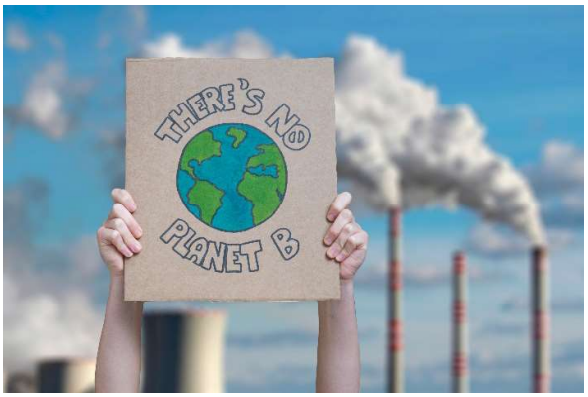
2. This question is about hydrogen as a fuel

Carbon dioxide emissions from fossil fuels are a major factor in climate change. Hydrogen is a potential alternative to fossil fuels, providing 'clean energy' with only water as a by-product. The UK government is investigating converting the natural gas grid to carry hydrogen instead.



For this question, assume all processes take place at 298 K.

Enthalpy change of formation of $CH_4(g)$, $\Delta H^{\ominus}_f = -74.8$ kJ mol^{-1}

Enthalpy change of formation of $CO_2(g)$, $\Delta H^{\ominus}_f = -393.5$ kJ mol^{-1}

Enthalpy change of formation of $H_2O(l)$, $\Delta H^{\ominus}_f = -285.8$ kJ mol^{-1}

Entropy change of formation of $H_2O(l)$, $\Delta S^{\ominus}_f = -163.0$ J K^{-1} mol^{-1}

One low cost method for producing hydrogen is reforming methane. Though this produces CO_2, this can be easily captured. The reforming process can be represented by the overall reaction:

$$CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 4H_2(g)$$

(a) Calculate the enthalpy change for this reaction.

Electrolysis of water is another method of producing hydrogen. On a large scale, it currently costs more than reforming methane.

In polymer electrolyte membrane electrolysis, protons are transferred through a membrane between the two electrodes. The two half reactions are:

1. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

2. $2H^+(aq) + 2e^- \rightarrow H_2(g)$

(b) Which of these half reactions occurs at the cathode?

The overall cell reaction is as follows:

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

(c) Calculate the enthalpy change for the overall cell reaction.

Given that $\Delta G^{\ominus} = -nFE^{\ominus}$ and $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

where n = moles of electrons transferred in the overall equation, F = Faraday constant

(d) Calculate the cell potential, $E^{\ominus}$, for the overall cell reaction in V.

(if you do not get an answer to this question, use −1.13 V in further calculations)

(e) What is the standard electrode potential for half reaction **1**?

To replace natural gas within appliances such as boilers or furnaces, there needs to be a similar amount of heat released per second from burning fuel.

(f) What is the standard enthalpy change of combustion of CH_4?

(If you do not get an answer to this question, use −943.2 kJ mol^{-1} in further calculations)

(g) What is the standard enthalpy change of combustion of H_2?

(If you do not get an answer to this question, use −352.8 kJ mol^{-1} in further calculations)

When fuel gases are supplied under the same pressure, the heat released per second in a burner may be expressed using:

$$\textit{heat released per second} \propto \frac{\textit{standard enthalpy change of combustion}}{\sqrt{\textit{relative molecular mass}}}$$

(h) What is the ratio of heat released per second in a burner fuelled by hydrogen compared to in the same burner fuelled by methane?

Assume hydrogen and methane are supplied under the same pressure.