Chemical and Mineralogical Study of South-Libyan Hematite Ore

Elhadi E. Saad, Nagy M. Kalil, Abeer, I. Alasfar and Hamida A. Saleh

Abstract**—** The aim of this work is studying the chemical and mineralogical compositions of hematite ore selected from Wadi El-shatti region, south Libya. The hematite sample was processed through crushing, grinding, sieving and quartering to obtain a representative sample. The mineralogical compositions of the studied samples was investigated using IR, XRD, TGA and DTG while the chemical composition was studies using XRF techniques. The results indicated that the investigated sample composed mainly of hematite in addition to a considerable content of quartz minerals.

Keywords**—** hematite mineralogical compositions IR, XRD, TGA and DTG

I. INTRODUCTION

HEMATITE, [1-3] also spelled as hæmatite, is the mineral form of iron (III) oxide (Fe_2O_3), one of several iron oxides. Hematite crystallizes in the rhombohedral system, and it has the same crystal structure as ilmenite and corundum. Hematite and ilmenite form a complete solid solution at temperatures above 950°C. It is colored black to steel or silver-gray, brown to reddish brown, or red. It is mined as the main ore of iron. Varieties include kidney ore, martite (pseudomorphs after magnetite), iron rose and specularite (specular hematite). While the forms of hematite vary, they all have a rust-red streak. Hematite is harder than pure iron, but much more brittle. Magnetite is a hematite- and magnetite-related oxide mineral. It is an accessory mineral in felsic igneous rocks, a late-stage sublimate in volcanic rocks, and in high-temperature hydrothermal veins. A product of contact metamorphism and in metamorphosed banded iron formations. A common cement in sedimentary rocks and a major constituent in oolitic iron formations. Abundant on weathered iron-bearing minerals. The name is derived from the Greek for blood, in allusion to its color. Huge deposits of hematite are found in banded iron formations. Grey hematite is typically found in places where there has been standing water or mineral hot springs, such as those in Yellowstone National Park in the United States. The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. Hematite can also occur without water, however, usually as the result of volcanic activity. Clay-sized hematite crystals can also occur as a secondary mineral formed by weathering processes in soil, and along with other iron oxides or oxy-hydroxides such as goethite, is responsible for the red color of many tropical, ancient, or otherwise highly weathered soils. Good specimens of hematite come from England, Mexico, Brazil, Australia, United States and Canada. Hematite is sometimes used in jewelry, either as black reflective stones or as a jewelry piece itself (such as a ring). Some jewelry is marketed as "magnetic hematite".According to a scientific research report carried in the Libyan Industrial Research Centre, [4] huge deposits of hematite ores are widespread throughout Libya especially in the south area (Sebha and surroundings e.g., Wadi Elshatti …etc.), Fig. 1. According to the recommendations of the Libyan Industrial Research Centre, these raw materials at these areas needs further research studies to evaluate their suitability for various possible industries.

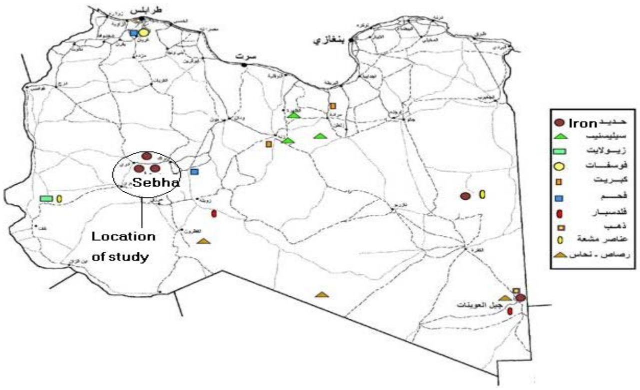

Fig. 1. Iron ore in Libya

II MATERIALS AND EXPERIMENTAL

A. Materials

A hematite rock (about 5 kg) was selected the core of huge accumulated raw material present in Wadi El-shatti area, South Libya for this investigation.

