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# VOC oxidation in excess of oxygen using flow-through catalytic membrane reactor

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ABSTRACT

Platinum gamma-alumina (Pt/$\gamma$-$Al_2O_3$) impregnated membrane was prepared through the evaporative-crystallization deposition method for volatile organic compounds (VOCs) conversion to carbon dioxide ($CO_2$) and water ($H_2O$). The catalytic oxidation of VOCs (propane, n-butane and propylene), fed alone with oxygen were obtained after characterization (SEM-EDXA observation, BET measurement, permeability assessment). VOC conversion of 95%, 52% and 82% for propane, n-butane and propylene was achieved at 378 °C, 245 °C and 420 °C respectively, by varying the reaction temperature using the contactor flow-through catalytic membrane reactor operating in the Knudsen flow regime. The BET surface area and the pore diameter of the 3.52 wt% Pt membrane are 0.426 $m^2$/g and 3.70 nm respectively. The results are comparable with the literature.



## Introduction

VOC abatement is a great challenge and of paramount importance to the process industry [1]. Some common VOCs are listed in Table 1 [2–4]. Besides the more established VOC abatement processes, destruction of VOC to form $CO_2$ and $H_2O$ (Fig. 1) has been widely studied using membrane reactors (MRs) [5–12].

A membrane reactor is a process which combines reaction and separation in a single unit [13]. They can be made from different materials such as metals, ceramics and polymers. Different definitions exist for MRs [14]. The International Union of Pure and Applied Chemistry (IUPAC) define a membrane reactor as a device for simultaneously carrying out a reaction and membrane-based separation in the same physical enclosure [15]. According to a wider definition any reactor in which a chemical reaction is performed in presence of a membrane is called membrane reactor [16]. The application of membrane reactors have received a lot of attention over the past five decades and quite a large number of papers have been published on the subject [17–21]. The membrane can also be used as an active candidate in a chemical conversion for increasing the reaction rate, selectivity and yield [17]. The interest of membrane reactors has been demonstrated at the laboratory scale for dehydrogenation, hydrogenation, decomposition and oxidation reactions among others [17]. The concept has yet to be used widely for industrial applications although some small industrial installations already exist. The drawback for commercial development of membrane reactors are the membrane themselves, their support and issues such as performance, cost and stability among others which still need to be optimized [17].

In recent years, the concept applied in the combination of membranes and reactors is being proposed. The concept is

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**Table 1 – Some common VOCs [2–4].**

| Number | VOCs |
|---|---|
| 1 | Acetaldehyde |
| 2 | Acetamide |
| 3 | Acetone |
| 4 | Acetonitrile |
| 5 | Benzene |
| 6 | Benzyl chloride |
| 7 | Carbon tetrachloride |
| 8 | Cyclohexane |
| 9 | Ethyl acetate |
| 10 | Ethylene glycol |
| 11 | Formaldehyde |
| 12 | Heptane |
| 13 | Hexane |
| 14 | Isopropyl alcohol |
| 15 | Methyl ethyl ketone |
| 16 | Methylene chloride |
| 17 | Naphthalene |
| 18 | Propylene |
| 19 | Styrene |
| 20 | Toluene |

classified into three groups namely; extractor, distributor and contactor which are related to the role of the membrane in the process [17]. Extractor mode is used to selectively remove the product(s) from the reaction mixture. Distributor mode is used to control the addition of reactants to the reaction mixture. And lastly, the contactor mode used to intensify the contact between reactants and the catalyst. The active contactor mode membrane reactor involves a forced flow-through membrane reactor, where the membrane acts as a diffusion barrier and is catalytically active [17,18]. This type of membrane is used to provide a reaction space where the catalyst is deposited inside the membrane pores. The catalyst-membrane arrangement leads to high catalytic activity [1,18].

The forced flow-through contactor mode has been widely employed by many researchers in the total oxidation of VOCs [5,22–32]. Our aim is to investigate the catalytic oxidation of propane, n-butane and propylene as a chemical reaction using membrane catalysts prepared via an evaporative-crystallization deposition method. The influence parameters such as platinum (Pt) loading, total gas flow rate, VOC concentration, oxygen content and conversion reaction temperature were examined.

## Experimental procedure

### *Materials*

Commercially available tubular porous alumina supplied by Ceramiques Techniques et Industrielles (CTI SA) France was used in this study. The tubular alumina possesses an internal and outer diameter of 7 and 10 mm respectively, with a permeable length of 348 mm and a porosity of 0.45. The support was found to be defect free after characterization.

### *Membrane preparation*

Hexachloroplatinic acid solution ($H_2PtCl_6$) was impregnated into the tubular alumina using dip-coating method. The tubular support was first dried at 65 °C. The support was dipped for 2 h in deionised water before Pt introduction. The deposition procedure used was based on evaporation-

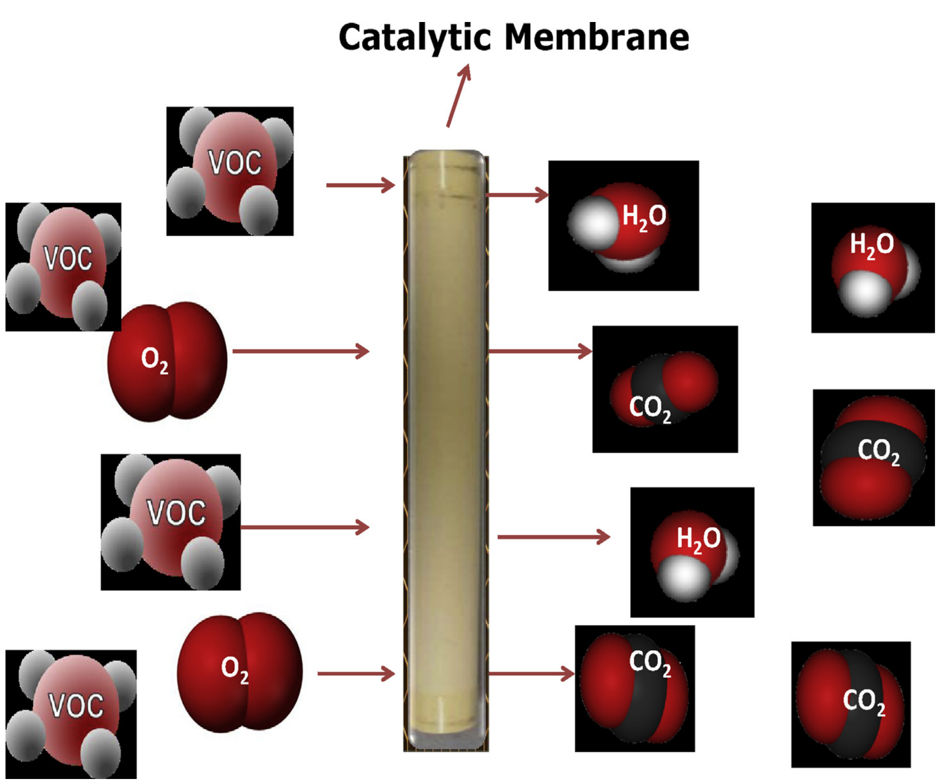


**Fig. 1 – Flow-through catalytic membrane reactor.**