INTRODUCTION

In the last decades, there is a high interest to reduce greenhouse gases (GHGs) by replacing conventional fossil fuels with good alternative fuel.1-6 Hydrogen is considered the most important solution to overcome global environmental issues.7,8 Hydrogen can be generated by different technologies such as steam reforming and water electrolysis.9,10 These studies showed that 90% of the available hydrogen gas in the market was produced by the steam methane reforming method and the remaining amount of hydrogen is produced by water electrolysis and coal gasification.11 The decomposition of water vapor using DBD plasma is not considered as a hydrogen production energy efficient method.12 However, hydrogen production using plasma technology has shown a lower cost compared to the water electrolysis method.13 However, the hydrogen production from plasma offers a low power requirement and it can be electronically controlled better than the other processes.14,15 The hydrogen production by plasma has been theoretically and experimentally investigated in previous studies.14,16-20

1 | INTRODUCTION

A simultaneous investigation of simulation and experimental analysis of hydrogen production from argon-water vapor mixture as a function in DBD plasma applied voltage were studied. The H$_2$ concentration results of two Ar-H$_2$O simulation kinetics models were compared with the experimental results. The simulation analysis was implemented for Ar-H$_2$O models with and without the dissociative attachment reaction (H$^-$). The effects of argon flow rate, input water vapor temperature, and water vapor flow rate on the H$_2$ concentration from the Ar-H$_2$O mixture were investigated. Furthermore, the effect of argon addition and reactor temperature on the hydrogen production from water vapor plasmolysis was performed. It was found that the hydrogen concentration was enhanced with the argon gas flow rate and plasma voltage increase. Moreover, the H$_2$ concentration results of the water vapor simulation model selecting the dissociative attachment reaction (H$^-$) were nearly the same as that obtained from the experimental results. Also, it was observed that the energy efficiency was enhanced with the plasma input power increased. Moreover, the comparison showed that the hydrogen concentration of argon gas addition was lower than that obtained from water vapor plasmolysis at PTR heating temperature of 90°C.

KEYWORDS
argon-water vapor, DBD plasma, hydrogen production, water vapor plasmolysis
The chemical conversion and synthesis analysis after applied the DBD plasma have been studied.26-29 The decomposition of gases using DBD plasma can be operated at low cost: atmospheric pressure, low input gas temperature, and fast conversion.30-32 Furthermore, the gas treatment by DBD plasma results in low energy efficiency due to plasma input power, additionally plasma electrodes and barriers.33 However, the water vapor decomposition to their elements H2 and O2 gases using DBD plasma would increase with a high wall temperature. In the discharge zone of the DBD plasma, high-energy electrons can be generated in the discharge zone. The DBD plasma reaction efficiency is suggested to improve by adding a dilution gas such as Ar, He, and N2, and it allows increasing the reaction opportunity between activated dilution molecules and the reactant molecules. Also, this method can be considered as a different way to get the plasma reaction performance.34-39 In this work, a detailed study of the simulation and experimental analysis of hydrogen production from the Ar-H2O mixture as a function in DBD plasma applied voltage is investigated. The effect of the dissociative attachment reaction (H−) on the Ar-H2O decomposition kinetics mechanism was simulated. The simulation and experimental analysis of the argon gas effect on the produced H2 concentration from water vapor decomposition at different plasma voltage are compared. The input water vapor temperature and flow rate effects on H2 production are investigated. Furthermore, the hydrogen production results of the present work are compared with the previous results of water vapor plasmolysis at different reactor heating temperatures.21

### 2 SIMULATION MODEL DESCRIPTION

The simulation analysis of argon-water vapor plasmolysis is carried out by combining the water vapor plasmolysis reaction model and argon reactions.14,40-43 Rehman et al14 model is the basis model of this DBD simulation study; additionally, same initial conditions are assumed like electron temperature (Te) of 3 eV. Moreover, the electron density in range of 1 × 10^18-1 × 10^20 m^-3 has been used in DBD plasma.44 The dissociative attachment and dissociation reactions are selected in this simulation study. The simulated water vapor plasmolysis reaction model is shown in Table 1. The overall kinetic modeling of water vapor plasma has been investigated.12,20 Also, it has been reported that the dissociative attachment reactions producing negative radicals species (OH-, H-, and O-) because of their weak cross sections and electron energies of 6-12 eV.45 Furthermore, the rates of negative ions production from water vapor plasmolysis are very small and less than 1%. The negative ions production from dissociative attachment reactions pathway of water vapor discharges were described as follow45,46:

\[
\begin{align*}
  \text{H}_2\text{O} + e & \rightarrow \text{H}^- + \text{OH} \\
  \text{H}_2\text{O} + e & \rightarrow \text{H}_2 + \text{O}^- \\
  \text{H}_2\text{O} + e & \rightarrow \text{H} + \text{OH}^- \\
  \text{H}_2\text{O} + e & \rightarrow \text{H}^+ + \text{OH}^- + e \\
  \text{H}_2\text{O} + e & \rightarrow \text{H} + \text{O}^- + \text{H}^+ + e \\
  \text{H}_2\text{O} + e & \rightarrow \text{O}^- + \text{H}_2^+ + e \\
  \text{H}_2\text{O} + e & \rightarrow \text{H}^- + \text{OH}^+ + e 
\end{align*}
\]

| No. | Reaction                  | Type                     | Rate constant (K) [m^3/mol-sec, m^6/mol-sec] | Ref. |
|-----|---------------------------|--------------------------|---------------------------------------------|------|
| 1   | H2O + e → H + OH + e      | Dissociation reaction    | 9.978E+07                                   | 51,52|
| 2   | H2O + e → H^- + OH        | Dissociative attachment  | 3.706E+07                                   | 51,53|
| 3   | OH + OH → H2O2            | Neutral-neutral reaction | 1.02E+07                                    | 52   |
| 4   | OH + H2O2 → H2O + HO2     | Neutral-neutral reaction | 1.02E+06                                    | 52   |
| 5   | HO2 + HO2 → H2O2 + O2     | Surface reaction 1       | 9.64E+05                                    | 52   |
| 6   | HO2 + H → H2 + O2         | Surface reaction 2       | 3.91E+07                                    | 52   |

**TABLE 1** Simulated reaction mechanism
A mathematical model of the chemical reactions of water in the discharge channel has been described as the output hydrogen molecular and the stoichiometric radical's generation of $\text{H}_2$, $\text{O}_2$, and $\text{H}_2\text{O}_2$. Furthermore, $\text{H}_2\text{O}_2$ is considered unstable molecule at the typical plasma conditions. However, it has been reported that $\text{H}_2\text{O}_2$ could be produced in low temperature water plasma especially if the process is carried out at supersonic flows. Although, $\text{H}_2\text{O}_2$ radical has low predicted concentration and it could be neglected, but it is being discussed because the overall reaction mechanism kinetics process was affected with the reactions included $\text{H}_2\text{O}_2$ and the same was found for $\text{HO}_2$, $\text{OH}$, and $\text{H}$. Additionally, the following radicals have been shown by optical emission spectroscopy $\text{OH}$ and $\text{H}$, while $\text{H}_2$ and $\text{H}_2\text{O}_2$ have been detected by chemical methods. The nonthermal plasma processes are started including a high electric field, ultraviolet radiation and shock waves, and the formation of new reactive radicals such as hydrogen atom-$\text{H}$, hydroxyl-$\text{OH}$, and oxygen-$\text{O}$ which are reacted with each other’s and starting a chain of the chemical activity reactions. It has been reported that the initiation of water vapor dissociation pathway with the dissociative attachment reaction formed negative hydrogen ions ($\text{H}^-$) will participate to initiate reactions with other water molecules. The simulation reaction mechanism is initiated with the dissociative attachment reaction producing negative $\text{H}^-$ and $\text{OH}$ radicals to combine with electron producing $\text{H}$ radical}

\[
\text{H}_2\text{O} + e^{-} \rightarrow \text{H}^- + \text{O}^+ + \text{H} + e^{-} \quad (h)
\]

\[
\text{H}_2\text{O} + e^{-} \rightarrow \text{H}^- + \text{O} + \text{H}^+ + e^{-} \quad (i)
\]