B. Processing and investigation of the raw hematite

The selected hematite ore batch was crushed in a jaw crusher, then ground in a porcelain ball mill with porcelain balls as grinding medium until they completely passed through a 75-micron standard sieve. To obtain representative samples, the batch was thoroughly hand mixed then divided into four equal portions; two of them from the opposite sides were removed while the two other portions were taken, hand

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mixed and quartered repeatedly until we finally obtained 50 g of the hematite ore batch. The representative sample was investigated for its mineralogical compositions using Infrared (IR) and X-ray diffraction (XRD) technique. IR spectra were recorded on a Perkin Elmer Model 337 Grating Spectrophotometer using KBr as the matrix. A Phillips PW1710 diffractometer with Ni filtered Cu-Kα radiation operating at 30 mA and 40 kV was used for XRD testing. The chemical composition of the hematite ore batch was investigated through X-ray fluorescence technique using a BRUKER XRF 3400 instrument. The thermal behavior including thermogravimetric (TG) and differential thermogravimetry (DTG) of such sampl was also investigated using a thermogravimetric analyzer (Brand: Mettler Toledo, model: TGA/SDTA 851e), over a range of temperatures from room temperature up to ≈ 1000 °C.

III RESULTS AND DISCUSSION

The IR spectra of the used raw material is shown in Fig (2) which shows the IR absorption bands of hematites characterized by a sharp band at 470 cm $^{-1}$ and a broad asymmetric band at about 539 cm $^{-1}$, which are probably due to Fe-O stretching vibrations. [5]

Fig (3) and Table (1) shows the solid phase compositions indicated from XRD patterns and the chemical compositions determined by XRF for the investigated raw sample. Fig (3) shows all the main peaks characterizing hematite mineral, however, the peaks charactering quartz mineral could also be detected which means that the sample under investigation composed, qualitatively, mainly of hematite with some impurities of quartz minerals. The relatively higher intensity of the peaks characterizing quartz is due to its relatively higher crystallinity compared with the hematite one. Table (1) indicates that the sample composed mainly of Ferric oxide (47.25 %) and silicon dioxide (16.24 %) in addition to a considerable content of loss on ignition (23.10 %) which may be due to carbon dioxide or hydroxyl groups. The sample contains also a relatively high content of aluminum oxide (11.16%) with little impurities of other oxides (calcium, potassium and titanium oxide) could also be detected which totally do not exceed ≈ 3 %. The results of chemical analysis confirm those of XRD patterns that the starting raw sample is mainly hematite with some impurities of quartz, however, the relatively higher content of aluminum oxide with silicon dioxide indicates their presence in the form of kaolinite mineral but its content is not so much enough that it could not be detected in the XRD pattern .

Thermal behavior (TG and DTG) shown in Fig (4) indicates a total loss of mass of ≈ 9.27 % observed in TG diagram, this loss takes place on three distinct stages; the first at ≈ 50-150 ^{o}C , this loss is corresponded with a relatively slight endothermic peak on the DTG diagram. The second stage of mass loss which is relatively higher occurred at ≈ 250- 350 ^{o}C corresponded with a more pronounced endothermic peak on the DTG diagram. The last stage occurred at two consecutive steps; the first at ≈ 500 - 700 ^{o}C, the next occurred at ≈ 700 - 900 ^{o}C which was very limited compared with the others. The two latter steps of mass loss are corresponded with two endothermic peaks; the first is more pronounced at ≈500- 550 ^{o}C while the second is relatively less pronounced at ≈ 700 ^{o}C. This thermal behavior could be explained as follow; since hematite mineral is known that it shows no thermal changes up to 1000 ^{o}C [6], any thermal effects appeared on the thermal curves are certainly due to one or more component associated with hematite. So, the first slight thermal effect at ≈ 50-150 ^{o}C is due to the loss of physically adsorped water, the second pronounced stage at ≈ 250- 350 ^{o}C is due to the dehydroxylation of goethite mineral (α- FeO(OH)). Theoritically [7] the chemical composition of goethite is 89.90 % Fe_2O_3 and 10.10 % H_2O, this percent of water is very close to the total weight loss in the TG diagram (9.27 %) which supports this hypothesis. The second stage composed of two steps; the first which is more pronounced at 550-550 ^{o}C is due to the loss of chemically combind water in the kaolinite mineral that may exist in low proportion (supported by chemical analysis in Table 1, the latter at ≈ 700 - 900 ^{o}C may be due to the loss of CO_2 resulting from the decomposition of calcite mineral that may exist in very little proportions so it could not be detected in XRD, but CaO could be detected in XRF (2.25 %) as given in Table (1).

