property of the sample and the strength of magnetic field. The intensity of saturation magnetization of each

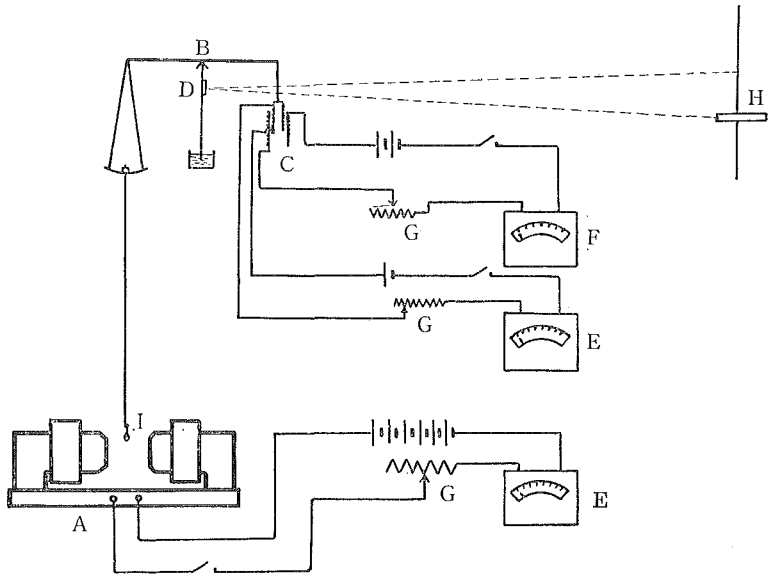


**Fig. 1** Measurement apparatus of magnetization.

A: Magnet B: Balance C: Compensator D: Mirror
E: Ammeter F: Milli-ammeter G: Variable Resistance
H: Scale and Telescope I: Sample basket

sample can be compared by plotting the current of inside solenoid to the current of magnet when the weight of a sample is constant.

d. Studies by Norelco X-ray Spectrometer

On the samples of $ZnO \cdot Fe_2O_3$ X-ray diffraction lines are detected. Based upon the lines with high angle region the determination of lattice constant of the sample is made using Fe $K_{\alpha 1}$ (1.93597 Å).

## III. Studies on Leaching

a. Formation of Zinc Ferrite and its Solubility in Acid

The specimens which have known composition of $ZnO \cdot Fe_2O_3$ are calcined for 2 hours from 530°C to 1100°C and quickly cooled in air when the calcining is finished (Series A).

When the calcined samples are leached with ammoniacal ammonium chloride solution, free ZnO which does not combine with $Fe_2O_3$ is determined. By deducting free ZnO from total, insoluble ZnO in the specimen is obtained as the ZnO combined with $Fe_2O_3$.

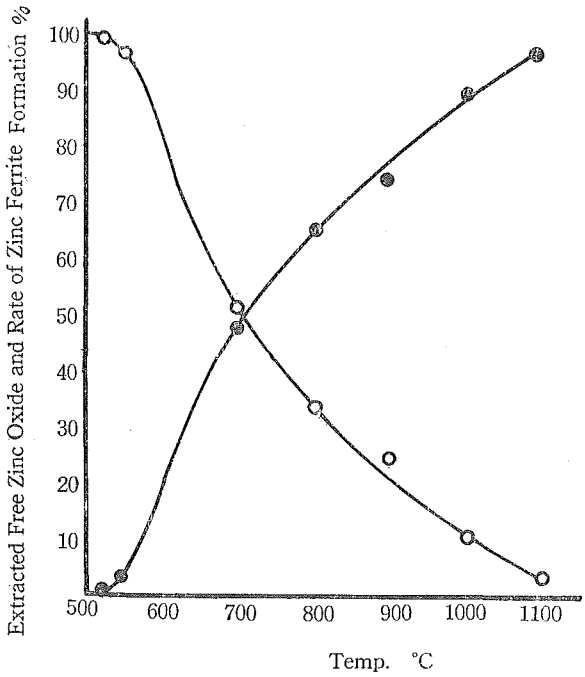


**Fig. 2** Curves of zinc ferrite formation.

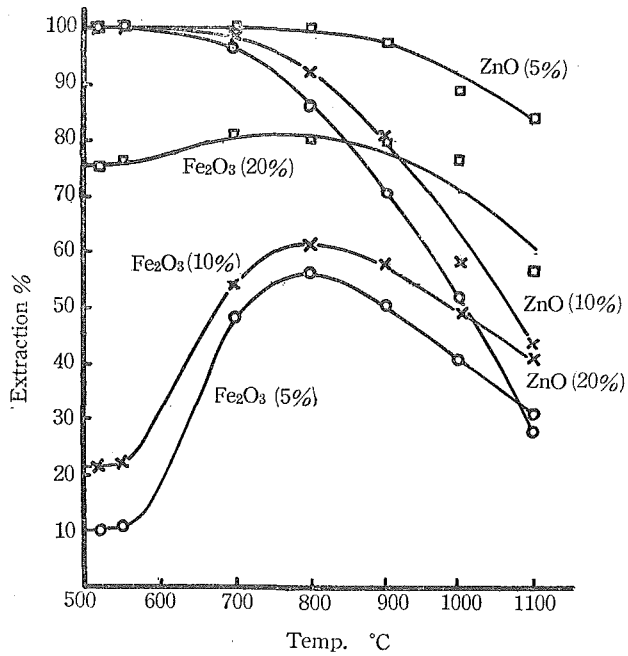


**Fig. 3** Acid extraction curves for calcined samples.

Fig. 2 shows that the formation of $ZnO \cdot Fe_2O_3$ increases as the calcining temperature rises.