The extra electron produced from electron detachment reaction will participate in starting a chain of water dissociation process reactions. In this study, the argon effect on hydrogen production from water vapor plasmolysis is investigated and compared with the experimental results. The simulation kinetic model was carried out using COMSOL Multiphysics™ reaction engineering laboratory (REL) package. It was seen that this package can provide an automatic sensing of stiff systems and an adaptive time-stepping algorithm with a tolerance of $10^{-6}$. Also, the simulation analysis was carried out with and without the dissociative attachment reaction to investigate the effect of ($\text{H}^-$) on the hydrogen production from the water vapor. Furthermore, the simulation and experimental results are compared at different plasma applied voltage. The plasma applied voltage is input to the simulation model as a function of plasma charge which is determined as a function of the plasma current and reaction time. The effect of the input water vapor flow rate and temperature on the hydrogen production are simulated and compared with experimental results. Water vapor could be produced from industrial applications waste heat and utilized for $\text{H}_2$ production from water vapor plasmolysis. Pure steam can be generated from demineralized water using typical waste heat to prevent any impurities from entering the plasma reactor.

The excitation and ionization reactions (7), (8) of plasma-Ar reactions can be described as follows:

\[
e^{-} + \text{Ar} \rightarrow \text{Ar}^+ + e^{-} \quad (7)
\]
It is reported that these produced radicals interact with water vapor through the following reactions (9)-(11),

\[
e^- + \text{Ar} \rightarrow \text{Ar}^+ + 2e^- \quad (8)
\]

\[
\text{Ar}^* + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^* + \text{Ar} \quad (9)
\]

\[
\text{H}_2\text{O}^* \rightarrow \text{H} + \text{OH} \quad (10)
\]

\[
e^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^* (+e^-) \rightarrow \text{H} + \text{OH} (+e^-) \quad (11)
\]

3 EXPERIMENTAL SETUP AND METHODS

A schematic diagram of the experimental setup is given in Figure 1. The dielectric barrier discharge (DBD) plasma is generated between high voltage and ground electrodes in the plate type reactor (PTR) with a reaction volume of 3.969 cm³ and in an electrode gap distance of 4.5 mm. The sine wave frequency of 10 kHz is applied for plasma ignition at a high voltage range of 8-18 kV at DBD plasma power ranges of 82-120 W, respectively. A quartz glass part is used to insulate between both electrodes. The high voltage electrode is installed on the top center of the reactor over the glass part. The ground electrode is connected into the base plate and the dissociation of water vapor occurred between both electrodes. The water vapor is produced by a steam generator at a temperature range of 523-623 K, pressure of 100 kPa, and flow rate in ranges of 0.075-0.125 mol/min. The distilled water is prepared and fed into the steam generator. The water vapor is injected combining with Ar gas inflow rates range of 0.01-0.025 mol/min. The PTR is not heated, and the water vapor is mixed inside the steam generator and then fed into the reactor. The effect of Ar gas flow rates on the hydrogen production from water vapor plasmolysis is analyzed at different applied voltage. The outlet gases are separated in an ice trap, and the concentration of the condensed water vapor is also measured. The feeding gas mixture was included water vapor, and the dilution gas was Ar gas with a purity of 99.99%, which was flowed into the plasma discharge gap zone by the mass flow controller. The temperature and water vapor flow rate is settled using the steam generator device, while the plasma applied voltage is controlled by a high voltage controller (variac). Furthermore, the gas samples are collected in a 0.5 mL syringe; then, the samples are analyzed using the single-phase gas chromatography (GC). The outlet gas concentrations were measured using GC model type of GC-2014S, SHIMADZU. Furthermore, the calibration of the GC is performed before starting the gas samples analysis using standard gas concentrations and the GC error is estimated within a range of ±5%. It has been reported that the H₂ generation studies have been successfully quantified by the single gas phase chromatography (GC) analysis. The measurements and the analysis of the outlet gas concentrations of all experimental conditions were repeated four times at the same conditions. The simulated hydrogen peak intensities concentrations are compared with the experimental GC results of Ar-H₂O mixture. The morphology and kinetics of H₂O₂ production using DBD plasma have been investigated, and it was focused on the OH and H₂O₂ production using DBD plasma. The mixing process of Ar-H₂O is achieved inside the steam generator; after finishing the mixing process, the mixture gas is sent to the PTR and the plasma ignition is initiated after 10 minute. The total input gas mixture flow rate to the PTR was constantly kept according to all experimental conditions. The high purity argon was utilized, and the flow rate was controlled by the mass flow controller. The DBD plasma ignition images of water vapor dissociation with and without argon gas are shown in Figure 2. The images of the
plasma applied voltage of 12 and 14 kV. This figure shows a uniform plasma ignition by combining argon gas with water vapor compared to the plasma ignition with water vapor only at the same plasma applied voltage. The concentration of the microdischarges was mostly found near to the high voltage electrode surface. Moreover, three current pulses of filament microdischarges were breakdown at each half cycle. However, the filamentary discharges are randomly generated along with the dielectric electrode surface. Also, it was found that plasma ignition is filled the PTR reaction volume with the filaments. It has been reported that the filamentary structure depending upon the plasma ignition frequency. They found that more filaments at a frequency of 10 kHz than at 1 kHz. Therefore, the DBD plasma was ignited at a frequency of 10 kHz. The addition of the dilution gas such as argon gas to the water vapor stream is suggested to improve the DBD plasma reaction efficiency.

