

X-Ray Studies and The Activation Energy for The Lattice Destruction of Talc

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Egyptian talc was subjected to different methods of analysis, Chemical analysis, differential thermal analysis, thermo-balance methods and x-ray analysis were used in this study. x-ray qualitative and quantitative analyses were carried out to identify the raw mineral. These methods showed that the raw talc is a mixture of 93.7% talc and 6.3% chrysotile. A discussion was made in terms of the hypothetical formula and the chemical analysis.

The activation energy for the lattice destruction of talc was studied. The break down of the reaction was described mathematically. The order of reaction, the frequency and the activation energy were calculated and were found to be 0.989, 8933×10^6 and 58.21 cal./mol. respectively.

Talc is a layer structure mineral⁽¹⁾. This is composed of silica layers and brucite layers. The former consists of Si-O tetrahedra connected at three corners in the same plane so that a two dimensional network of the hexagonal rings is obtained. The brucite layers consists of hydroxyl ions in tow planes, above and blew a plane of magnesium ions which are octahedrally coordinated by the hydroxyls. The structures of talc can be generated by simple combinations of these two units.

Experimental Results

Egyptian Eastern Desert talc was subjected to the following analysis:

1. Chemical Analysis

Different methods of chemical analysis were used in this study. The results of those methods are shown in the following table:

MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O	K ₂ O	TiO ₂	MnO	Loss on ignition
29.26	52.10	3.96	2.88	1.87	1.88	1.17	-	-	6.56

2. Differential thermal Analysis (D.T.A.) and Thermo-balance (T.B.)

These methods of analysis give the temperature at which the endothermic and exothermic solid state reactions take place in the materials as they are heated up. Fig.(1) showed the D.T.A. and T.B. curves for the raw talc under test. There is an endothermic reaction at 620°C followed by exothermic one at 820°C. These are characteristic of chrysotile, $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. There is an endothermic reaction at 990°C characteristic of talc.

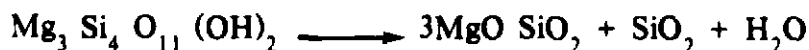
3. X-ray Diffraction Analysis

According to D.T.A. results x-ray powder photographs were taken for specimen preheated at 650°, 850°, 1000° and 1400°C using 19 cm Powder camera. The photograph of the raw talc shows the diffraction patterns of talc together with few lines due to chrysotile. The diffraction patterns of the sample preheated to 650°C showed the presence of talc and forsterite ($2\text{MgO} \cdot \text{SiO}_2$) which in turn changes into enstatite ($\text{Mg} \cdot \text{SiO}_3$) at 850°C. More intense patterns of enstatite were observed for the sample preheated to 1000°C. These results are in agreement with those of Caillere⁽²⁾. Protoenstatite ($\text{Mg} \cdot \text{SiO}_3$) and β -cristobalite (SiO_2) were observed at 1400°C.

X-ray quantitative analysis was carried out using a diffractometer. This method showed that Egyptian talc is a mixture of 93.7% talc, $3\text{MgO} \cdot 4\text{SiO}_2 \cdot \text{HO}_2$, and 6.3% chrysotile, $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$.

4. Activation Energy

By the action of heat talc breaks down according to the following reaction:



The kinetics of this reaction are governed by the following equation^(3,4).

$$-\frac{dn_a}{dt} = K n_a^x \quad (1)$$

where K being the specific rate and is given by

$$K = Z e^{-E/RT}$$

n_a = number of molecules of reactant present at time t,

x = order of reaction, z =frequency constant,

R = gas constant,

T = absolute temperature and

E = activation energy.

If w_o = total weight loss at completion of reaction

w = total weight loss up to time t,

n_a = number of reactant molecules present initially, and $w_r = w_o - w$, then equation (1) becomes:

$$\begin{aligned}\frac{dw}{dt} &= K w_r^x \left(\frac{n_o}{w_o} \right)^{x-1} \\ &= Z e^{-E/RT} w_r^x \left(\frac{n_o}{w_o} \right)^{x-1}\end{aligned}$$

Therefore

$$\log \frac{dw}{dt} = \log Z + \log \left(\frac{n_o}{w_o} \right)^{x-1} - \frac{E}{2.3 RT} + X \log w_r$$

A plot of $\log \frac{dw}{dt}$ against $\log w_r$ at constant temperature should give a straight line of slope X. For a certain value of w_r determined from these straight lines a plot of $\log \frac{dw}{dt}$ against $\frac{1}{T}$ should give a straight lines of slope $E/2.3R$.