On the acid leaching, as shown in Fig. 3 the higher the calcining temperature, the lower the extraction of zinc, and it is indubitable that zinc ferrite is scarcely attacked by dilute sulphuric acid. Solubility courve of iron differs from that of zinc, i.e., on the specimens heated from 530°C to 800°C the iron dissolved in acid increases as the temperature rises and over the temperature of 800°C it begins to decrease.

b. Leaching Test for Various Samples

In this section the specimens having various compositions (Series D) are used. It is expected that the solid reaction proceeds if $Fe_2O_3$ dissolves in $ZnO \cdot Fe_2O_3$, or ZnO dissolves in $ZnO \cdot Fe_2O_3$, or $ZnO \cdot Fe_2O_3$

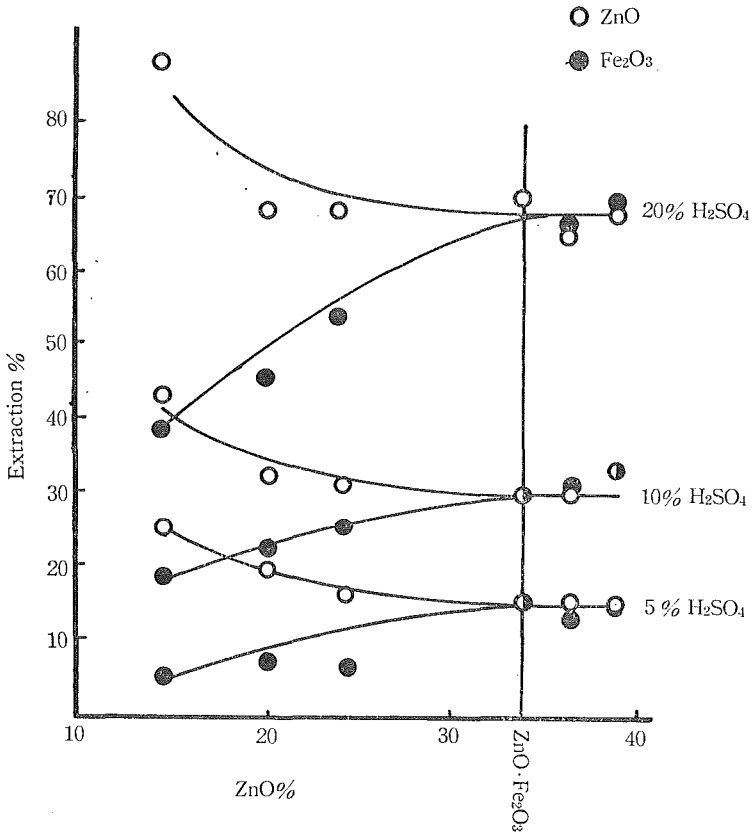


**Fig. 4** Relation between extraction and composition.

dissolves in $Fe_2O_3$, or $ZnO \cdot Fe_2O_3$ dissolves in ZnO.

Fig. 4 shows the results of acid leaching tests of these samples.

From the samples containing more ZnO than the normal zinc ferrite, $ZnO \cdot Fe_2O_3$, excess ZnO is leached by means of a solution of ammoniacal ammonium chloride.

Acid leaching is carried out on residues from leaching with ammoniacal ammonium chloride solution. The combined oxide without free oxide is detected. From these data leaching curves are plotted. It is shown in Fig. 4 that the samples which are prepared to have more ZnO than $ZnO \cdot Fe_2O_3$ are leached with acid at constant extraction percentage, i. e., excess ZnO has no influence on leaching of zinc ferrite.

On the contrary, where the $Fe_2O_3$ content is greater than that of $ZnO \cdot Fe_2O_3$, more ZnO and less $Fe_2O_3$ are extracted with acid.

