

KINETICS OF GRAPHENE OXIDE THERMAL DECOMPOSITION IN THE PRESENCE OF CARBON SUBOXIDE

Rūta Aukštakojytė¹, Justina Gaidukevič¹, Jurgis Barkauskas¹

¹ Institute of Chemistry, Faculty of Chemistry and Geosciences, Vilnius University, Naugarduko str. 24, LT-03225 Vilnius, Lithuania
ruta.aukstakojyte@chgf.vu.lt

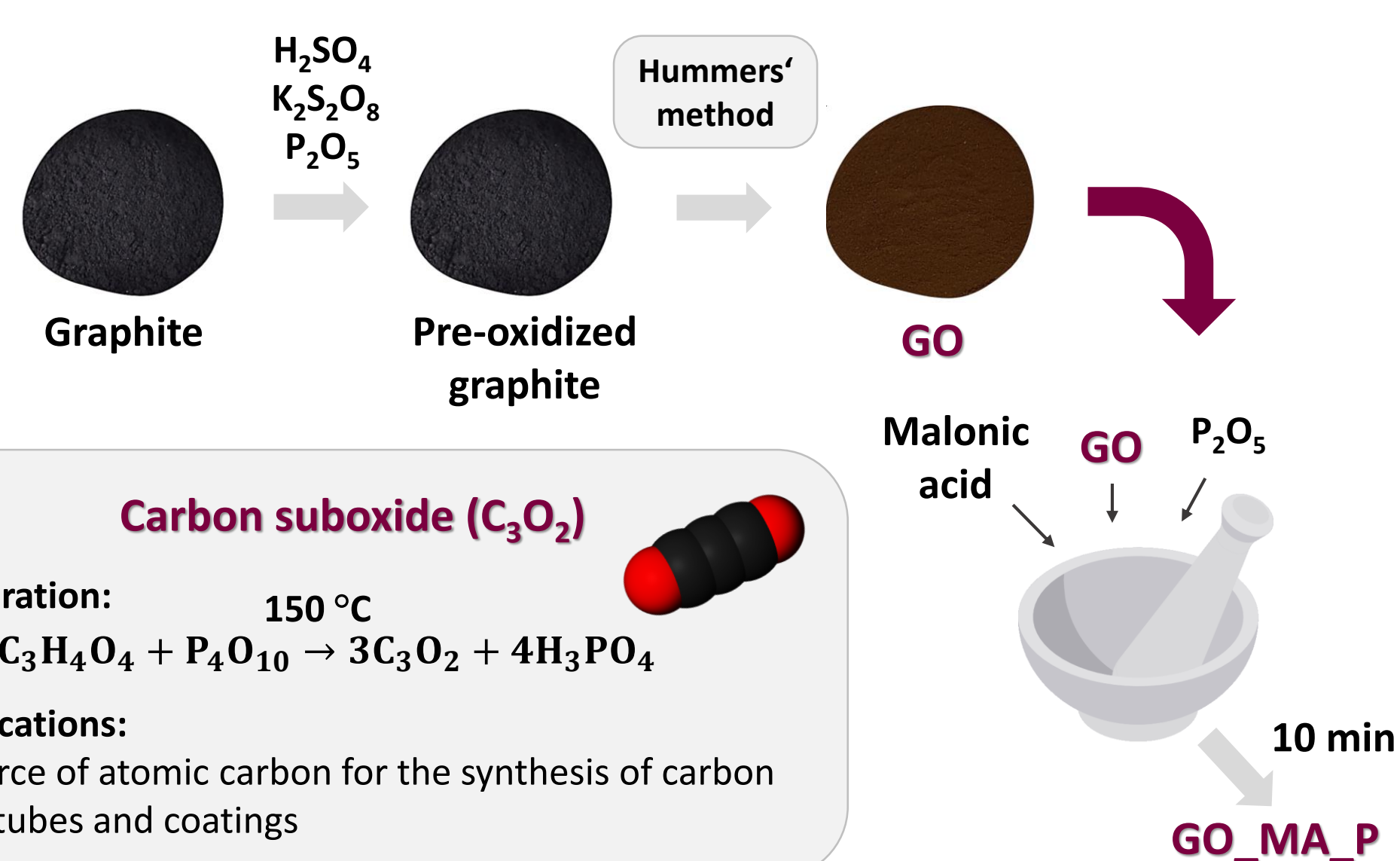


INTRODUCTION

Graphene is an allotrope of carbon that possesses unique thermal, chemical, electrical, optical, physical, and mechanical properties. It has broad application prospects in high-frequency electronics, water purification systems, semiconductor materials, drug carriers, flexible energy storage, and biosensing devices [1]. Nowadays, thermal reduction of graphene oxide (GO) is one of the potential synthesis methods to obtain graphene in a simple, low-cost, high yield, and time-saving way. However, GO is attributed to a class of energetic materials due to its high enthalpy change of thermal decomposition (ΔH). Thus, it could decompose violently if not properly stored and handled, and cause irreversible damage [2]. Furthermore, the mechanism of thermal reduction of GO is complex and not yet fully understood because of the consecutive stages of water evaporation, oxygen-containing functional groups removal, and basal-plane carbon decomposition occurring during the thermal exfoliation [3]. Therefore, it is necessary to focus on the kinetic analysis of GO thermal decomposition for a deeper understanding of the behaviour of the exothermic reduction reaction and ensuring safe manufacturing of graphene.

The aim of this study was to analyse the impact of **carbon suboxide (C_3O_2)** on the kinetics of GO thermal decomposition.

