Kinetics of boric acid dissolution

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Abstract. *This paper explores the dissolution kinetics of boric acid balls in water at 293-323 K and a blade agitator speed of 100-400 rpm. The study examines both external and internal diffusion of boric acid balls during mixing and identifies the mass transfer coefficient's mathematical relationship with temperature and agitator speed.*

Keywords: boric acid, dissolution, blade agitator, mechanical mixing, diffusion, mass transfer coefficient.

Boric acid is used in many industries, in particular, the production of glass, ceramics, fertilizers and medicines. The study of the kinetics of boric acid dissolution and the factors affecting it allows to reduce the time and energy consumption for the dissolution process, as well as provides an opportunity to design new materials with certain properties and optimize synthesis processes. Various methods are used to intensify processes of the dissolution of solid materials in a liquid, namely dissolving in the liquid stream by bubbling the solution with gas, cavitation of the solution, using ultrasonic vibrations, by mechanical stirring, etc.

In this paper, presented are the results of experimental studies of the kinetics of boric acid dissolution by mechanical mixing. The studies were conducted at different temperatures and speeds of rotation of the agitator. In this study, a mechanical three-bladed agitator was used, driven by an asynchronous motor. The scheme of the experimental installation is shown in Fig.1.

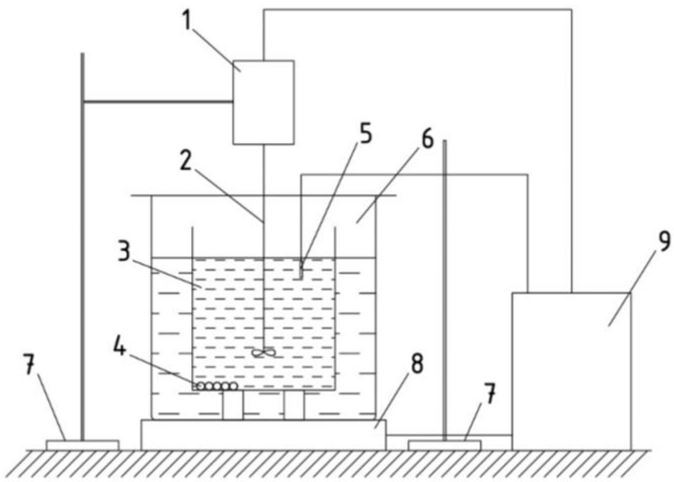
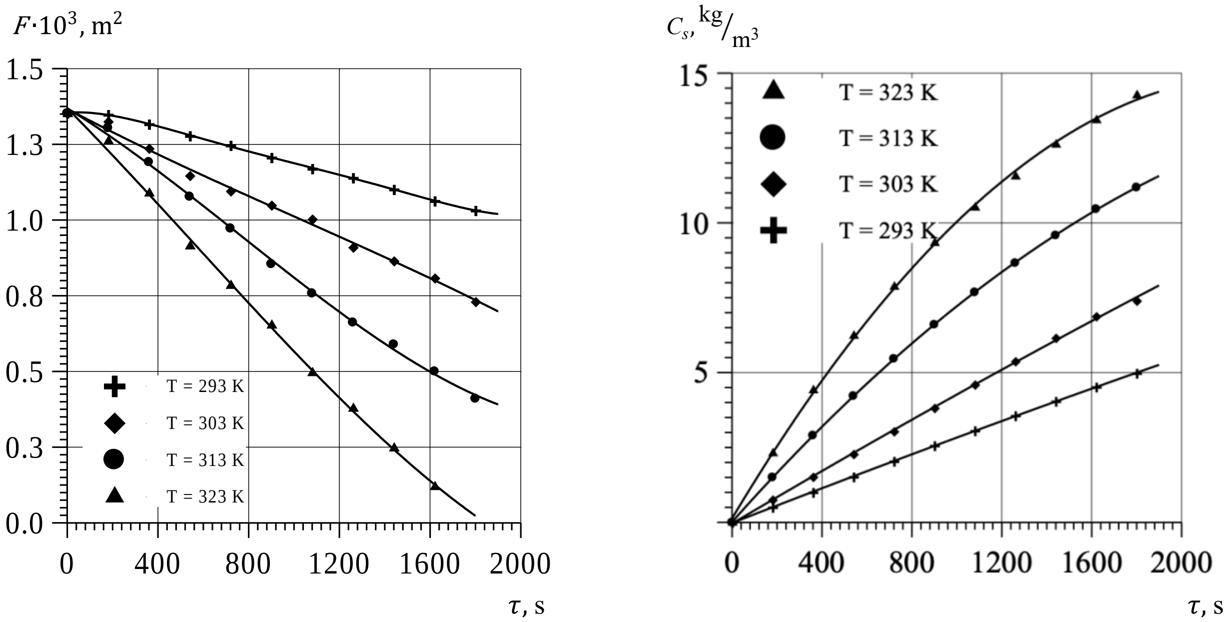