## IV. Studies on the Intensity of Saturation Magnetization of Zinc Ferrite

### a. Influence of Temperature on the Solid Solution of Ferric Oxide in Zinc Ferrite

The normal zinc ferrite, having the component of $ZnO \cdot Fe_2O_3$ and the structure of normal spinel type, is known to have no intensity of magnetization. But it comes to exhibit the intensity of magnetization

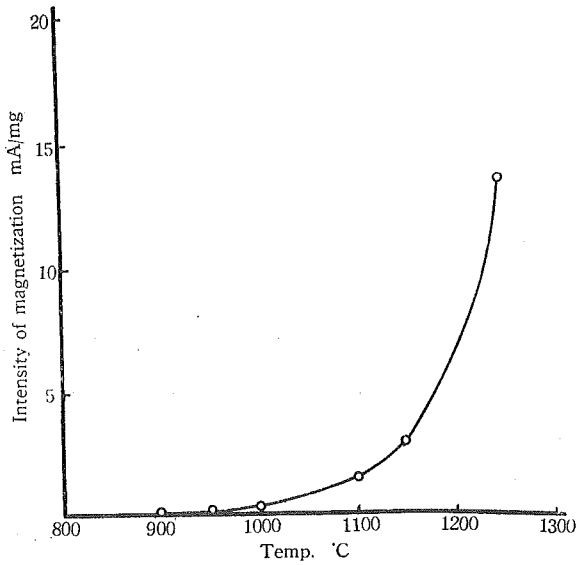


**Fig. 5** Effect of temperature on intensity of magnetization.

when $\gamma$-$Fe_2O_3$ dissolves in it.

In this respect, research is carried out on the temperatures promoting the formation of solid solution of $ZnO \cdot Fe_2O_3$ and $Fe_2O_3$.

The samples whose ratio of $Fe_2O_3/ZnO$ is 2 are heated at various temperatures for 2 hours and quickly cooled in air (Series E). Fig. 5 shows that $Fe_2O_3$ begins to dissolve in $ZnO \cdot Fe_2O_3$ from 950°C. And from 950°C to 1100°C intensity of magnetization rises almost linearly with temperature. Over 1200°C as the curve increases rapidly, magnetite is assumed to be formed.

b. Relation between Intensity of Saturation Magnetization and Dissolved Ferric Oxide

The mixed samples of ZnO and $Fe_2O_3$ are calcined at the temperatures 1000°C, 1100°C and 1150°C (Series F, G and H).

Curves of intensity of saturation magnetization vs. ratio of $Fe_2O_3/ZnO$ for these three calcining temperatures are plotted in Fig. 6 which shows that the intensity of magnetization of zinc ferrite increases suddenly up to a certain ratio of $Fe_2O_3/ZnO$, then stops rising and begins to fall, thus showing the maximum intensity.

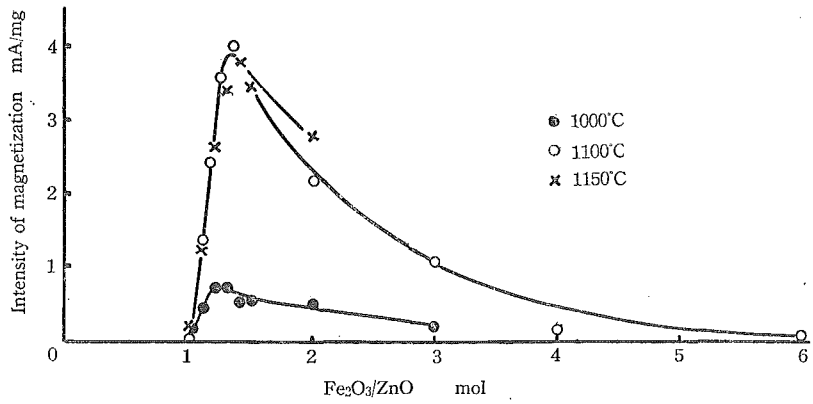


**Fig. 6** Change of magnetization by different $Fe_2O_3/ZnO$.

The increase of the intensity of magnetization is indicated by the amount of dissolved $Fe_2O_3$. The maximum point of curve seemes to correspond with the point of limited solid solution of $Fe_2O_3$ in $ZnO \cdot Fe_2O_3$. Lowering of magnetization curve over the range of the point of limited solution, however, has not been clearly explained. In this respect further discussion will be offered in a succeeding chapter.

## V. Studies on Zinc Ferrite by means of Norelco X-ray Spectrometer

### a. Studies on the Formation of Compound of Zinc Oxide and Ferric Oxide (Series B)

Samples made of ZnO and $Fe_2O_3$ at various ratios are calcined at 1050°C for 30 min. and the calcined samples are tested by Norelco X-ray spectrometer.

Fig. 7 shows the diffraction lines from spectrometer charts. In Fig. 7, sample B–6 has been prepared so carefully that no ZnO is leached from it with ammoniacal ammonium chloride solution.

According to the authors' chemical analysis the ratio of $Fe_2O_3$/ZnO is 1.00, and consequently it can be assumed that the sample B–6 is nearly perfect zinc ferrite. It is clear, from Fig. 7, that diffraction lines of B–3, B–4 and B–5 consist of lines B–1 (ZnO) and lines B–6 ($ZnO \cdot Fe_2O_3$), and that the lines of B–7, B–8 and B–9 consist of lines B–2 ($Fe_2O_3$) and lines B–6 ($ZnO \cdot Fe_2O_3$).

All of these lines are composed of three kinds, namely the lines of ZnO, $Fe_2O_3$ and $ZnO \cdot Fe_2O_3$ and do not contain any other diffraction line. From these results it can be concluded that only a zinc ferrite is formed out of ZnO and $Fe_2O_3$.