SYNTHESIS



KINETIC ANALYSIS

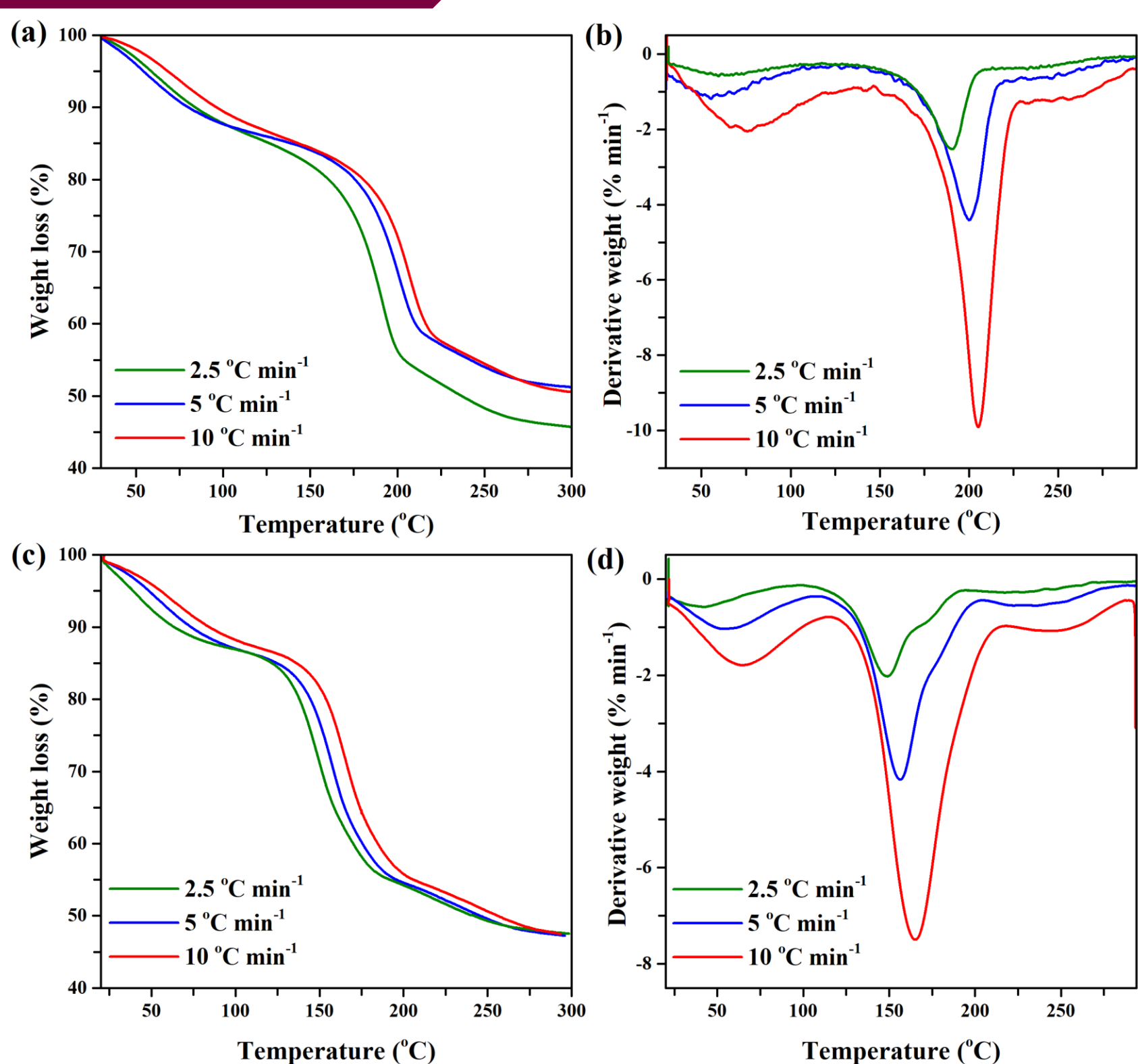


Fig. 1. TG curves of (a) GO and (c) GO_MA_P and DTG curves of (b) GO and (d) GO_MA_P at heating rates of 2.5, 5, and 10 °C min⁻¹.