4 | RESULTS & DISCUSSIONS

4.1 | The effect of Ar gas on H₂ production

In this simulation study, argon gas is added to the water vapor stream reactions. The simulation has been carried out using the suggested model by Fahad et al. Also, the effect of the dissociative attachment reaction (H⁻ anion) on hydrogen production from water vapor plasmolysis was investigated. The experimental results of the effect of argon gas on the water vapor dissociation using DBD plasma at different plasma applied voltage are shown in Figure 3. From this figure, it was found that the hydrogen concentration increased with increasing the argon gas flow rate. Also, more H₂ gas is produced with the increasing of plasma voltage because the high-energy electron ionization is generated that leads to water vapor dissociated into their constituents elements. It can be found that this method of the different levels of the input dilution argon gas changed the physics of the plasma discharge and improve the efficiency of the plasma reaction. Moreover, the dilution gas will reveal the reaction opportunity between activated dilution argon gas molecules and reactant molecules.

The Ar-H₂O simulation results of the reaction model with and without the dissociative attachment reaction are presented and also discussed in this section. The concentration results of H₂, H₂O, and H₂O₂ are compared for both models. The residence time in the PTR reactor could be set such that \( \tau_{\text{reaction}} = \tau_{\text{residence}} \) by selecting a suitable combination of superficial velocity and characteristic length of reactor. Figure 4 depicts the hydrogen concentration with the plasma reaction time of both simulated models at the same input conditions. It was found that the hydrogen concentration of the simulated model with the dissociative attachment reaction was lower than that obtained from the simulated model.
FIGURE 4  Simulated hydrogen concentration vs reaction time (A) simulation model with H\(^-\) anion and (B) simulation model without H\(^-\) anion.
Figure 5  Simulated H$_2$O concentration vs reaction time (A) simulation model with H$^-$ anion and (B) simulation model without H$^-$ anion.
Comparison between H₂ concentration results of both simulated models with experimental results are presented in (A), (B), (C), and (D).

Steam flow rate 0.0755 mol/min, Ar flow rate 0.01 mol/min and steam input temperature is 523 K.
Experimental results

Simulation model + Ar
Simulation model without H- radical

Steam flow rate 0.0755 mol/min, Ar flow rate 0.020 mol/min and steam input temperature is 523 K

H₂ concentration [%]

Plasma voltage [kV]
without selecting the dissociative attachment reaction. It has been reported that the $H_2$ concentration produced from the water vapor dissociation pathway dropped by selecting of the dissociative attachment reaction. Figure 5 indicates the $H_2O$ concentration as a resulting reaction product from both simulation models. It was clear that the $H_2O$ concentration reaches zero in the simulation model without $H^-$ anion while in the simulated model selecting the $H^-$ anion showed that the water vapor has a value as a reaction product. It was remarkable that the simulation model selecting the dissociative attachment reaction was more reliable to the experimental results due to some of the separated $H_2$ and $O_2$ gas were recombined and condensed inside the ice trap. In the water vapor plasmolysis process, it has been reported that the hydrogen and oxygen molecules should be separated directly because of the product mixture is unstable and likely to result in the recombination to form water. Moreover, various studies have been developed to evaluate the hydrogen permeation through palladium-based membranes. The $H_2O_2$ production reaction was described in Table 1, while the destruction reactions of $H_2O_2$ can be described in Table 2. The main source of $H_2O_2$ production in the absence of oxygen-$O_2$ was the recombination of the hydroxyl radicals-$OH$. The losses and destruction of $H_2O_2$ have been reported in four contributions: electron dissociation reactions, $H_2O_2$ removal through the gas flow, the diffusion to both electrodes, and $H_2O_2$ reactions with produced radicals such as $OH$, $H$, and $O$, additionally the losses of $H_2O_2$ through the glass part has been registered much smaller than the loss due to the smaller area of the glass.

