

INVESTIGATION ON PROCESS VARIABLES AFFECTING BIOHYDROGEN CONCENTRATION USING A COMMERCIAL GAS SEPARATION MEMBRANE

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ABSTRACT

In this work biohydrogen recovery measurements were performed by using a commercial polyimide membrane module – product of UBE Industries Ltd. – in mixed gas experiments. The impact of major process variables (gas composition, temperature, ratio of retentate and feed flow) on real selectivity was sought by statistical experimental design. It was found that all the parameters tested could considerably influence the attainable selectivity. It was also shown that the theoretical and real separation factors were significantly dissimilar. Nevertheless, in comparison with other commercially available membranes the module used possessed potential for hydrogen purification.

The research on environmental-friendly and renewable energy sources has gained considerable attention in the recent decades [1]. Among possible alternatives, hydrogen is highly promising and can play a key role in sustainable economical growth due to its carbon neutral characteristic. Moreover, it has the highest energy content (122 MJ/kg) of all the known fuels – excluding nuclear energy carriers – on gravimetric base. However, the annual hydrogen consumption is presently being satisfied through the conversion of traditional, fossil-based chemical substances such as methane [2]. Therefore, H₂ generation needs green technologies to be developed in order to make it an attractive option. In recent years, enormous efforts have been done to achieve the aforementioned aim and the biological production ways – providing biohydrogen – are in the spotlight of the research [3-5]. These methods can help to accomplish the dual goal of simultaneous organic waste management and energy production. The biohydrogen produced can be fed into highly energy-efficient fuel cells or internal combustion engines [6,7]. However, these applications require purified hydrogen and therefore its separation from the different gaseous by-products – mainly CO₂ – formed during the fermentation is an essential task.

A broad range of processes e.g. chemical absorption, cryogenic distillation, adsorption and membrane separation are available and compete with each other for biohydrogen upgrading purposes [8-10]. Recently, significant improvements have been realized in membrane technology, hence it is being considered as an energy- and cost-effective, environmental-gentle method [11,12]. Furthermore, a main benefit of membranes is that they can easily be attached to hydrogen producing bioreactors leading to the chance of integrated production and purification.

Among the various membrane-based purification systems, membrane contactors, supported liquid membranes and gas separation membranes show potential for biohydrogen enrichment.

Independent research reports on the applicability of membrane contactors for biohydrogen concentration demonstrated that this technique was sufficient to remove carbon-dioxide from biohydrogen containing gaseous mixtures [13,14]. However, this technology suffers from the drawback that various chemicals must be used in the process for CO₂ absorption taking place within the membrane contactor itself.

Beside membrane contactors, supported liquid membranes employing different room temperature ionic liquids are also potential candidates for biohydrogen separation [15,16]. However, this approach is still under intense research and development. Thus, more time and experience is needed to make it feasible at larger scale.

Nevertheless, membrane gas separation is a mature option and has already been commercialized. Therefore, its viability is more realistic compared to the other above-mentioned procedures. In addition, it has some advantages e.g. no need of extra chemicals during operation, ease of processing, robustness and moderate operating requirements in case they are manufactured from synthetic polymers e.g. polyimide [17].

However, the application of gas separation membrane for H₂ purification is limited due to some reasons. For one thing, most of the membranes reflecting both reliable permeation and selectivity features are still to be fabricated [18]. Moreover, the membranes have mainly been studied in pure gas experiments [19] and gaseous mixtures have much less frequently been used [20-22] although it is crucial for industrial spread. Therefore, expanding the knowledge about the membranes' behavior expressed during mixed gas measurements is recommended.

Hence, in this work we aimed to test a commercially available polyimide membrane module – product of UBE Industries Ltd. – for H₂/CO₂ separation employing binary mixed gases differing in composition. Furthermore, the impacts of other important process parameters such as temperature and the ratio of retentate and feed flow on the performance of the membrane were statistically investigated applying a 3-level full-factorial experimental design.

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