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<tr>
<td>Author(s)</td>
<td>Teranishi, Hiroshi</td>
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<tr>
<td>Citation</td>
<td>The Review of Physical Chemistry of Japan (1956), 25(2): 58-63</td>
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<tr>
<td>Issue Date</td>
<td>1956-02-20</td>
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<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2433/46730">http://hdl.handle.net/2433/46730</a></td>
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<tr>
<td>Type</td>
<td>Departmental Bulletin Paper</td>
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<td>Textversion</td>
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Kyoto University
STUDIES ON THE EXPLOSIONS UNDER HIGH PRESSURES, III

The Explosions of Acetylene mixed with Oxygen or Air

and the Effects of Pressure and of Added Substances

BY HIROSHI TERANISHI

Introduction

In the previous paper, Kiyama, Osugi and Teranishi reported on the explosions of acetylene mixed with oxygen under high pressure and the effects of added substances, i.e. carbon tetrachloride and water, to the explosion limits, and also reported briefly on the results of the preliminary experiments on the explosions of acetylene mixed with air\(^1\). In the present paper the author will mention on (1) the correctional results of the effect of water on the explosion limits of acetylene—oxygen mixtures, (2) the effect of methanol on the explosion limits of acetylene—O\(_2\) mixtures, (3) the explosion limits of acetylene—air mixtures, and (4) the effect of pressure on the explosion limits of acetylene mixed with air or oxygen.

Experiments

The experimental apparatus and the procedures are as described in the previous paper. The reaction gases are mixed and stored in the steel reservoir of about 55 cc in capacity, and then the gas mixtures are poured rapidly into the reaction vessel (4 cm and 1 cm in outer and inner diameters respectively and 9.42 cc in capacity) which is previously evacuated and heated to a given temperature. The occurrences of explosions at a given pressure in the reaction vessel are perceived by the sound and are observed by means of a membrane pressure gauge. The membrane pressure gauge\(^2\) is constructed with a spring steel membrane (0.8~3.0 mm in thickness and 44 mm in effective diameter) and a mirror which rotates proportionally to the deflection of the membrane due to pressure change. The pressure changes are measured from the displacements on a scale of light spot reflected from the mirror and also recorded with time by means of a wire resistance strain meter and an electromagnetic oscillograph. The strain meter measures the changes of the electric resistance of the gauge which is cemented on the membrane of the pressure gauge. In the experiments of the effects of added substances, about 15 cc of water or methanol is stored in the reservoir of gas mixture and the vapor is mixed with the reaction gas.

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Experimental Results and Considerations

The effect of water on the explosion limits of acetylene—oxygen mixtures

As described in the previous paper, the violence of the explosion of C₂H₂—O₂ mixture seems to become severer when water vapor is added. It was, therefore, favorable to make the connecting pipe line between the reaction vessel and the reservoir of gas mixture fine and long for the explosion to be prevented from propagating to the reservoir. However, a doubt was arisen on the mixing of reaction gases in the connecting pipe. Therefore the mixing has been re-examined and the correctional experiments have been performed to determine the effects of water.

The results of the experiments on the explosion limits of C₂H₂—O₂ mixtures under such conditions as the total pressure is 10 kg/cm² and the partial pressure of the water is 0.02—0.03 kg/cm² are shown in Fig. 1. Curve a shows the explosion limits of C₂H₂—O₂ mixtures without any added substance, curve b shows the limits in the presence of the water vapor reported in the previous paper, and the shaded part shows the results of the correctional experiments. Comparing the latter with curve c, that is the limits in the presence of CCl₄ vapor whose partial pressure is about 0.15 kg/cm², it is shown that in the cases of adding H₂O, even though whose vapor pressure is one-seventh of that of CCl₄, the temperatures of explosion limits are almost equally elevated as in the cases of adding CCl₄.

![Graph showing explosion limits](image)

**Fig. 1** The explosions of acetylene-oxygen mixtures when added H₂O

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<td>(total pressure: 10 kg/cm²)</td>
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**Fig. 2** The explosions of acetylene-oxygen mixtures when added CH₃OH

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The effect of methanol on the explosion limits of acetylene—oxygen mixtures

In the same manner as in the cases of adding CCl₄ and H₂O, the measurements have been performed on the effect of adding CH₃OH to the explosion limits of C₂H₂—O₂ mixtures. Aldehydes having been removed, about 15 cc of CH₃OH are distilled and
stored in the gas reservoir and its partial pressure is 0.17〜0.2 kg/cm² in the reaction gas.

The results of the experiments under 10 kg/cm² of total pressure are shown by the shaded part in Fig. 2. Comparing with the limits of C,H₂—O₂ mixtures without any added substance (curve a), no effect is observed except under such conditions as the partial pressure ratio is C₄H₁₂/O₂>2/1, where the added methanol elevates the limits by a degree slightly higher than 10°C, that is higher than the accuracy of determining the temperature of explosion limits. Methanol itself, on the contrary to CCl₄ and H₂O, is combustible in oxygen atmosphere but the oxidation process is not elucidated clearly. The thermal ignition temperature of methanol (461〜555°C at 1 atm³) is higher than that of C₂H₆. Although the effect of methanol can not be discussed exactly but the experimental results show neither elevating nor descending effect on the temperature of explosion limits of C,H₂—O₂ mixtures.