A known weight of the material is placed in a platinum crucible and is suspended from the sensitive balance and lies in the hot zone of the furnace. The temperature was raised with a constant rate until the temperature of the specimen attained 650°C. The temperature was kept constant until a constant weight of the specimen was attained. So, the lattice water of chrysotile was expelled out. The crucible was drawn from furnace and the temperature was raised until it reaches 880°C. The crucible was introduced again and the weight was recorded against time and at constant temperature till a constant weight is attained. The procedure was repeated again for 900°, 920 and 940°C.

Results & Discussion

The results of chemical composition, D.T.A. and x-ray analysis were considered as a whole to see how far they complement or support each other. X-ray studies showed that Egyptian talc was composed of a mixture of 93.7% talc and 6.3% of the chrysotile. The ratios of MgO: SiO₂: H₂O in the hypothetical mixture of talc and chrysotile with proportions of 93.7: 6.3 stand as:

MgO	:	SiO ₂	:	H ₂ O
120.96	:	232.78	:	19.0

The observed ratios stand as, Table 1,

29.26	:	52.10	:	6.56
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A reasonable explanation is possible if those values are referred to SiO₂. The hypothetical and the observed ratios are as follows:

Hypothetical	: 0.519	: 1	: 0.08
Observed	: 0.561	: 1	: 0.12

With SiO_2 as a reference, there is an excess MgO which may be present as magnesite. This mineral usually occurs with talc⁽⁵⁾. However the excess MgO amounts only to 2.5% of the total and is not likely to be identified by x-ray diffraction or by D.T.A. The excess water may be partly due to adsorbed water and partly due to organic matter.

A curve between $\frac{w_r}{w_o} \times 100$ and time t was drawn for constant temperature, Fig. (2a). It is clear that for the values of the reactant temperature the first stage of composition obeys a linear relationship with time t . One can, therefore conclude that in the first stages of decomposition, the reaction has neither a retarding nor a catalytic effect and thus the reaction moves at a constant velocity. This condition is one of the requirements of the experiment⁽⁶⁾. Our procedure has the advantage of giving zero-loss at zero time and there is no need to shift the w_r axis⁽⁷⁾.

The rate of reaction $\frac{dw}{dt}$ at any time t was determined by the slope of the tangent in the reaction rate curve. A plot of $\log \frac{dw}{dt} V_s \log w_r$ at constant temperatures of 880°, 900°, 920° and 940°C is shown in Fig. (2b). The slope of these equi-inclined lines gives the order of reaction, $X=0.989 \approx 1$. The dehydration reaction is apparently of the first order type. Fig. (2c) shows a plot of $\log \frac{dw}{dt} V_s \frac{10^4}{T}$ for various values of $\log w_r$. The graph gives the activation energy as 58.21 cal/mol. The frequency Z was determined and is equal to 8933×10^6 .