Fig. 8 shows the Norelco diffraction lines of the sulphide samples (series C). In Fig. 8, the same conclusion is obtained in respect to the roasted samples of the mixtures of zinc blende and pyrite.

### b. Influence of Temperature on the Formation of Zinc Ferrite

Fig. 9 shows the results obtained by X-ray spectrometer when it was applied on A series. It can be concluded from leaching tests that zinc ferrite forms even from 530°C and that ZnO remains at 1100°C (Fig. 2). But these two facts are not confirmed by X-ray diffraction lines, while it was concluded from the Norelco charts that the amount of formation of $ZnO \cdot Fe_2O_3$ increases as the temperature rises.

### c. Influence of Dissolved Ferric Oxide on Lattice Constant of Zinc Ferrite

The change of lattice constant is expected when $\gamma$-$Fe_2O_3$ dissolves in zinc ferrite, but further details have not been reported. In this research precise measurement of lattice constant is made using Norelco X-ray spectrometer.

Zinc ferrite has a cubic structure, and measurement is made on

the diffraction lines of (553) and (800). In this study F, G and H series are taken.

Fig. 10 shows the curves for the results obtained from these measurements. As is shown in Fig. 10 curves of lattice constants have certain characteristics.

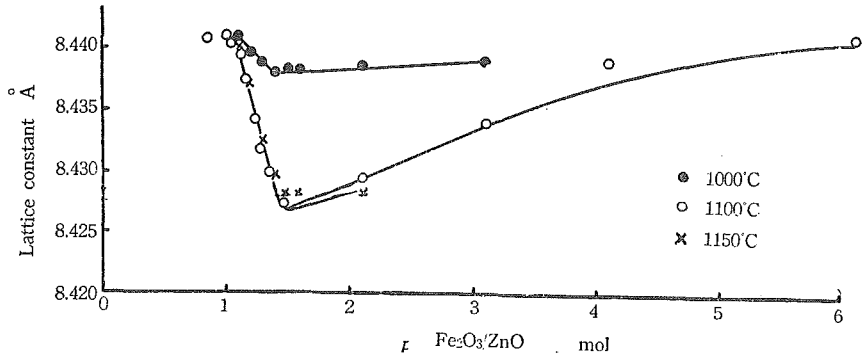


**Fig. 10** Change of lattice constant in various conditions.

In the region of $ZnO \cdot Fe_2O_3$ or excess of ZnO, lattice constants show somewhat invariable value.

As the dissolved $\gamma$-$Fe_2O_3$ in $ZnO \cdot Fe_2O_3$ is increased, the lattice constant curves suddenly go down to the minimum point, and then go up progressively. But the above characteristics are changeable according to the calcining temperature. At the temperature of 1000°C the change of curve is not distinct, but great variation is visible at 1100°C and 1150°C.

The point of minimum lattice constant is not definite according to the temperature, but appreciable decrease may be visible as the temperature rises.

In high $Fe_2O_3$ range, the curve of lattice constant at 1100°C seems to increase.

## VI. Researches on the Solubility of Zinc Oxide and Ferric Oxide in Zinc Ferrite

### a. Solubility of Zinc Oxide in Zinc Ferrite

The solubility of ZnO has been reported to be slightly visible and to form solid solution of ZnO and $ZnO \cdot Fe_2O_3$. The methods of determination seem to depend upon the comparison obtained by the decrease