A comparison between simulation and experimental results of the Ar-$H_2O$ model with and without the dissociative attachment reaction ($H^-$) was investigated at different argon gas flow rates. Figure 6 shows that the hydrogen concentration results of the water vapor dissociation at different argon feeding flow rates in a range of 0.010-0.025 mol/min. The feeding water vapor flow rate and temperature were
The $H_2$ concentration results of both simulated models compared with experimental results of water vapor input temperature effect are presented in (A), (B), and (C).

(A) Steam input flow rate 0.0755 mol/min, Temperature 523 K and Ar flow rate 0.025 mol/min

(B) Steam input flow rate 0.0755 mol/min, Temperature 573 K and Ar flow rate 0.025 mol/min
remained constant at 0.0755 mol/min and 523 K, respectively, for all Ar-H₂O experimental conditions. It was found that argon gas enhanced the hydrogen concentration results from water vapor by DBD plasma. Also, it was observed that the plasma applied voltage has a positive effect on the H₂ production from water vapor, the concentration of H₂ increased with the plasma voltage increased. Furthermore, the effect of the dissociative attachment reaction (H⁻) on the H₂ concentration results from Ar-H₂O simulation models was investigated by selecting and deselecting the dissociative attachment reaction in both models. It was found that the H₂ concentration results of the simulation model selecting the dissociative attachment reaction were more acceptable and showed results are nearly same as the experimental results. These results were confirmed the effect of the dissociative attachment reaction which decreased the produced hydrogen gas in water vapor plasma dissociation.\textsuperscript{14} Also, other electron impacts of water vapor breakdown pathways are not included in the current study such as dissociative ionization reaction, ionization reactions, and dissociative excitation because it has been reported that the concentrations of species with the plasma reaction time scale did not change.\textsuperscript{14}

4.2 The effect of input water vapor temperature and flow rate

The water vapor temperature was adjusted and controlled by the steam generator according to the experimental conditions. The steam generator temperature calibration accuracy was ±0.5°C. To clarify the water vapor temperature effect on the H₂ production from Ar-H₂O plasmolysis, the water vapor and argon gas feeding flow rates remained constant for all experimental conditions. The measurements are carried out at plasma applied voltage range of 8-18 kV and sinusoidal wave frequency of 10 kHz. Figure 7 presents the experimental results of the H₂ concentrations at different input water vapor temperatures vs the plasma applied voltage. It was found that the hydrogen production yield increased with the input gas temperature increased. The maximum obtained hydrogen concentration was at the highest feeding input water vapor temperature of 623 K. This figure is also evidence that the gas temperatures have a clear relation to increasing the concentration of the hydrogen production.

As discussed in the simulation results earlier, the simulation models were analyzed for the Ar-H₂O model with and without the selecting of the dissociative attachment reaction...
(H\textsuperscript{−}). Figure 8 shows a comparison between the simulation and experimental results for the effect of feeding gas temperature at different plasma applied voltage. It was found that the results of the full simulation model included the dissociative attachment reaction (H\textsuperscript{−}) have a lower H\textsubscript{2} concentration results than that obtained from the simulation model deselecting the dissociative attachment reaction. However, the concentration profiles trend of both models is found to be similar. Furthermore, the hydrogen concentration of the simulation model selecting the dissociative attachment reaction is more acceptable to experimental results than the other model for all comparisons of simulation and experimental results. The simulation results of both models showed that the feeding gas temperature has an important effect on the water vapor plasmolysis dissociation process. Also, it was found that the dissociation reaction and the dissociative attachment reaction to being an important starting reaction step in the argon-water vapor plasmolysis process.\textsuperscript{14}

