

# Activation Energies for the Reaction Rates of Muonium with Alkanes: the $\text{Mu} + \text{C}_3\text{H}_8 \rightarrow \text{MuH} + \text{C}_3\text{H}_7$ Reaction

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In a recent paper [1], the reaction rate for the  $\text{Mu} + \text{C}_3\text{H}_8$  reaction was measured at the ISIS pulsed muon source [2] of the Rutherford Appleton Laboratory by a radio-frequency (RF) resonance technique, which followed the development of the diamagnetic final state. The reaction rate was expected to be too slow, except at high pressures, to be determined by the standard TF- $\mu$ SR method [3]. Our RF measurement gave the rate constant  $k_{\text{Mu}} = (6.8 \pm 0.5) \times 10^{-15} \text{ cm}^3 \text{ s}^{-1}$  at 300 K, surprisingly fast for this H-abstraction reaction when compared to previous results for the  $\text{Mu} + \text{CH}_4$  and  $\text{Mu} + \text{C}_2\text{H}_6$  reactions [3], and with the predictions of elementary TST. This, in turn, suggested that the activation energy,  $E_a$ , for the  $\text{Mu} + \text{C}_3\text{H}_8$  reaction should be very much less than for reactions of Mu with either methane or ethane, prompting a further study of the temperature dependence. At higher temperatures and even, as it turned out, down to 300 K, the reaction rate was measurable by the TF- $\mu$ SR technique after careful attention was paid to “gettering”  $\text{O}_2$  from both the propane and nitrogen gases. This allowed us to bypass the systematic errors that can occur in the RF technique [1], to give the results shown in Figure 1.

The slope of this Arrhenius plot gives  $E_a = 3.5 \pm 0.2 \text{ kcal/mol}$  (0.15 eV), to be compared with 1.07 eV and 0.67 eV for the  $\text{Mu} + \text{CH}_4$  and  $\text{Mu} + \text{C}_2\text{H}_6$  reactions [3], respectively. We note that the value measured for propane is much smaller than for other alkane reactions, a result in accord with suggestions made in [1] of a large Mu tunnelling contribution in this reaction. These results, together with a comparison with their isotopic analogue  $\text{H} + \text{alkane}$  reactions, will be discussed.

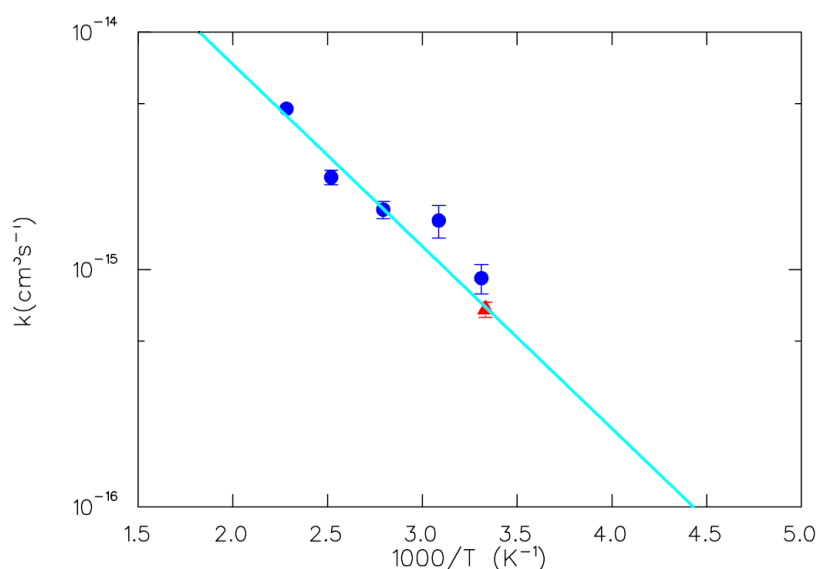


Figure 1: Standard Arrhenius plot for the  $\text{Mu} + \text{C}_3\text{H}_8$  reaction, solid blue points determined by the TF- $\mu$ SR technique from recent experiments at ISIS, solid red point from the RF measurements reported earlier at 300 K [1].

## References

- (1) Fleming, D.G. et al., *Phys. Chem. Chem. Phys.* **2015**, 17, 19901
- (2) Giblin, S.R. et al., *Nucl. Instrum. Methods Phys. Res. Sect. A* 2014, 751, 70
- (3) Snooks, R. et al., *J. Chem. Phys.* **1995**, 102, 4860