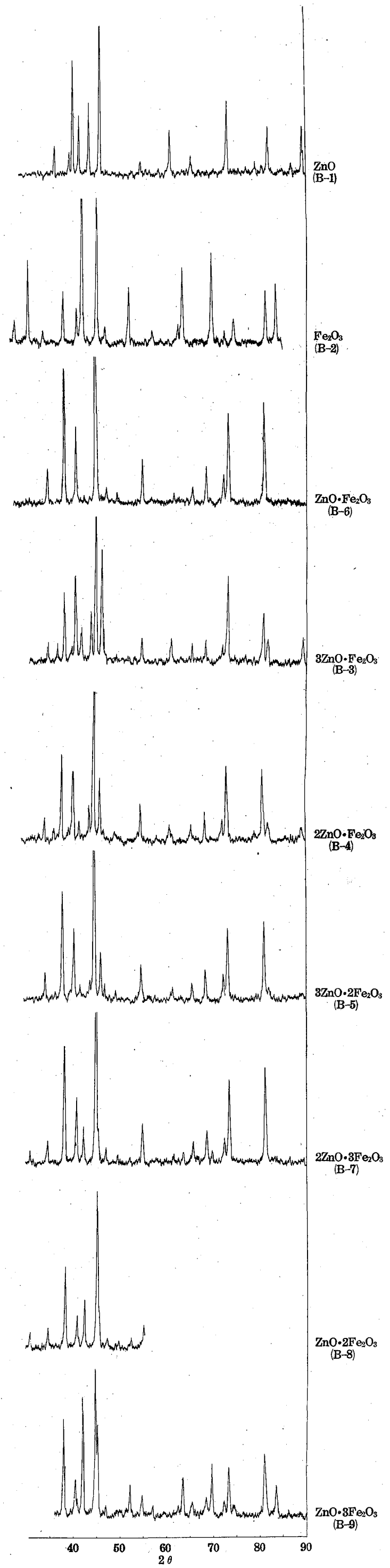


Fig. 7. Norelco Diffraction Lines for B Series

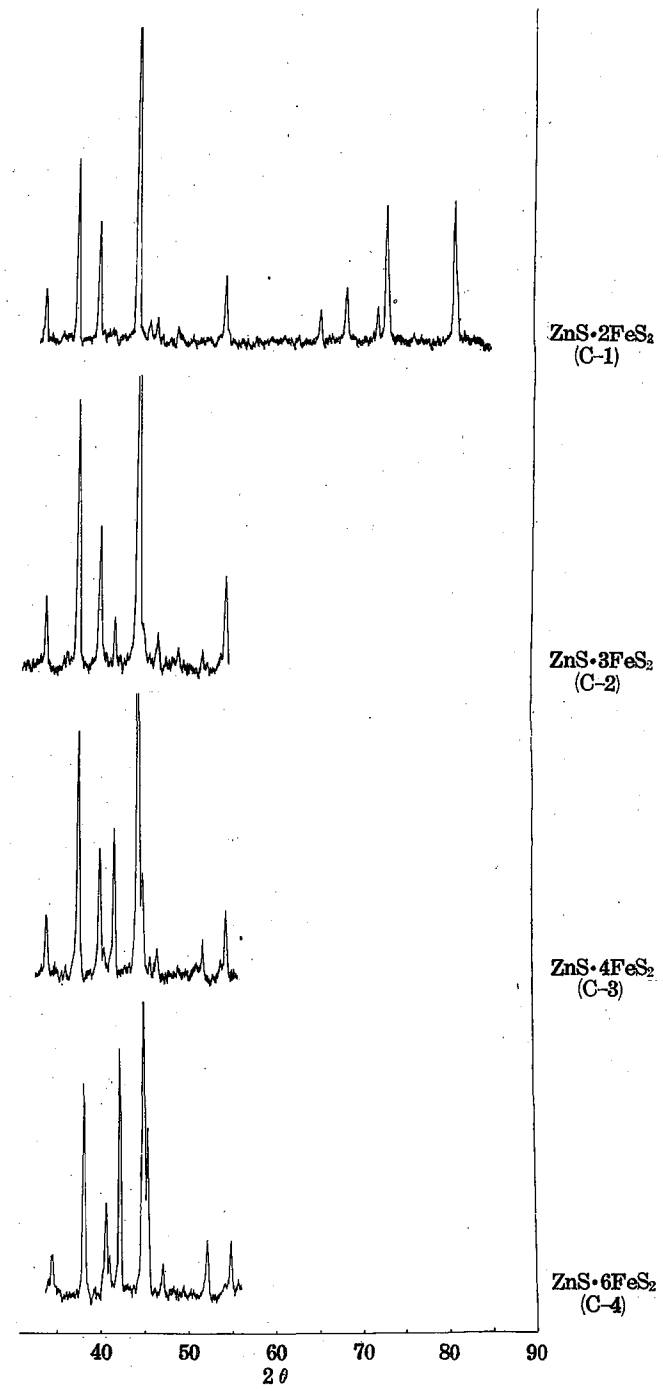


Fig. 8. Norelco Diffraction Lines for C Series

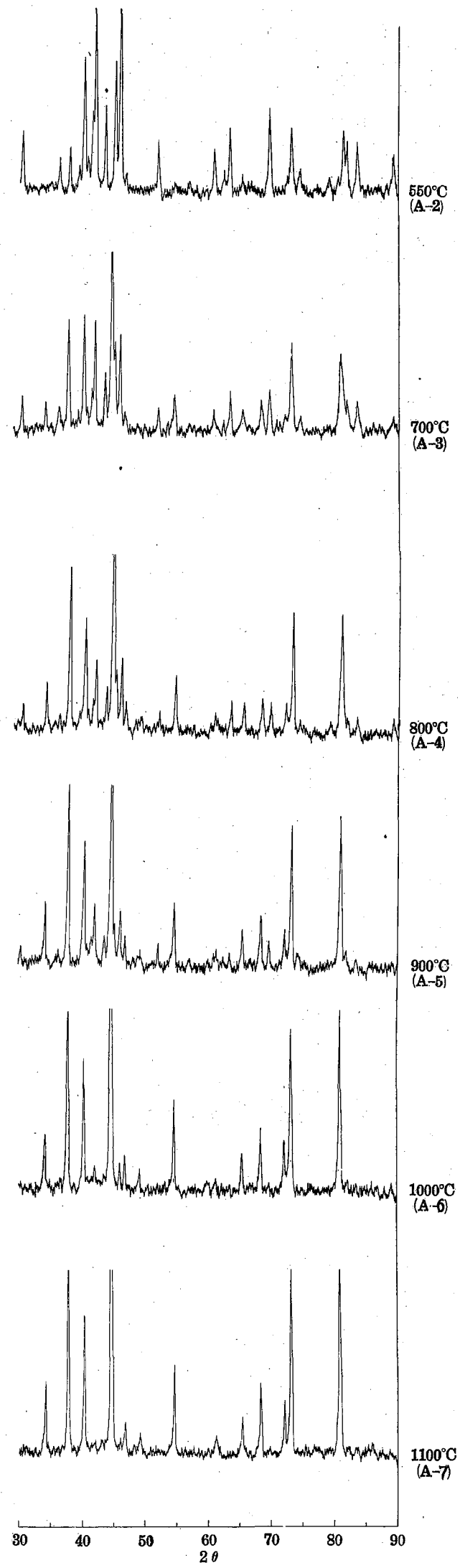


Fig. 9. Norelco Diffraction Lines for A Series

of X-ray diffraction intensity due to decrease of free ZnO by the formation of solid solution of ZnO and $ZnO \cdot Fe_2O_3$.

The present writers have had a chance to check the intensity of diffraction lines by Noreloc X-ray spectrometer. In spite of precaution on the size of the sample, the result was not reliable, and that conclusion shows that it seems difficult to decide the solubility of ZnO by this method.

It is found preferable to take the method of measurement of lattice constant. In spite of the excessive addition of ZnO to $ZnO \cdot Fe_2O_3$ the lattice constant of the zinc ferrite is almost invariable as shown in table 2 (Series I) and Fig. 10.

TABLE 2.

| Specimens No. | Lattice Constant Å |
|---|---|
| I—1 | 8.4394 |
| I—2 | 8.4394 |
| I—3 | 8.4391 |
| I—4 | 8.4401 |
| I—5 | 8.4390 |
| I—6 | 8.4410 |

b. Solubility of Ferric Oxide in Zinc Ferrite

Fig. 11 shows the curve for the results obtained from measurement of lattice constant and the intensity of magnetization.

The curve for lattice constant, starting from $ZnO \cdot Fe_2O_3$, suddenly goes down to the minimum point. The point of maximum intensity of saturation magnetization corresponds to the point of minimum lattice constant.

