

Shock Tube Study of the Ignition of Propane at intermediate Temperatures and high Pressures

Jürgen Herzler, Ludger Jerig, and Paul Roth

Institut für Verbrennung und Gasdynamik

Gerhard-Mercator-Universität Duisburg, 47048 Duisburg, Germany

Corresponding author: Paul Roth, e-mail: Roth@ivg.uni-duisburg.de

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The ignition delay times of lean ($\Phi = 0.5$) propane-air mixtures were measured in the temperature range of 900 to 1300 K at 10 and 30 bar, respectively. The results are in very good agreement with measurements of Cadman et al. [1]. The experiments confirm their findings that the activation energy of the ignition delay time decrease at around 1000 K and a linear extrapolation is not possible. It seems that the reaction schemes used in literature cannot predict the ignition delay times at these low temperatures.

1. Introduction

Propane is the simplest hydrocarbon used as fuel. It is a component of natural gas and is also used as jet fuel and as vehicle fuel in the form of LPG (liquefied petroleum gas). Ignition delay time measurements help to identify the rate determining steps of propane oxidation during the ignition period. In the present work the ignition delay times have been measured in the intermediate temperature region at elevated pressures up to 30 bar. The aim of the study was to investigate whether changes in activation energy and a negative temperature dependence (NTC) for the ignition delay time occurs in analogy to other hydrocarbons. This

behaviour is quite probable because changes in activation energy have been found for the propane oxidation rates [2] and the combustion of propane-air mixtures in a flow reactor [3]. Ignition delay measurements in a shock tube have the advantage of very rapid heat-up of the test gas with advantages compared to rapid compression machines. The necessary long ignition delay times in the intermediate region were realized by tailoring the driver gas thus avoiding the reflection of the reflected shock at the contact surface.

2. Experimental Section

The experiments were carried out in a high pressure shock tube with an internal diameter of 90 mm. It is divided by an aluminium diaphragm into a driver section of 6.1 m and a driven section of 6.4 m in length. The driven section can be baked out and pumped down to pressures below 10^{-5} mbar by an oil diffusion pump. Gas mixtures were prepared manometrically in a stainless storage cylinder, which also could be baked out and evacuated using a separate oil diffusion pumping unit. The purity of the used oxygen was better than 99.998 %, of nitrogen better than 99.996 % and of propane better than 99.5 %. He or mixtures of 7.5 and 8.5 % Ar in He were used as driver gas.

The ignition delay times were recorded by measuring pressure profiles with a piezo-electric gauge (PCB HM 112 A03) located next to the end flange. Also, the CH* emission at 431.5 nm was measured with a photomultiplier after passing a narrow band filter.

3. Results

The temperature range of the present propane ignition delay study was 900 to 1300 K at pressures of about 10 bar and 30 bar, respectively. Mixtures of 2.1 % propane, 20.6 % O₂ and 77.3 % N₂ ($\Phi=0.5$) were used. Typical pressure and CH* emission profiles at about 1000 K

and 10 and 30 bar, respectively, are shown in Fig. 1. The pressure signal of the experiment at 10 bar (Fig.1 a)) shows a fast increase due to the reflected shock wave at time zero, a constant pressure for about 2.3 ms and then a relatively weak increase by the mild ignition. The CH* emission (Fig. 1 b)) remains at zero level until the ignition occurs. Then a relatively slow increase of the emission simultaneously to the pressure rise can be observed. The experiment at 33 bar shows a much stronger ignition. A fast and large pressure increase can be observed (Fig. 1 c)). The emission signal (Fig.1 d)) also shows a much faster rise and is more intense compared to the signal at 10 bar. The delay times determined with the pressure profiles and the emission signals were identical.