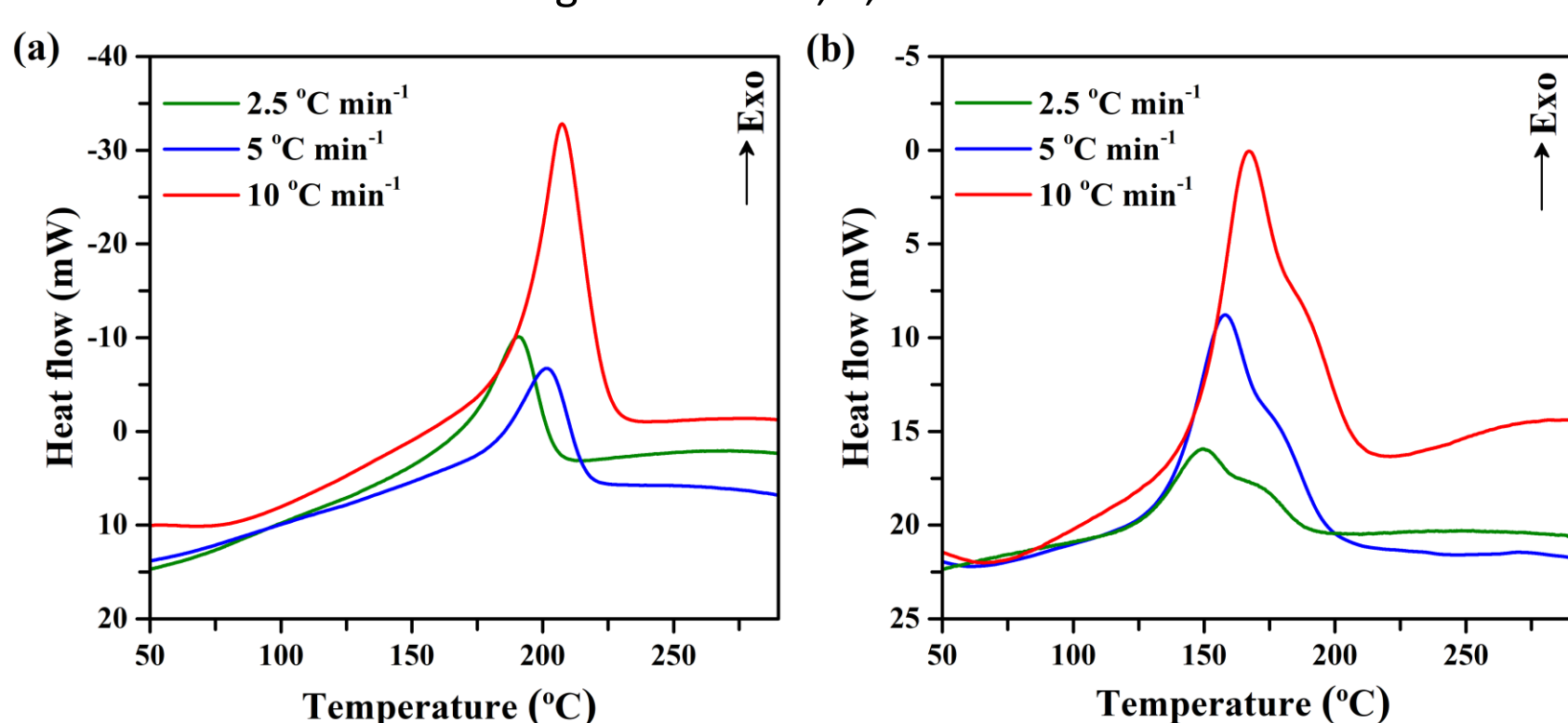


Fig. 2. DSC curves of (a) GO and (b) GO_MA_P at heating rates of 2.5, 5, and 10 °C min⁻¹.

Table 1. Parameters of DSC peaks and determined values of decomposition enthalpy at the heating rates of 2.5, 5, and 10 °C min⁻¹.

	β (°C min ⁻¹)	T_{onset} (°C)	T_m (°C)	ΔH (J g ⁻¹)
GO	2.5	166	190	1449.52
	5	173	201	1477.89
	10	186	207	1534.12
GO_MA_P	2.5	125	149	1083.47
	5	133	158	1169.65
	10	140	167	1296.88