The writers have considered that the solid solution of minimum lattice constant which corresponds with maximum intensity of magnetization is the limited solution in the system of $ZnO \cdot Fe_2O_3$ and $Fe_2O_3$.

These phenomena above mentioned can be explained by the behaviour of simple solid solution of the ferrite, but the lowering of magnetization curve in the range over the point of limited solid solution has not been previously reported in details.

Concerning the deterioration of intensity of magnetization in the range over the point of limited solid solution, the following causes are

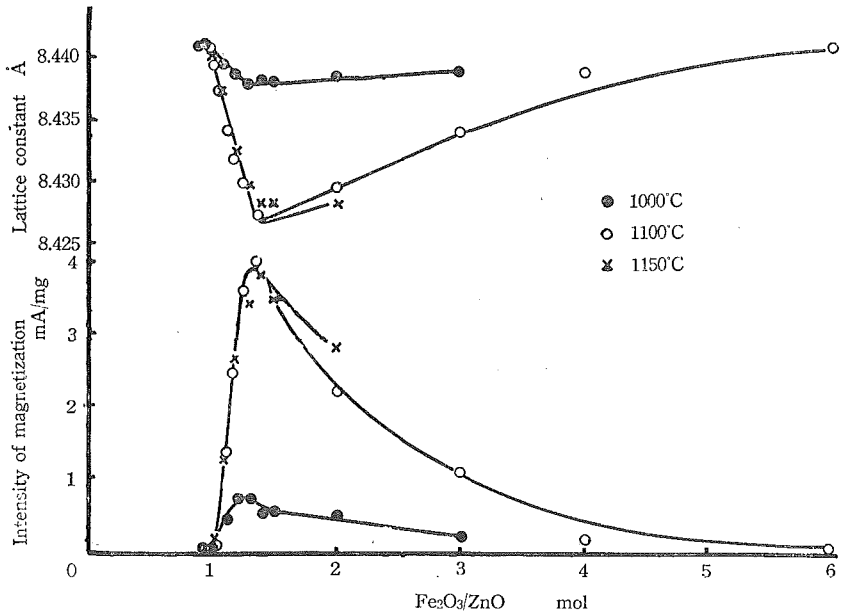


**Fig. 11** Relation between magnetization curve and lattice constant curve.

considered.

1. Different type of solid solution, such as the solid solution ot $ZnO \cdot Fe_2O_3$ in $Fe_2O_3$ is formed.

2. Or such a phenomenon as that which is seen between $CdO \cdot Fe_2O_3$ and $FeO \cdot Fe_2O_3$ takes place.

3. In the presence of limited solution the deterioration of intensity of magnetization is simply caused by the dilution of excessive $\alpha$-$Fe_2O_3$.

4. In addition to the cause of simple dilution, the amount of dissolved $\gamma$-$Fe_2O_3$ in $ZnO \cdot Fe_2O_3$ decreases due to the existence of the excessive $\alpha$-$Fe_2O_3$.