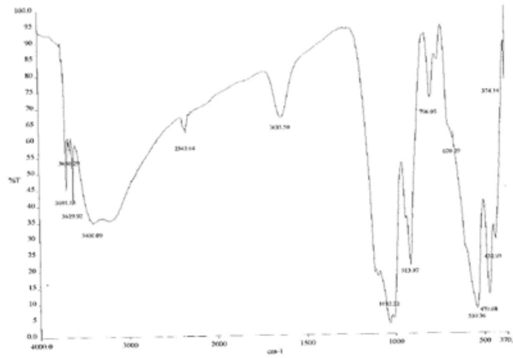

Fig. 2. IR Spectra of the raw material

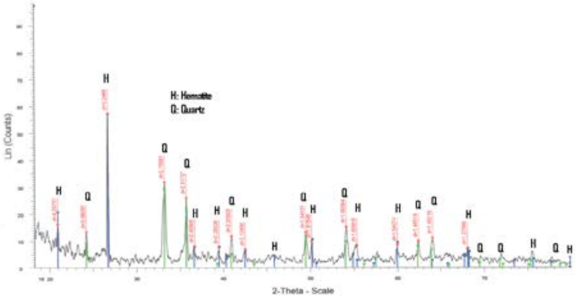

Fig. 3 XRD patterns of the started raw material

TABLE 1. CHEMICAL COMPOSITION OF THE STARTING RAW SAMPLE

Wt. (%)	Oxide
SiO2	16.24
Al2O3	11.16
K2O	0.47
CaO	2.25
TiO2	0.26
Fe2O3	47.25
L. O. I.	23.10

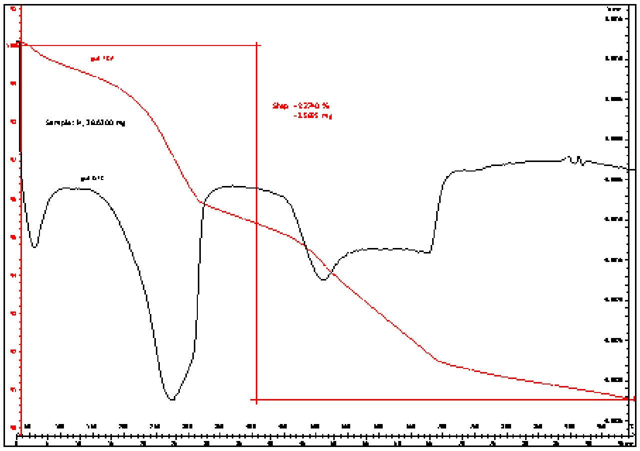

Fig. 4. TG and DTG of the raw sample

IV SUMMARY AND CONCLUSION

The hematite ore present in Wadi El-shatti, South Libya is composed mainly of hematite mineral with some impurities of quart and kaolin. Chemically it composed mainly of Fe_2O_3 (47.25 %) with considerable contents of SiO_2 (16.24 %) and Al_2O_3 (11.16 %) in adition to little contents of other impureties e.g. CaO, TiO_2 and K_2O, they not exceed together 3 % of the chemical composition of the hematite sample. These mineralogical and chemical compositions of the invesyigated hematite sample encourage their use as a source of Fe_2O_3 for various industrial applications especially in iron and steel as well as cement industries.

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