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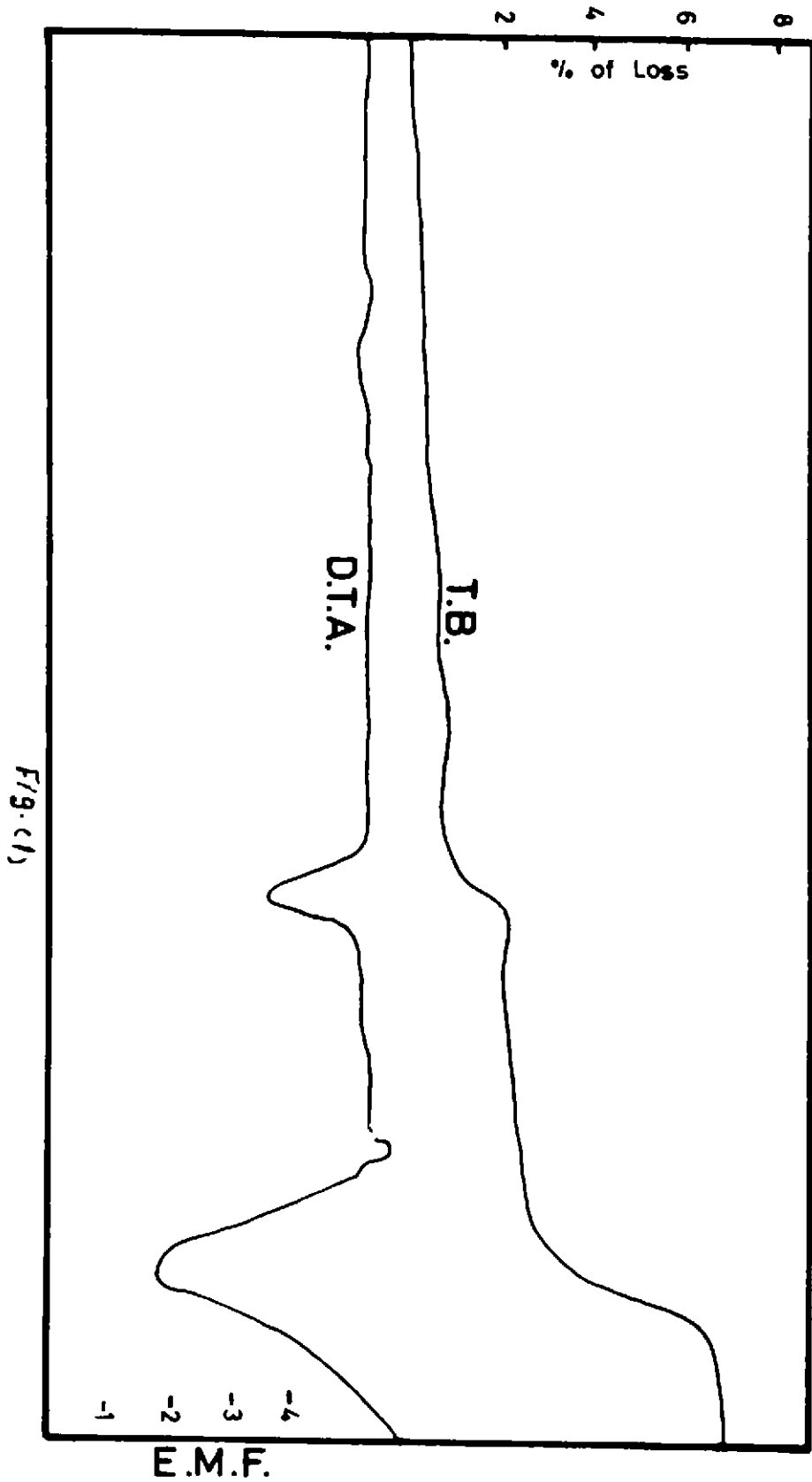


Fig.(1) shows the results of differential thermal and thermo-balance analyses.