From the results of Norelco X-ray studies as shown in Fig. 7, however, the same solid solution is also found in the range over the point of limited solid solution and the diffraction lines of zinc ferrite and free oxide can be clearly detected. From the stand point of crystal systems the occurrence of the solid solution of $ZnO \cdot Fe_2O_3$ in $\alpha$-$Fe_2O_3$ is not considered probable. These facts point out that cause 1 is not tenable.

If the cause 2 plays a large part in the deterioration of intensity of magnetization, the lattice constant must change almost linearly. But

Fig. 10 shows that the lattice constant curve makes a minimum point. Then the cause 2 becomes unimportant.

If, in the range over the limited point, the limited solution and $\alpha$-$Fe_2O_3$ exist, and if lowering of magnetization depends only upon the dilution of free $\alpha$-$Fe_2O_3$, the curve of magnetization must be shown by the dotted line in Fig. 12. In addition, the lattice constant should be observed as possessing the same value as the point of limited solid solution. But these considerations do not agree with present observations. Then it follows that the cause 3 is hardly probable.

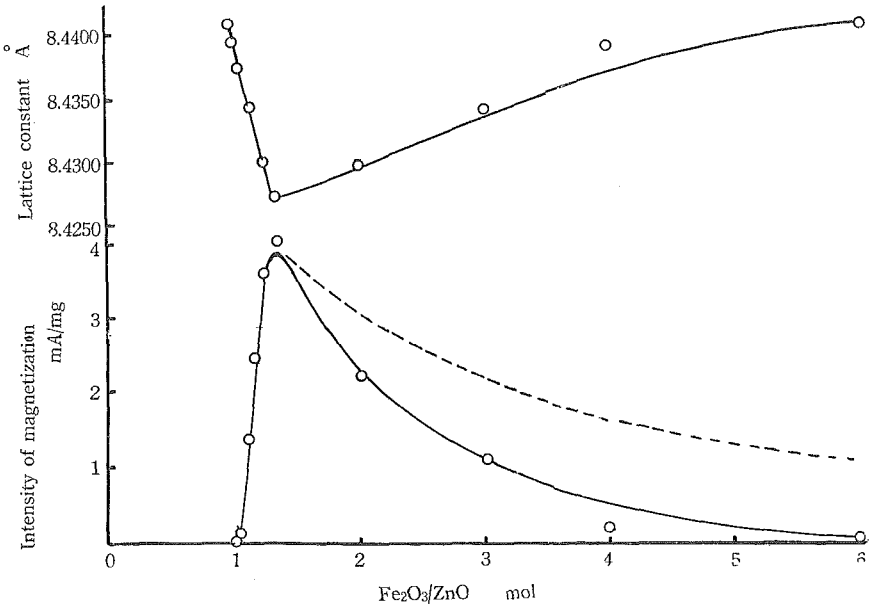


**Fig. 12** Relation between lattice constant and magnetization Intensity.

The amount of dissolved $\gamma$-$Fe_2O_3$ is shown to correlate with the intensity of magnetization of zinc ferrite. Further more the deterioration of the intensity of magnetization is considered to depend in part upon the decrease of amount of dissolved $\gamma$-$Fe_2O_3$.

Thus, the conclusion was reached that the deterioration of intensity of magnetization in the range over the point of limited solid solution depends generally upon the following two facts:

(1) It is caused by the dilution of excessive $\alpha$-$Fe_2O_3$.

(2) It is caused by the formation of solid solution of $Fe_2O_3$ in

$ZnO \cdot Fe_2O_3$, having less solubility than that of the limited solid solution, as the solubility of $Fe_2O_3$ decreases progressively with the addition of excessive $Fe_2O_3$.

In the present results the limited point showing the maximum intensity of magnetization has the ratio 1.4 of $Fe_2O_3/ZnO$.

In the curve of lattice constant it increases in correspondence with the deterioration of intensity of magnetization.

Then it can be assumed that the solid solution with the same value of lattice constant has the same composition and the same intensity of magnetization.