Fig.1. Scheme of experimental installation:
1 – asynchronous motor,
2 – three-bladed agitator,
3 – heat-resistant glass cup,
4 – balls of boric acid,
5 – thermocouple,
6 – water bath,
7 – stand,
8 – heating element,
9 – regulating device.

For experimental studies, granulated boric acid was used in the form of compressed balls with a diameter of 20 mm and a mass of 6 grams. For each experiment, 5 balls of boric acid were immersed in the heat-resistant glass cup. The constant temperature in the glass cup was maintained by the thermostat, and the set speed of rotation of the agitator – by the regulating device, the change in diameter and mass of the balls was determined every 180 seconds. To obtain reliable results, at least 3 experiments were conducted for each part of the study. The general methodology consisted of a standardized approach to the experiment that would ensure the repeatability and reliability of the results. The obtained data were analyzed using statistical methods and used to determine the kinetics of dissolution of boric acid in water. The physicochemical properties of boric acid (over 293 K) were as follows: density – 1.47 g/cm^3, saturation concentration – 4.7 g/100 ml, ph = 8.4, diameter of balls – 20 mm, initial weight of balls – 6 grams, initial cut of balls – 1.2%.

According to the determined values of the change in the diameter of the balls, the mass transfer surface was determined at temperatures of 293–323 K and the rotational speed of the agitator being 5 s^{-1} (Fig. 2). Experimental studies of the kinetics of dissolution of granulated boric acid were carried out at temperatures of 293–323 K and agitator speeds of 1.7, 3.3, 5, and 6.7s^{-1}.



a) b)

Fig. 2. a) change in the area of the boric acid ball over time at the agitator speed of 5 s^{-1}; b) kinetics of dissolution of boric acid at the agitator speed of 5 s^{-1}

Generalizations of the results were presented in the form of dimensionless dependence complexes of the Sherwood criterion on the criteria of Reynolds, Schmidt and the geometric simplex:

$$Sh = f(Re, Sc, \Gamma), \quad (1)$$

where $Sh = \overline{\beta} \cdot \overline{d}/D^T$ – Sherwood criterion, $Re = \rho \cdot n \cdot d_m^2/\mu$ – Reynolds criterion, $Sc = \nu/D$ – Schmidt criterion, $\Gamma = d_m/D_a$ – geometric simplex, n – the number of revolutions of the agitator, d_m – agitator diameter, μ – coefficient of dynamic viscosity of the solution at experimental temperature, ρ – solution density at experimental temperature, ν – cinematic viscosity of the solution at experimental temperature, D^T – molecular diffusion coefficient, $\overline{d}$ – average diameter of the ball.

The mass transfer coefficient was determined by the common equation:

$$\overline{\beta} = \frac{M_0 - \overline{M}}{F \cdot (C_s - \overline{C_\tau}) \cdot \tau} \quad (2)$$

where M_0, $\overline{M}$ – initial and flowing masses of 5 balls of boric acid, F – flowing surface 5 balls of boric acid, C_s, $\overline{C_\tau}$ – saturation concentration and flowing concentration of boric acid in solution, τ – experiment time.

Conclusion. The results were presented in the form of dependence:

$$Sh = A \cdot Re^x \cdot Sc^y \cdot \Gamma \quad (3)$$

Exponents of degree and unknown coefficient A of dependence (3) were determined, and comparison of theoretically calculated values of boric acid dissolution concentration based on calculated dependence (3) with experimental data does not exceed 10%, which is quite acceptable for practical application.