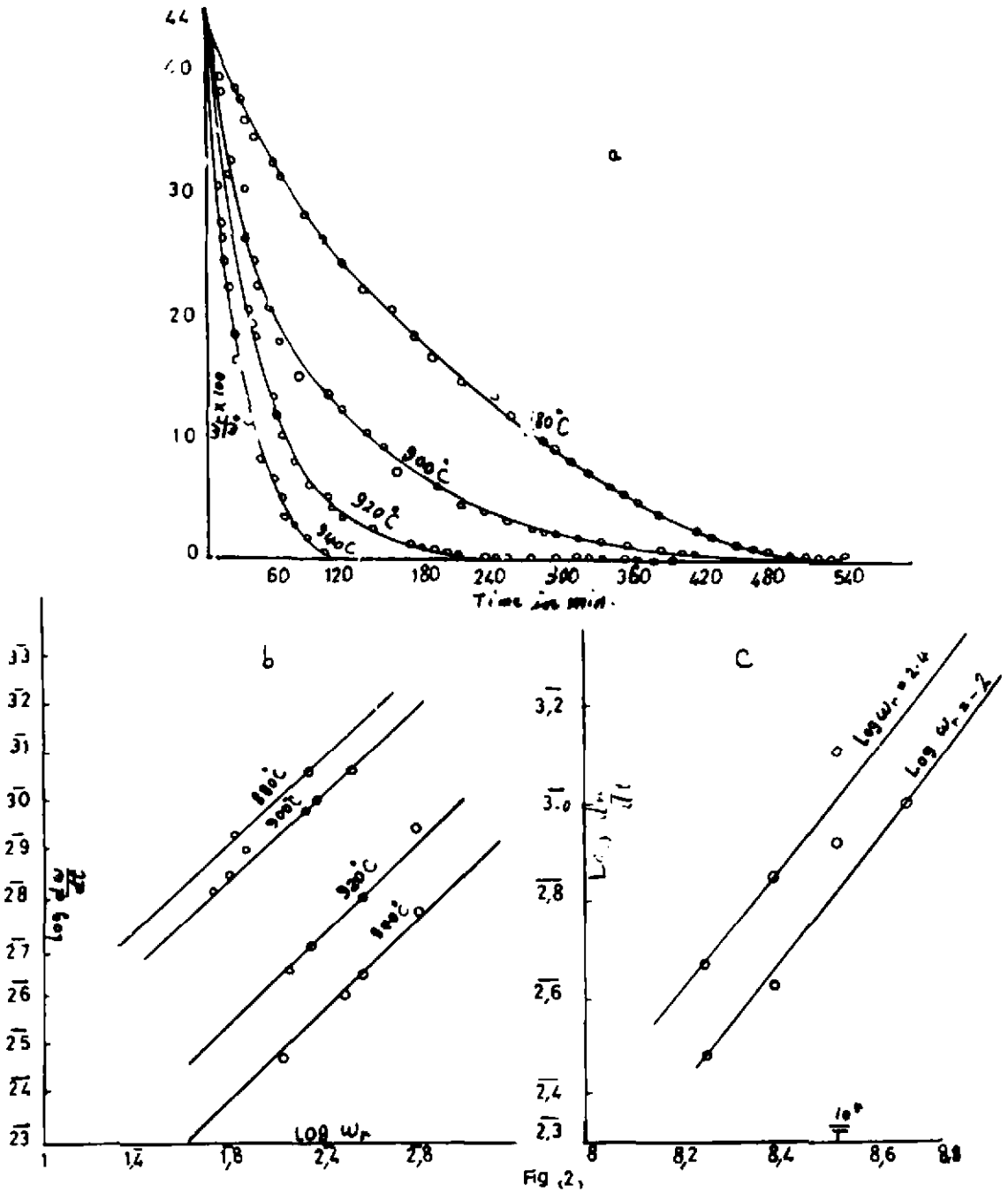


Fig.(2) Treatment (a) shows the relation between $\frac{w-t}{w} \times 100$ and time (t).
 treatment (b) shows the relation between $\log \frac{dw}{dt}$ and $\log w_r$ at constant temperatures 880°, 900°, 920° and 940°C.
 treatment (c) shows the relation between $\log \frac{dw}{dt}$ and $\frac{10^4}{T}$ for various values of $\log w_r$.

دراسة خامة التالك المصري بواسطة الأشعة السينية وتعيين الطاقة المنشطة اللازمة لتحطيم الشبكة البلورية.

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الغرض من هذا البحث دراسة التركيب البلوري لمادة التالك المصري بواسطة الأشعة السينية وتعيين طاقة التنشيط اللازمة لتحطيم الشبكة البلورية وذلك بدراسة السلوك الحراري لها. بدأ البحث بتحليل كامل لهذه المادة بعدة طرق مختلفة ولقد دلت النتائج على أن هذه المادة تتكون أساساً من مادة التالك وذلك بنسبة ٩٣,٧ مخلوطة بمادة الكريزوتيل بنسبة ٦,٣. ولقد تم تعيين الطاقة المنشطة ووجد أن قيمتها هي ٥٨,٢١ سعر/جزء.