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KINETICS OF SINTERING OF IRREGULAR PARTICLES OF GLASS. PART II. NON-ISOTHERMAL SINTERING

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ABSTRACT

Part I of this series discussed isothermal sintering of a commercial window glass powder. In this paper results of a non-isothermal study are reported. It is shown that the isothermal kinetic equation can be used for analysis of non-isothermal data. The non-isothermal activation energy E value is significantly different from the isothermal E value.

INTRODUCTION

Non-isothermal kinetic studies involve recording of the progress of densification under rising temperature, within a well defined heating programme. The equations for non-isothermal kinetic data are well known. In the present work three equations have been used for analysing data. These are as follows

Ray and Dixit equation

$$\ln g(\alpha) = \text{const} - E/RT \tag{1}$$

Ingraham's equation

$$\ln(\alpha B/T^3) = \text{const} - E/RT \tag{2}$$

Coats and Redfern equation

$$\ln g(\alpha)/T^2 = \text{const} - E/RT \tag{3}$$

where the isothermal equation is given by $g(\alpha) = kt$. In the present case we may equate α with $\Delta L/L_0$.

Although there are many methods of analysing non-isothermal kinetic data, these methods do not generally yield identical values for activation energy. Moreover, it has been established that non-isothermal activation

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energy values which do not generally agree with isothermal values have no well defined meaning. They can only serve as useful experimentally defined parameters.

EXPERIMENTAL

The materials and experimental techniques used in this work were as described in Part I. Heating rates used were 5, 10 and 20 °C min^{-1}. Compacts were sintered in the temperature range room temperature to 700 °C.

RESULTS AND DISCUSSION

Non-isothermal data plotted according to eqn. (1) are shown in Fig. 1. The average value of 0.28 has been used for n. The slope is linear and yields an activation energy value of 158 kcal mol^{-1}. This value does not vary with heating rate.

The same non-isothermal data were also analysed according to Ingraham's method, eqn. (2). Figure 2 shows the plot of $\ln(\alpha B/T^3)$ vs. $(1/T)$ for the three different heating rates. The slopes of these linear plots yield activation energy values of 150, 165 and 132 kcal mol^{-1} for the heating rates 5, 10 and 20 °C min^{-1}, respectively. These plots show variation in activation energy due to change in heating rate.

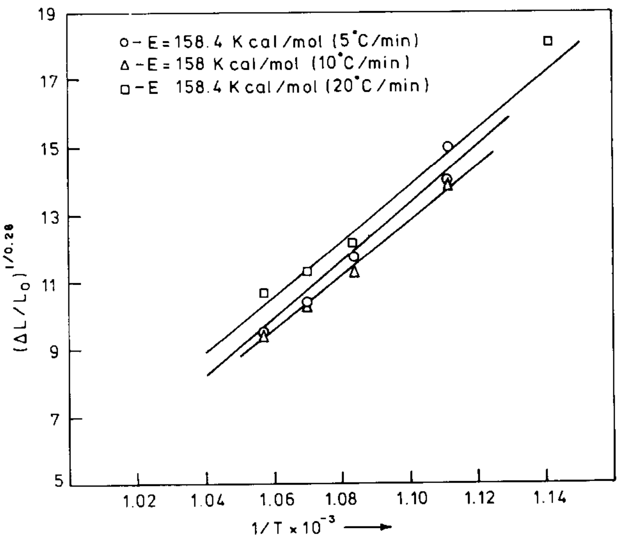

Fig. 1. Analysis of non-isothermal sintering data by Ray and Dixit model.

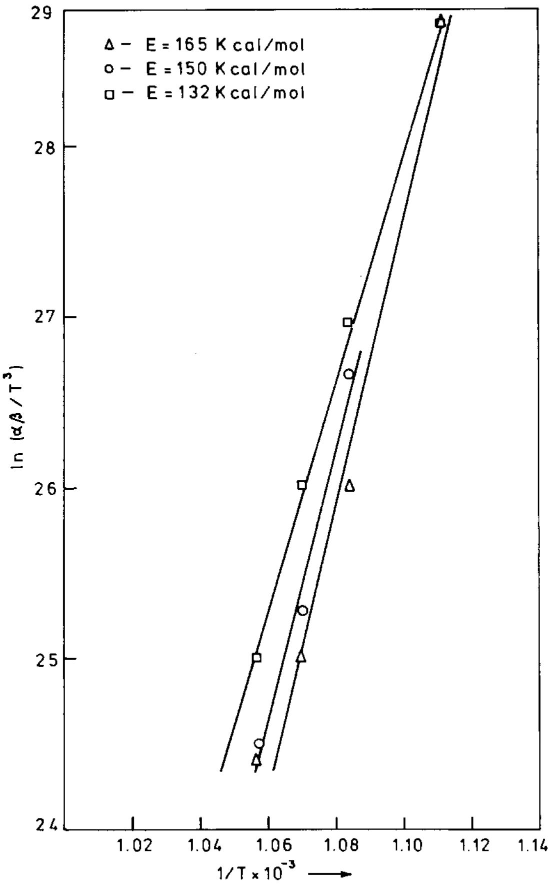

Fig. 2. Analysis of non-isothermal sintering data by Ingraham model.

Analysis of the same non-isothermal kinetic data using the Coats and Redfern equation is shown in Fig. 3, where values of

$$\ln\left|\frac{(\Delta L/L_0)^{1/0.28}}{T^2}\right| \text{ vs. } 1/T$$

are plotted for the three different heating rates. The activation energy is found to be 217, 198 and 118 kcal mol^{-1} for the heating rates, 5, 10 and 20°C min^{-1}, respectively.

Apparently the Ray and Dixit method allows the best analysis.

CONCLUSIONS

It has been shown that the isothermal rate equation can be used for analysis of non-isothermal data. However, the non-isothermal E value

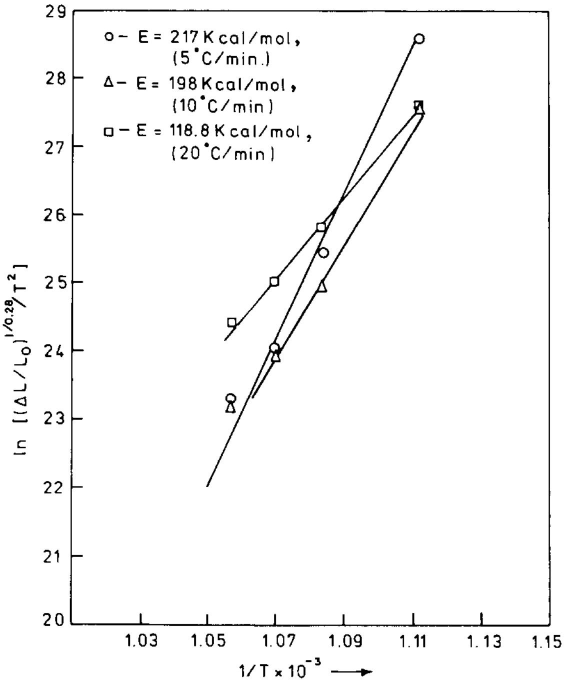

Fig. 3. Analysis of non-isothermal sintering data by Coats and Redfern model.

obtained depends on the method used for analysis. The Ray and Dixit equation yields a value of about 158 kcal mol^{-1}, which does not vary with heating rate. In the case of the Coats and Redfern equation and Ingraham's equation, however, the E value does appear to vary with heating rate.