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Gas-phase reactivity of CH_3OH+OH down to 11.7 K: Astrophysical implications

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Abstract. Methanol (CH_3OH) and hydroxyl (OH) radicals are two species abundant in cold and dense molecular clouds which are important for the chemistry of the interstellar medium (ISM). CH_3OH is a well-known starting point for the formation of more complex organic molecules (COMs) in these molecular clouds. Thus, the reactivity of CH_3OH in the gas-phase with OH may play a crucial role in the formation of species as complex as prebiotic molecules in the ISM and reliable rate coefficients should be used in astrochemical models describing low temperature reaction networks.

Keywords. Astrochemistry, methods: laboratory, ISM: molecules

1. Overview

Since the detection of CH_3OH in several objects of the ISM, astrochemical models have been used to interpret the observed abundances, taking into account all potential formation and depletion processes. The rate coefficient (k) for many gas-phase reactions is not known at temperatures as down as 10 K due to the difficulties of the experimental methods. Usually, k values used in these models are extrapolations from temperature dependencies reported at high temperatures. One of the potential depletion processes of methanol is the gas-phase reaction with OH radicals:

$$OH + CH_3OH \rightarrow \text{Products} \qquad \text{(R1)}$$

The rate coefficient for this reaction has previously been reported at $T = 20 - 202$ K (Antiñolo *et al.* (2016); Gómez-Martín *et al.* (2015); Shannon *et al.* (2013)). Since k has not been determined at temperatures closer to 10 K, Antiñolo *et al.* (2016) proposed an extrapolated value of $k(10\text{K}) = 1.1 \times 10^{-10}$ cm^3 molecule^{-1} s^{-1} to be used in astrochemical models.

In this work, we have revisited the kinetics of R1 extending the temperature range down to 11.7 K, the lowest temperature achieved until now using a pulsed CRESU apparatus (Jiménez *et al.* (2015)), and up to 177.5 K. Additionally to the determination

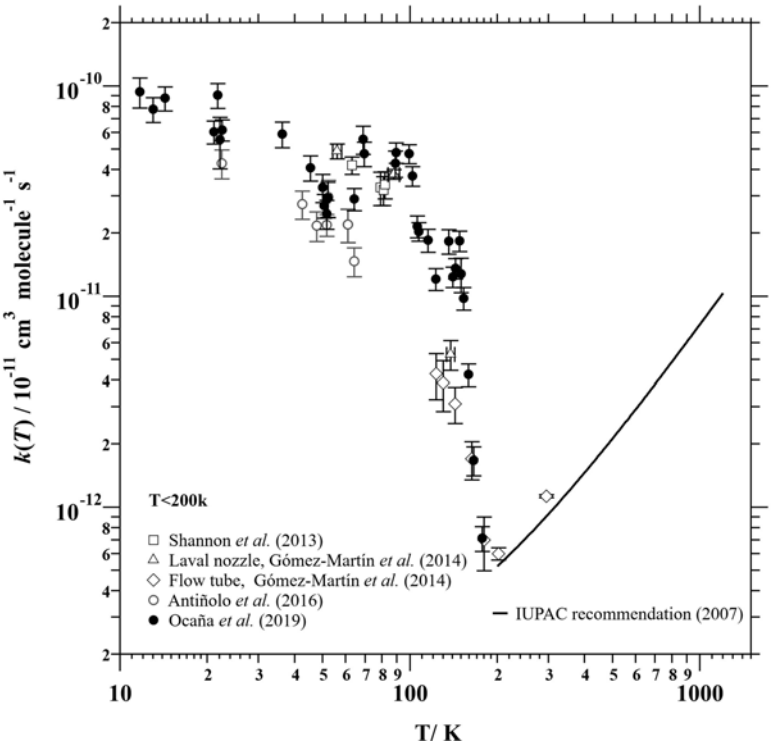

Figure 1. Kinetic behaviour of the CH_3OH + OH reaction.

of $k(T)$, we have studied the pressure dependence of $k(T)$ in a large range of gas densities (1.5×10^{16}–4.3×10^{17} cm^{-3}) by combining our results with those reported in previous works.

2. Results and astrophysical implications

It has been confirmed that $k(T)$ abruptly increases by almost 2 orders of magnitude from 177.5 K to around 100 K. At T<100 K, this increase is less pronounced, reaching the capture limit at temperatures below 22 K (Figure 1.) (Ocaña *et al.* (2019)).

Despite the presence of CH_3OH in the ISM has been known for decades, there is still a debate on what processes release methanol into the gas phase from the grains once it is formed and what its depletion routes are. Our results show the efficiency of one of the potential depletion reactions of methanol in the gas-phase which is a key issue to model the abundance in different interstellar environments.

These results, combined with observations, theoretical studies and solid-phase studies would help to improve/ shed light on the interpretation of observed abundances not only of CH_3OH but also all molecules which are present in chemical networks as, for example, CH_3O radical, CH_3OCH_3, CH_3OCH_2 radical and $HC(O)OCH_3$ (Balucani *et al.* (2015)).

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