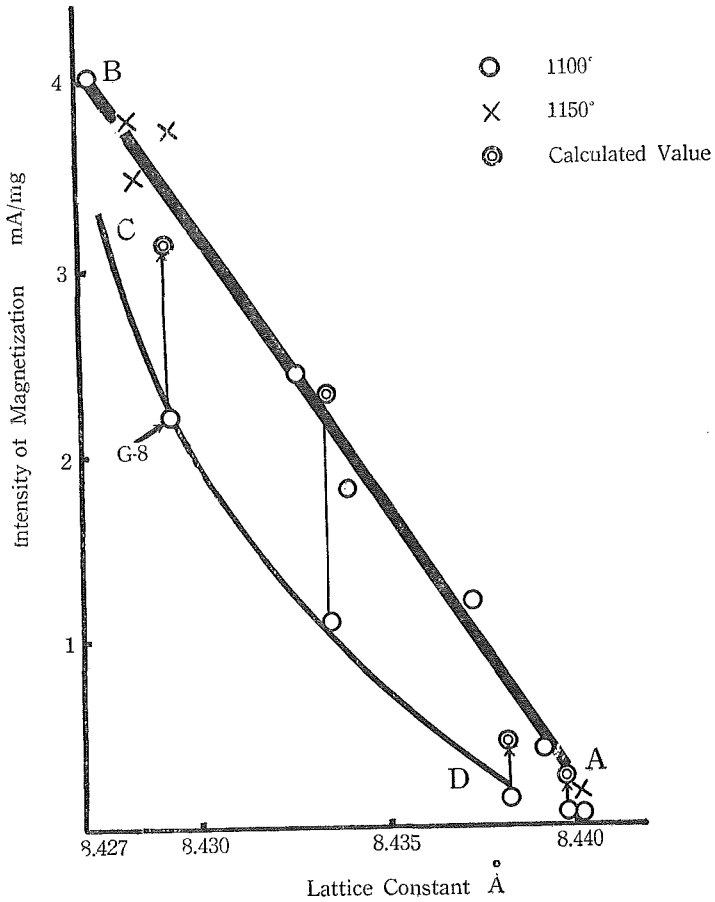


**Fig. 13** Relation between reasonable and observed values.

Linear relations have been obtained between lattice constant and intensity of magnetization, and in H and G series this relation is found to be the same in the limit point of solid solution; this is shown in Fig. 13 (Line A–B).

From these points of view calculation can be made on the reasonable intensity of magnetization about the solid solution part of G series sample whose ratio of $Fe_2O_3/ZnO$ is over the limited point. For example, let the sample G–8 be taken of which the ratio of $Fe_2O_3/ZnO$, the lattice constant of the solid solution and the intensity of magnetization are respectively 2, 8.4293 Å and 2.205 mA/mg on the curve (C–D) in Fig. 13. Referring to the same value of lattice constant it is found that the ratio of $Fe_2O_3/ZnO$ is 1.257. Consequently the solid solution of $ZnO \cdot 1.257\ Fe_2O_3$ and free $0.643\ Fe_2O_3$ are considered to exist relatively, and the amount of the solid solution becomes 70.39 wt%.

From these data the intensity of magnetization can be reasonably determined to be 3.4 mA/mg.

This reasonable intensity of magnetization is shown in Fig. 13 to be high enough to coincide with the standard line A–B.

## VII. Summary

According to the leaching test the temperature at which the formation of zinc ferrite occurs is found to be 530°C.

As to sulphuric acid leaching the higher the calcining temperature, the lower the leaching extraction of zinc.

Solubility of ferric iron differs from that of zinc.

Extraction curves for zinc decrease gradually as the temperature rises but the curves for ferric iron increase as the temperature rises in the range lower than 800°C whereas they begin to decrease in the range over 800°C.

From the results of acid leaching, the presence of an excessive ZnO is shown to have no influence on the leaching of zinc ferrite. On the contrary, where $Fe_2O_3$ is added excessively, the more $Fe_2O_3$ is contained, the more zinc and the less iron are extracted by the acid.

According to the experiment with samples having the ratio of $Fe_2O_3/ZnO=2$, $Fe_2O_3$ begins to dissolve in $ZnO \cdot Fe_2O_3$ from 950°C and from that temperature to 1100°C the intensity of magnetization rises linearly while dissolved $\gamma$-$Fe_2O_3$ increases as temperature rises.

At temperatures over 1200°C magnetite would be formed and the curve increases rapidly.

In the present experiments the maximum intensity of magnetization is obtained from the sample whose ratio of $Fe_2O_3/ZnO$ is 1.4.

From the studies using Norelco X-ray spectrometer it was ascertained that only a zinc ferrite is formed as the compound of ZnO and $Fe_2O_3$, and the same conclusion is obtained for the roasted samples of the mixtures of zinc blende and pyrite.

In this research precise measurement of lattice constant is made using Norelco X-ray spectrometer. In the region of $ZnO \cdot Fe_2O_3$ or more ZnO somewhat invariable high lattice constant is obtained. With the increase of dissolved $\gamma$-$Fe_2O_3$ in $ZnO \cdot Fe_2O_3$, the lattice constant suddenly declines to a minimum point. In the range of higher $Fe_2O_3$ than the point of minimum lattice constant the curve seems to rise progressively at 1100°C.

From the result of the measurement of lattice constant and the leaching test it is found that ZnO is not soluble in $ZnO \cdot Fe_2O_3$.

On the contrary, $Fe_2O_3$ dissolves in $ZnO \cdot Fe_2O_3$ and the curves for intensity of magnetization suddenly increase up to the maximum point.

The point of maximum intensity of magnetization corresponds to the point of minimum lattice constant. It appears that the corresponding solid solution of minimum lattice constant is the limited solution of the system of $ZnO \cdot Fe_2O_3$ and $Fe_2O_3$.

The amount of dissolved $\gamma$-$Fe_2O_3$ in $ZnO \cdot Fe_2O_3$ increases linearly with the amount of added $Fe_2O_3$ up to the point of limited solid solution where the intensity of magnetization is maximum and the lattice constant is minimum. But lowering of magnetization curve over this point of solid solution has not been reported. Concerning this point further discussions are presented.

**Acknowledgement**

The authors wish to express their appreciation to the members of Dr. Miyahara's laboratory in Hokkaido University for advices during this investigation.

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