Kinetic models

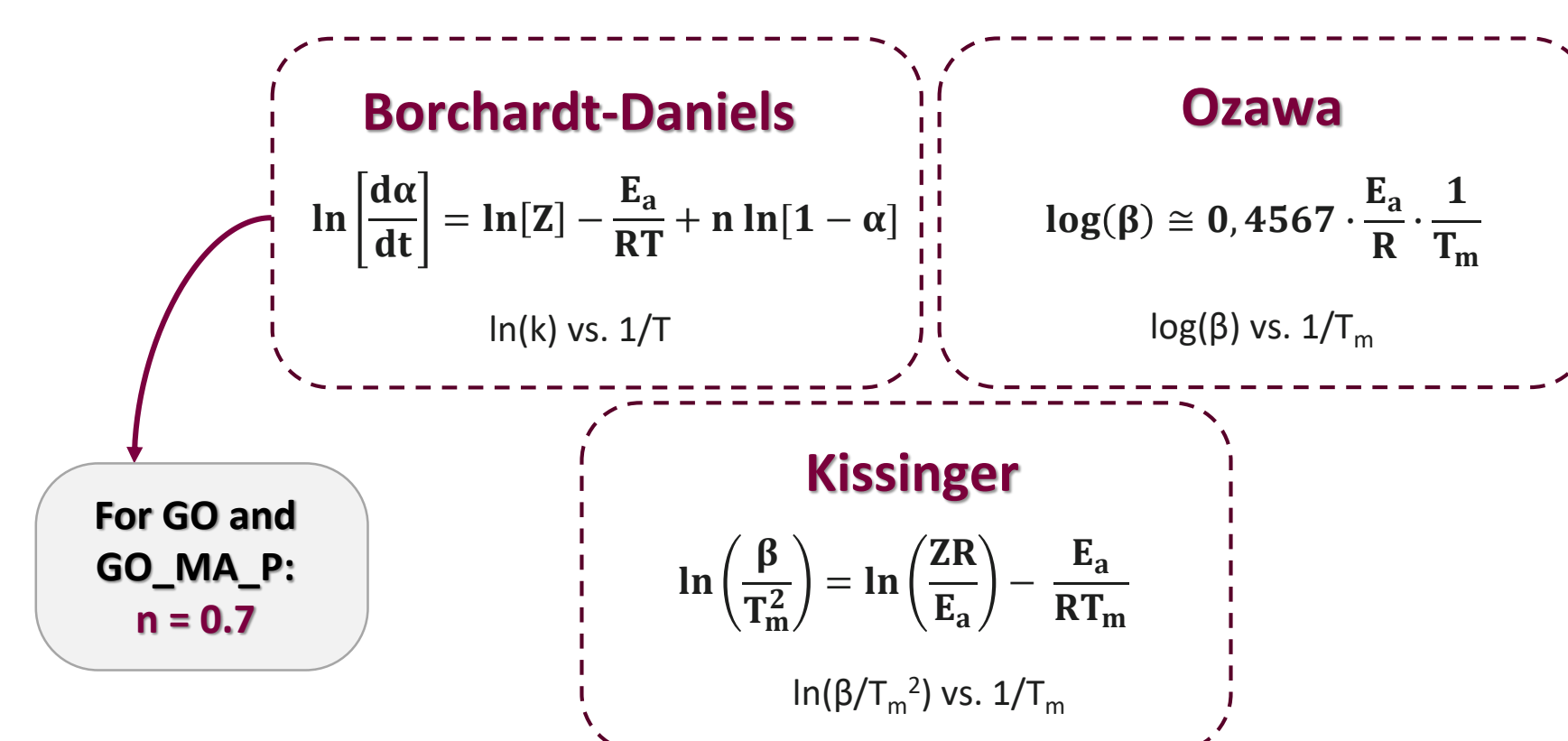


Table 2. Determined values of activation energy for GO and GO_MA_P by different kinetic models.

	Borchardt-Daniels			Ozawa		Kissinger	
	β (°C min ⁻¹)	E_a (kJ mol ⁻¹)	R ²	E_a (kJ mol ⁻¹)	R ²	E_a (kJ mol ⁻¹)	R ²
GO	2.5	134.9	0.9980	142.1	0.9713	141.5	0.9682
	5	137.8	0.9941				
	10	143.1	0.9931				
GO_MA_P	2.5	107.5	0.9991	115.2	0.9999	114.0	0.9999
	5	110.7	0.9948				
	10	115.8	0.9990				

CONCLUSION

DSC results revealed that the reduction temperature of GO is reduced (up to 125 °C) by using C_3O_2 . Moreover, it was observed that C_3O_2 lowers the enthalpy ΔH and activation energy E_a but does not influence the reaction order n of GO thermal decomposition. The values of E_a for the thermal deposition of GO and GO_MA_P were obtained similar by using all three methods (Kissinger, Ozawa and Borchardt-Daniels). Results obtained by Borchardt-Daniels method showed that the values of E_a increase with increasing the heating rate for both studied samples. The apparent reaction order n for both GO and GO_MA_P equals 0.7. In fact, the mechanism of this process can be modelled including simultaneous zero-order and first-order stages. The zero-order process may originate in the case when the energy consumed in the thermal decomposition reaction comes through the basal graphene plane; then the reaction rate should not depend on the reagent concentration (i.e., the concentration of functional groups). The first-order process may occur in the case when the energy is absorbed directly by a functional group; this time the reaction rate depends only on the concentration of the reagent. The same reaction order for GO and GO_MA_P reduction reveals the same mechanism for both processes.

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