Explosion limits of acetylene—air mixtures In the previous paper, it was reported that the violence of the explosion of C₂H₂—air mixture was much weaker than that in the case of C₂H₂—O₂ mixture, and the occurrence of the explosion could scarcely be perceived neither by the sound nor by the displacement of the light spot on the scale, and yet could be determined from the pressure change curve which was recorded by means of the strain meter and electromagnetic oscillograph. A few results of the preliminary experiments were reported, but reliable explosion limits were not yet determined in the previous paper. Therefore a number of ex-

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3) B. P. Mullins, Spontaneous Ignition of Liquid Fuels, p. 67 (1955)
experiments have been performed, taking care of the complete mixing of \( \text{C}_2\text{H}_2 \) and air, to determine the explosion limits.

The results of the experiments under the total pressure of 10~12 kg/cm\(^2\) are shown in Fig. 3. The explosion limits can be determined clearly and become a smooth curve. The minimum temperature of the limits, 230~240°C under the condition of \( \text{C}_2\text{H}_2/\text{air} = 1/5~1/2 \) is about 150°C lower than that reported by Rimarski and Konschak\(^4\) for the explosion under 1 atm, and this difference, as will be described in the next section, is due to the effect of the total pressures of the reaction gases. Converting the results into the figure where the ratios of partial pressure of \( \text{C}_2\text{H}_2 \) to that of \( \text{O}_2 \) in air are taken as abscissa, the explosion limits of \( \text{C}_2\text{H}_2-\text{air} \) mixtures are shown by the shaded part in Fig. 4 A. The minimum temperature which is found under the condition that \( \text{C}_2\text{H}_2/\text{O}_2 \) is about 1, shows no difference from that of \( \text{C}_2\text{H}_2-\text{O}_2 \) mixture (curve a). The sums of the partial pressures of \( \text{C}_2\text{H}_2 \) and \( \text{O}_2 \) are about 4 kg/cm\(^2\) in the \( \text{C}_2\text{H}_2-\text{air} \) mixture and 10 kg/cm\(^2\) in the \( \text{C}_2\text{H}_2-\text{O}_2 \) mixture, but in the former mixture \( \text{N}_2 \) is contained and the total pressure is 10 kg/cm\(^2\). Under the condition of the total pressure 10 kg/cm\(^2\), the differences of the explosion temperatures between the both curves is not observed. Converting also the results into the figures where the percentages of the content of \( \text{O}_2 \) and \( \text{C}_2\text{H}_2 \) are taken as abscissa respectively, the explosion limits of \( \text{C}_2\text{H}_2-\text{air} \) mixtures are shown by the shaded parts in Fig. 4 B and Fig. 4 C respectively. In both

![Fig. 4 C The explosions of acetylene-air mixtures abscissa taken as the percentage of \( \text{C}_2\text{H}_2 \)](image)

![Fig. 4 B The explosions of acetylene-air mixtures abscissa taken as the percentage of \( \text{O}_2 \)](image)

\(^4\) W. Rimarski and M. Konschak, *Azetylen in Wiss. und Ind.*, 31, 24 (1928)
figures, curves a show the explosion limits of C₂H₂—O₂ mixtures. In Fig. 4 B, both curves show the minimum temperatures at the composition of about 16% O₂, where C₂H₂/O₂ is 1 and the sum of the partial pressures of C₂H₂ and O₂ is 4kg/cm² for the C₂H₂—air mixture, and C₂H₂/O₂ is 5/1 and total pressure is 10kg/cm² for C₂H₂—O₂ mixture. The former mixture contains a large amount of N₂ and the latter contains excess amount of C₂H₂. Comparing both limits, in the O₂ poor range, it is shown that the explosion limits are elevated when the excess of C₂H₂ is replaced by N₂ under the condition of constant contents of O₂ and the constant total pressure. On the other hand, in the C₂H₂ poor ranges, the explosion limits for C₂H₂—air mixtures are, as shown in Fig. 4 C, lower than that for C₂H₂—O₂ mixture under the same content of C₂H₂. From this fact the explosion limits are descended when the excess amount of O₂ is replaced by N₂.

Effect of pressure on the explosion temperature of acetylene mixed with air or oxygen The relations between total pressures and explosion temperatures have been measured, and the results on the gas mixtures of C₂H₂/air=1/1 and of C₂H₂/O₂=1/1 are shown in Figs. 5 and 6 respectively. In these figures the plots at 1kg/cm² are cited from the results by Rimarski and Konschak's measurements and they coincide with the extrapolations of the curves of the present results and the results of the present experiment on the C₂H₂—air mixture coincide with those by Schlapher and Brunner5 on the explosion of the mixture under up to 2.5 atm. The curvature of the curve of explosion temperature against the total pressure is larger in the case of C₂H₂—O₂ mixture than in that of C₂H₂—air mixture.

As described above, the violence of explosion of C₂H₅—air mixture was much weaker than that of C₂H₅—O₂ mixture, and even under the severest condition of the present experiment where the total pressure was 27.5 kg/cm², the maximum pressure of explosion was 58 kg/cm² and the sound of the explosion was scarcely heard. On the other hand, in the case of C₃H₈—O₂ mixture, the sound was clearly heard even in the explosion under the total pressure of 3 kg/cm². Though the effect of N₂ on the explosion limits is not yet so clearly elucidated as in the cases of CCl₄ and H₂O, but the addition of N₂ is considered to retard the propagation of the explosion.

The author has great pleasure in expressing his sincere thanks to Prof. Ryo Kiyama and Dr. Jiro Osugi for their valuable guidance and encouragement throughout the course of this work, and the author is indebted to the Department of Education for the Grant in Aid for Fundamental Scientific Research shared out Prof. Ryo Kiyama.

*The Laboratory of Physical Chemistry, Kyoto University*