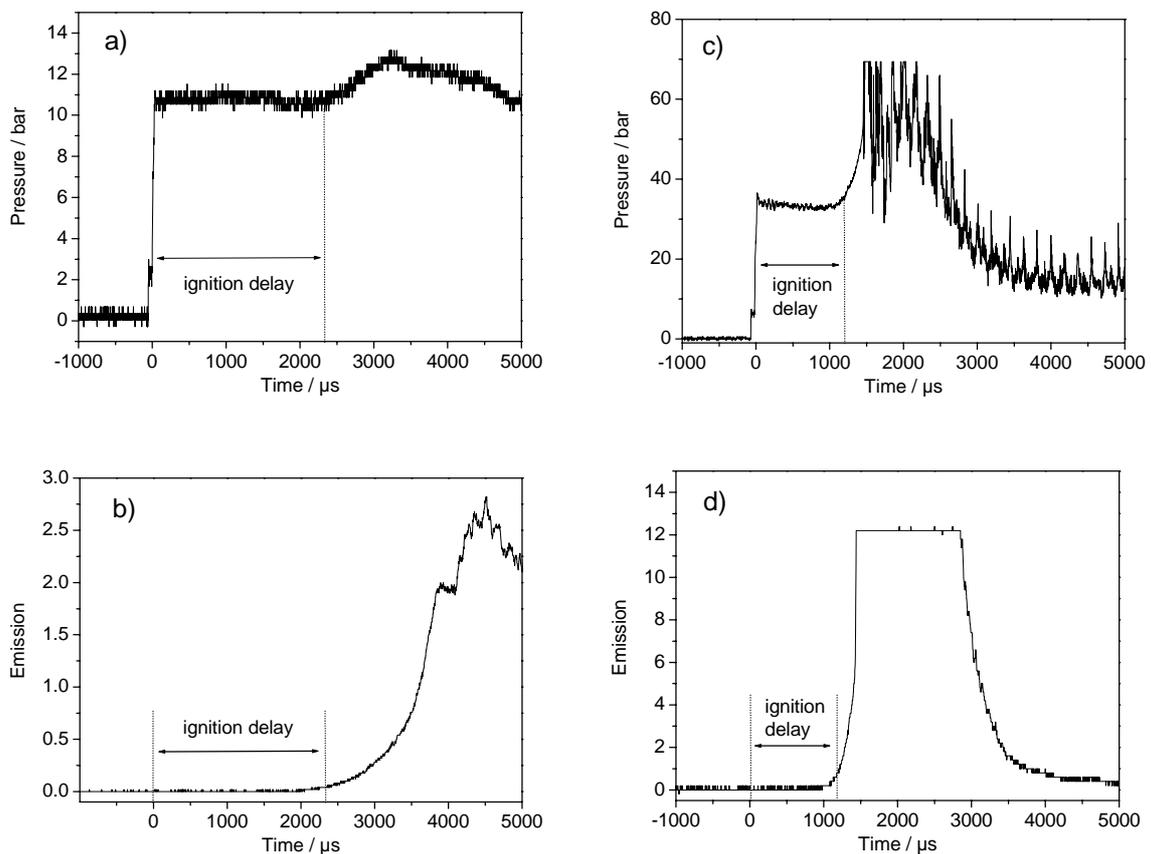


Figure 1: Typical pressure and emission profiles obtained for 2.1 % C_3H_8 , 20.6 % O_2 and 77.3 % N_2 ($\phi=0.5$). a), b): $T_5 = 995$ K, $p_5 = 10.7$ bar, c), d): $T_5 = 1040$ K, $p_5 = 33.4$ bar

4. Discussion

The individual ignition delay times evaluated from both the pressure increase and the CH emission signals are summarized in Figs. 2 and 3. The results obtained for the 10 bar experiments are in good agreement with the data of Cadman et al [1], see lines. Our data at 30 bar support the findings of [1] that a decrease in activation energy occurs around 1000 K and a linear extrapolation is not possible. This strong decrease in activation energy cannot be simulated with reaction schemes from literature, see [1].

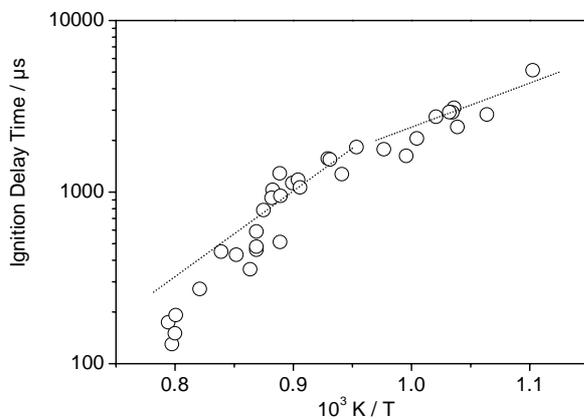


Figure 2: Measured ignition delay times for 2.1 % C_3H_8 , 20.6 % O_2 and 77.3 % N_2 at pressures of about 10 bar. Dotted lines: data of Cadman et al. [1].

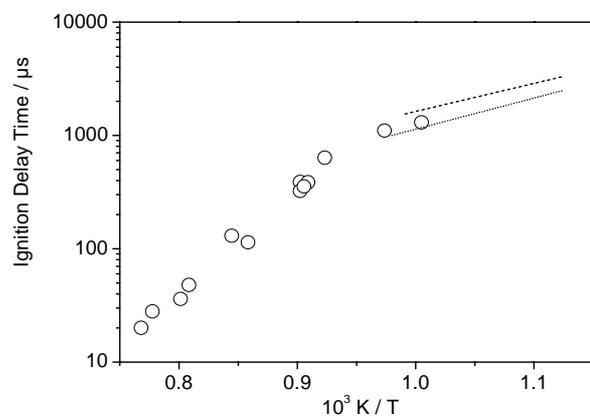


Figure 3: Measured ignition delay times for 2.1 % C_3H_8 , 20.6 % O_2 and 77.3 % N_2 at pressures of about 30 bar. Dotted and dashed lines: data of Cadman et al. [1] for 20 and 40 bar.

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