Enhancement of plasma generated H_2O_2 in water by the addition of ethanol

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We are exploring the potential to develop plasma-induced chemistry in the liquids, specifically salt solutions, by the addition of organic molecules to the solutions. We have observed that the hydrogen peroxide production can be enhanced by the addition of ethanol. We are developing chemistry models to inform and explain our present results and future approaches.

Plasma generation in liquids has became a widely studied topic in the past few years with most of the interest in water or inorganic solutions [1-3]. Electrical discharges are found to produce chemical changes in the liquids in which they are created. In high conductivity liquids, discharges can be produced at relatively low applied voltages (~200 V). Here we explore potentially new plasma-induced chemistry in such liquids initiated by the addition of organic molecules.

The plasmas are created with a multielectrode configuration driven with 100 kHz RF bipolar, square wave voltage. The electrical behaviour of the system is determinated by a variety of factors that influence the, often time-varying, impedance of the system. This tends to be dominated by the creation and behaviour of the vapour phase which is where the plasma is initiated. The vapour phase creation in turn depends on the properties of the liquid including its conductivity and temperature. Chemical changes in the liquid can be induced by various reactive chemical species (atoms and radicals, both also in excited states), charged particles and radiation generated by the plasma and crossing the vapour-liquid interface.

The work to be reported here has focused on solutions of 0.15 M NaCl and 0.15 M KCl in distilled water which have conductivities of 13.8 $mS.cm^{-1}$ and 15.3 $mS.cm^{-1}$ respectively. In these liquids, discharges can be readily produced when 0.05 ml of ethanol is added into 20 ml samples. The ethanol, as a primary alcohol, should be oxidized to acetic acid by atomic oxygen which is present in the plasma and may penetrate into the liquid.

The effect of the ethanol and time of liquid exposure to the plasma on the liquid pH, conductivity c and hydrogen peroxide concentration have been studied. The pH values has been measured using HI 9124 pH meter and the conductivity with an HI 9033 meter. The hydrogen peroxide concentration was determined by UV-VIS absorption spectroscopy. The hydrogen peroxide gives a yellow complex in reactions with a titanium reagent so there is an absorption maximum for this complex at 407 nm [4]. Since the plasma production involves vapour phase creation the liquid temperature is also monitored.

We find enhanced hydrogen peroxide generation when 0.25 % of the ethanol is added into the studied solutions. In addition there is a pronounced decrease in the pH of the liquid.

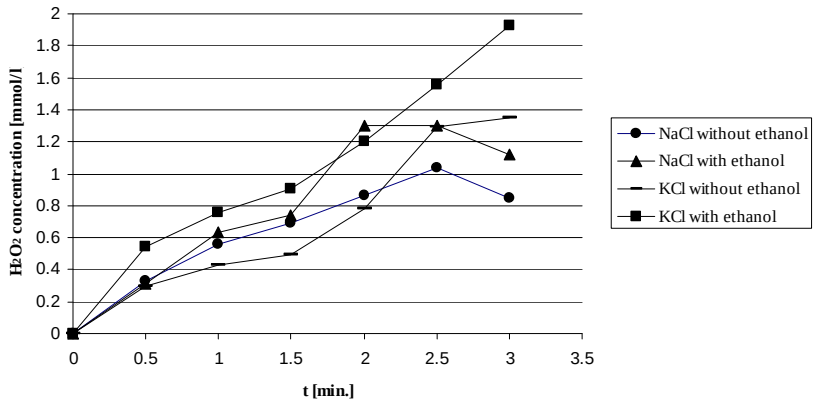

Fig. 1: Hydrogen peroxide generation in time.

We soppose that the ethanol, as an organic molecule, can be dehydrogenated by energetic plasma electrons to produce hydrogen atoms [5] which can support the hydrogen peroxide generation according following equations [6].

$$H + H_2O^* \rightarrow H_2 + OH \quad (1)$$

$$OH + H_2O^* \rightarrow H_2O_2 + H \quad (2)$$

Work to clarify the role of other theoretical pathways for ethanol enhancement of hydrogen peroxide generation is underway.

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