The addition of the electron of the dissociative attachment reaction mechanism caused a significant decrease in the hydrogen concentration. It was observed from the simulation results that the concentration of produced H\textsubscript{2} to be the most affected species with the addition of negative hydrogen ions by selecting the dissociative attachment reaction. The second step of the negative hydrogen ion produced from the dissociative attachment reaction is converted by the ion-electron detachment reaction as discussed in reaction (j). The dependence of hydrogen production on the water vapor feeding flow rate from Ar-H\textsubscript{2}O plasmolysis was investigated. Figure 9 represents the H\textsubscript{2} concentration obtained from experimental results at different input water vapor flow rates vs plasma applied voltage. Different input water vapor flow rate was fed into the PTR at a temperature of 523 K and argon gas flow rate of 0.01 mol/min. The results indicated that the hydrogen concentrations increased with the feeding water vapor and plasma applied voltage increased. Moreover, the energy efficiency is considered an important parameter to evaluate the hydrogen production processes. The energy efficiency was defined as the ratio of the H\textsubscript{2} gained energy to the total amount of heat added as follow\textsuperscript{72}:

\begin{equation}
\text{Energy efficiency \ [%] = \frac{HHV \times H_2 \text{ output flow rate \ [W]}}{\text{[Plasma Power + Qadd + Condensation heat] \ [W]}} \times 100}
\end{equation}

where HHV is the hydrogen higher heating value, Qadd is the heat added to produce steam, and the condensation heat to get hydrogen and oxygen gas using ice trap. Figure 10 illustrates the energy efficiency of hydrogen production from Ar-water vapor mixture at different input plasma electric power and flow rates. It was found that the energy efficiency increased with the
**FIGURE 10** Energy efficiency results at different input plasma power

**FIGURE 11** Experimental results of the effect of input water vapor temperature on the H₂ production
plasma input power and input flow rates. The maximum obtained results of energy efficiencies at high plasma input power were 0.0107%, 0.0253%, and 0.047% at Ar-H2O flow rates of 0.075, 0.1, and 0.125 mol/min, respectively.

However, argon gas is added to the water vapor stream but the hydrogen concentration was still low. In the current study, the argon-water vapor mixture was injected into the reactor at the PTR temperature of 20°C. The hydrogen concentration results of the current study showed higher results than the previous argon-water vapor study by Varne et al.40 The maximum hydrogen concentration yield of 1500 ppm has been registered at voltage 7.3 kV, 50 Hz, and water vapor concentration of 10 400 ppm. To clarify the PTR heating effect and the addition of argon gas effect on the H2 concentration produced from the water vapor plasmolysis, Figure 11 shows a comparison between the experimental results of hydrogen production from the water vapor plasmolysis under the addition of the argon gas to the water vapor stream and pure water vapor at PTR temperature of 90°C. The hydrogen production from water vapor plasmolysis were determined at plasma input power range of 82-120 W and applied voltage of 8-18 kV. The hydrogen concentration of water vapor only at PTR temperature of 90°C was higher than that obtained from the argon-water vapor system. However, the addition of argon gas improved the H2 concentration but was not similar to the PTR heating temperature which has a remarkable effect on the produced hydrogen gas from water vapor plasmolysis.

5 | CONCLUSION

It was reported a simultaneous investigation of a theoretical and experimental analysis of hydrogen production from an atmospheric pressure argon-water vapor mixture as a function of DBD plasma applied voltage. The produced hydrogen concentration in Ar-H2O increases with increasing argon flow rate and plasma voltage. Due to the importance of the dissociation reaction and the dissociative attachment of electrons, the simulation analysis was carried out by selecting and deselecting the dissociative attachment reaction (H−). Also, it was found the H2 concentration results of water vapor simulation model including the dissociative attachment reaction (H+) that was nearly same as experimental results. This most likely due to the water vapor did not completely convert into H2 and O2 gas which was confirmed by H2O and H2O2 concentration results of simulation models. The effect of the feeding water vapor temperature on the water vapor breakdown was investigated. It was found that the hydrogen concentration increased with the water vapor temperature increased. Also, a comparison between H2 concentration results of simulation models with and without the dissociative attachment reaction as well as experimental results was investigated. Also, the water vapor feeding flow rate was found that has an important effect on the produced H2 concentration. The hydrogen concentration increased with input gas and plasma voltage increased. To clarify the argon addition and reactor temperature effect on H2 production from water vapor plasmolysis, a comparison between H2 concentration of experimental results of the water vapor plasmolysis under the addition of argon gas and pure water vapor at PTR temperature 90°C. It was observed that the hydrogen concentration of pure water vapor at PTR temperature of 90°C has higher H2 concentration values than that obtained from the Ar-H2O system. However, the H2 concentration improved by the addition of argon gas but it was not similar to the effect of the PTR heating temperature on the produced hydrogen gas from water vapor plasmolysis.

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