Activation of kaolin with minimum solvent consumption by microwave heating

R. Z. AL BAKAIN 1, Y. S. AL-DEGS 2, A. A. ISSA 2, S. ABDUL JAWAD 3, K. A. ABU SAFIEH 2 AND M. A. AL-GHOUTI 4,*

1 Department of Chemistry, Faculty of Science, The University of Jordan, P.O. Box 11942, Amman, Jordan, 2 Department of Chemistry, The Hashemite University, P.O. Box 150459, Zarqa 13115, Jordan, 3 Department of Physics, The Hashemite University, Zarqa, 13115, Jordan, and 4 Department of Biological and Environmental Sciences, Qatar University, Doha, State of Qatar

(Received 31 March 2014; revised 10 October 2014; Editor: George Christidis)

ABSTRACT: A kaolin clay was activated with 1.0 M H2SO4 solution at minimum liquid to solid ratio (L/S) using microwave heating. The optimum experimental conditions for activation were L/S ratio 3.0 mL 1 M H2SO4 per gram kaolin, microwave input power 500–600 W, and heating time 5–10 min. Activation at L/S < 3.0 mL/g using 1.0 M H2SO4 was not efficient, indicating the influence of solvent for absorbing microwaves more intensively and thus improving activation. Significant physicochemical changes were observed by the proposed procedure with smaller volumes of activator compared to the conventional heating method. Microwave input power and heating time have a strong influence on the quality of the final material; activation at high input power (>700 W) and longer heating times (>10 min.) are not recommended since they cause dissolution of kaolinite structure. Microwave-heated kaolin manifested better adsorption for tartrazine dye due to improvements in textural and chemical properties of kaolinite. Moreover, irradiation of used kaolinite has significantly improved dye desorption, increasing the importance of microwaves in regeneration/recycling studies. Detailed dielectric measurements of kaolin-acid mixtures recorded at frequencies much lower than 2.45 GHz revealed that absorption of radiation is highly dependent on the activator solution in the mixture. For 3.0 mL/g mixtures, high dielectric constant \( \varepsilon' = 5223 \), dielectric loss factor \( \varepsilon'' = 5083 \), tangent loss \( \tan \delta = 1.30 \), penetration depth \( dp = 0.57 \text{ cm at } (10^3 \text{ Hz}) \), and AC-conductivity \( \sigma = 0.032 \ \Omega\text{m}^{-1} \) were determined at \( 10^3 \text{ Hz} \). Filling the pores of kaolin by acid solution increased the microwave absorption and hence de-alumination of kaolinite.

KEYWORDS: kaolinite, acid activation, microwave heating, dielectric properties, surface characterization.

Kaolins are important clays which find wide applications in numerous industries including ceramics, paper coating/filling, plastic filler, paint extender and cement, among others (Nkoumbou et al., 2009; Christidis 2011). The main clay mineral present in kaolins is kaolinite which often coexists with quartz, mica, feldspar, montmorillonite, Ti oxides, gibbsite and graphite (Belver et al., 2002).

Kaolinite is a 1:1 layer silicate and is considered as a promising catalyst or adsorbent (Panda et al., 2010; Christidis, 2011; De Sales et al., 2013) due to (a) the chemical inertness over a wide pH range, (b) its modifiable surface upon acid treatment to increase its intrinsic cation exchange capacity, (c) suitable pore structure for different industrial purposes, and (d) low-cost and wide availability. For effective utilization of natural kaolins, the surface should be activated to ensure high specific surface area and suitable chemical properties (Panda et al., 2010). The most adopted modification procedures for kaolins are mechanical activation.