



**Студенттер мен жас ғалымдардың  
Мансуров Батыр Зулхайрұлының құрметіне арналған  
“ХИМИЯЛЫҚ ФИЗИКА ЖӘНЕ НАНОМАТЕРИАЛДАР”  
атты III конференциясының еңбектер  
ЖИНАҒЫ**

**PROCEEDINGS  
of III Conference of Students and Young  
Scientists "CHEMICAL PHYSICS AND  
NANOMATERIALS" dedicated to the memory of  
Mansurov Batyr  
СБОРНИК ТРУДОВ**

**III конференции студентов и молодых ученых  
«ХИМИЧЕСКАЯ ФИЗИКА И НАНОМАТЕРИАЛЫ»,  
посвященной памяти Мансурова Батыра  
Зулхайрович**

Алматы 2018, Казахстан

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Алматы  
«Қазақ университеті»  
2018

## THE TEMPERATURE SENSITIVITY OR THERMAL BEHAVIOR OF STOICHIOMETRIC COMPOSITIONS AND THE LINEAR VELOCITY OF COMBUSTION

<sup>1,2</sup>Zh.K.Yelemessova., <sup>1,2</sup>B.T. Lesbayev., <sup>3</sup>Ruiqi Shen

<sup>1</sup>Al-Farabi Kazakh National University, Almaty

<sup>2</sup>Institute of Combustion Problems, Almaty

<sup>3</sup>Nanjing University of Science and Technology, China

[yelemessova.zh@mail.com](mailto:yelemessova.zh@mail.com)

Thermal behavior of  $\text{NH}_4\text{ClO}_4/\text{Mg}$  binary pyrotechnic mixtures heated in air was investigated by thermal analysis. Effects of oxygen balance and heating rates (5, 15 and  $20\text{ }^\circ\text{C min}^{-1}$ ) on the TG–DSC curves of mixtures were examined. Results showed that  $\text{NH}_4\text{ClO}_4/\text{Mg}$  had two separate exothermic processes, which corresponded to ignition and afterburning reactions, respectively. Exothermic peaks were influenced by both heating rates and the  $\text{NH}_4\text{ClO}_4/\text{Mg}$  ratios. When heating rates were increased, exothermic peaks of these two processes all shifted to higher temperatures. Compared with the stoichiometric composition  $\text{NH}_4\text{ClO}_4/\text{Mg}$  (58.8/41.2), the fuel-rich mixture  $\text{NH}_4\text{ClO}_4/\text{Mg}$  (50/50) had a lower peak ignition temperature, but the exothermic peak of afterburning reactions changed little. The ignition process was suggested to comprise five step overlapping reactions. The initial mass increase of samples heated in air revealed that the first step reaction was the oxidation of Mg by air. Reactions of four other steps were inferred based on published data on similar pyrotechnic systems. That is, the incomplete solid–solid reaction between  $\text{NH}_4\text{ClO}_4$  and Mg, the two-step decomposition of  $\text{NH}_4\text{ClO}_4$ , and the reaction of decomposition induced  $\text{O}_2$  with Mg. Apparent activation energies of the overall ignition process, afterburning process and individual reactions belonging to ignition process indicated that the whole combustion rate of  $\text{NH}_4\text{ClO}_4/\text{Mg}$  (58.8/41.2) in air was controlled by the afterburning process, and the solid–solid reaction of  $\text{NH}_4\text{ClO}_4$  with Mg was the controlling step in the ignition process. Fuel-rich  $\text{NH}_4\text{ClO}_4/\text{Mg}$  compositions were expected to obtain a better performance in practical applications in case of combusting in air.

Reaction kinetics of the two exothermic processes for the stoichiometric mixture was calculated using Kissinger method. Apparent activation energies for ignition and afterburning process were 153.6 and 289.5  $\text{kJ mol}^{-1}$ , respectively. A five-step reaction pathway was proposed for the ignition process in air, and activation energies for each step were also calculated. These results should provide reference for formula design and safety storage of  $\text{NH}_4\text{ClO}_4/\text{Mg}$ -containing pyrotechnics.

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