Kinetics of Magnetite Nanoparticles Formation in a Co-precipitation Process Using Avrami Model

Ahmad Fadli*, Amun Amri, Esty Octiana Sari, Adela Shofia Adabbsi

Department of Chemical Engineering, Faculty of Engineering, Universitas Riau,
Jl. HR Subrantas Km 12.5 Pekanbaru 28293 Riau, Indonesia
**Corresponding Author's Email: fadliunri@yahoo.com*

Abstract: Magnetite (Fe_3O_4) nanoparticles have attracted much attentions from multidiciplines scientist due to their potential applications in many fields. Characteristics of nanoparticles can be controlled by studying the reaction kinetics of crystal growth. The purpose of this research is to study the effects of temperature and stirring rate on the magnetite formation and to determine the kinetics of magnetite formation with Avrami model approach. The magnetite was synthesized from $FeCl_3$, $FeCl_2$ in mole ratio 2:1 and NH_4OH 10% using co-precipitation method at 40°C, 60°C, 80°C and stirring rate 300, 400, 500 rpm. Samples were taken about 10 mL in every 5 minutes for 30 minutes. Fe concentration in the filtrate was analyzed using AAS. The formation of magnetite can be approximated by the Avrami model with the value of core forming function (n) was ranging from 1.3-1.8. The value of the rate constant of transformation (k) increased with the temperature and stirring rate.

***Keywords*:** Avrami, co-precipitation, magnetite, nanoparticles

INTRODUCTION

Magnetite (Fe_3O_4) nanoparticles are attractive nanomaterials due to their excellent superparamegnetic, unique electric properties and high biocompatibility. Magnetite nanoparticles have huge potential applications in various fields, such as ferrofluids, magnetic recording media, heavy metal removal and various medical applications [1-5]. Magnetite nanoparticles with controllable manner are needed due to the fact that the morphology of particle plays a very important role in determining the optical, magnetic, electrical properties and their biocompatibility. Over the past decades, scientists have proposed several synthesis methods for preparing magnetite nanoparticles [6]. In this study, we investigate the effects of stirring rate and temperature on the formation of magnetite in co-precipitation process and also determine the kinetics of magnetite formation through the Avrami model approach.

MATERIALS AND METHODS

The magnetite was synthesized using the co-precipitation method. $FeCl_3.6H_2O$ (Merck, Germany) and $FeCl_2.4H_2O$ (Merck, Germany) were dissolved in 100 mL of distilled water and heated to a certain temperature for 10 min while stirring. Then, NH_4OH 10% (Merck, Germany) was added continuously while stirring until the pH reached 10. During the reaction, 10 ml of liquid sample was taken from the reaction container every 5 minutes for 30 minutes to determined Fe concentration via AAS analysis. Subsequently, the liquid and precipitates were separated by the external magnet. The precipitate was separated and rinsed to neutralize the pH. The precipitate was dried in the oven at 100˚C for 2 hours. The synthesis was performed in 40^0C, 60^0C, and 80^0C and stirring rate 300 rpm, 400 rpm and 500 rpm.

RESULTS AND DISCUSSION

Graph of the relationship between the transformation fraction (Y (t)) of the magnetite to the reaction time is shown in Fig. 1. The magnetite formation graph generated in this study is similar to that of the sigmoidal graph (S shape curve). So, the Avrami equation can be used in this study to illustrate the transformation of phase changes in magnetite formation.

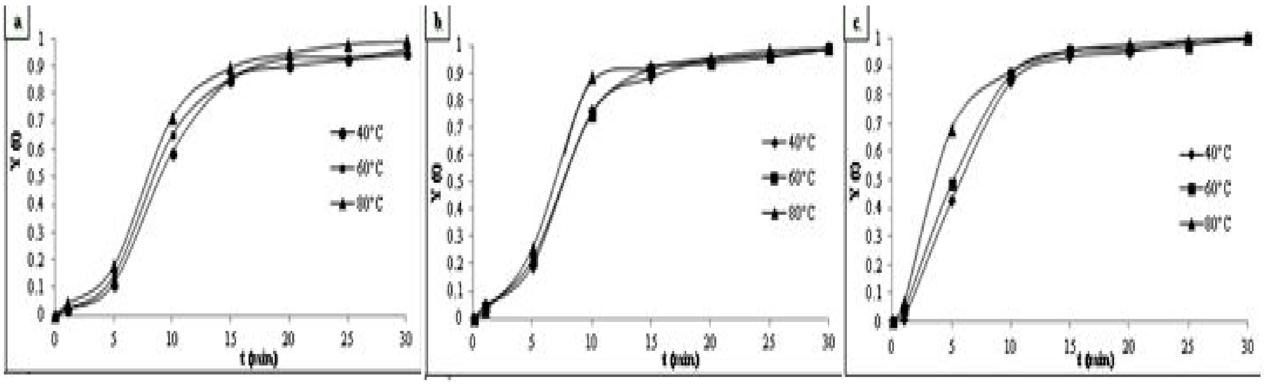

Fig. 1. Graph of magnetite formation at stirring rate of (a) 300, (b) 400 and (c) 500 rpm.

In order to investigate the accordance of these results with that of Avrami behavior. The correlation between *ln [- ln (1 - Y (t))]* to *ln t* plot was derived. The slope (n) shows the value of core formation. The n value around 1.3 - 1.8 indicates the mechanism of crystal growth occurring in one dimension (one way). The smaller value of n indicates the faster nucleation process [7]. The intercept shows the transformation rate of the reaction (K). The transformation rate (K) increases as the increase of temperature and stirring rate.

CONCLUSIONS

The synthesis of magnetite (Fe_3O_4) was successfully performed using co-precipitation method. The formation process of magnetite nanoparticles could be described by the Avrami equation with the value of the core forming function (n) ranging from 1.3 to 1.8, indicating that the magnetite formation reaction in this study occurred homogeneously and the crystal growth mechanism occurred in one dimension. The value of the rate constant of transformation (k) increased as the increase of temperature and stirring rate.

ACKNOWLEDGMENT: We acknowledge The Ministry of Research, Technology and Higher Education of the Republic of Indonesia (Kemenristekdikti) for the research grant.

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