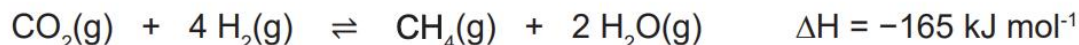


Question 38**(18 marks)**

SpaceX is an American company that wants to send humans to Mars to explore the planet and establish a colony. One of the challenges of such a mission is finding reliable fuel sources away from Earth.

SpaceX plans to solve this problem by using the Sabatier reaction. The equation for the reaction is:



The optimal conditions for this reaction are:

- temperature of 300 – 400 °C
- pressure of 200 – 300 kPa
- nickel catalyst.

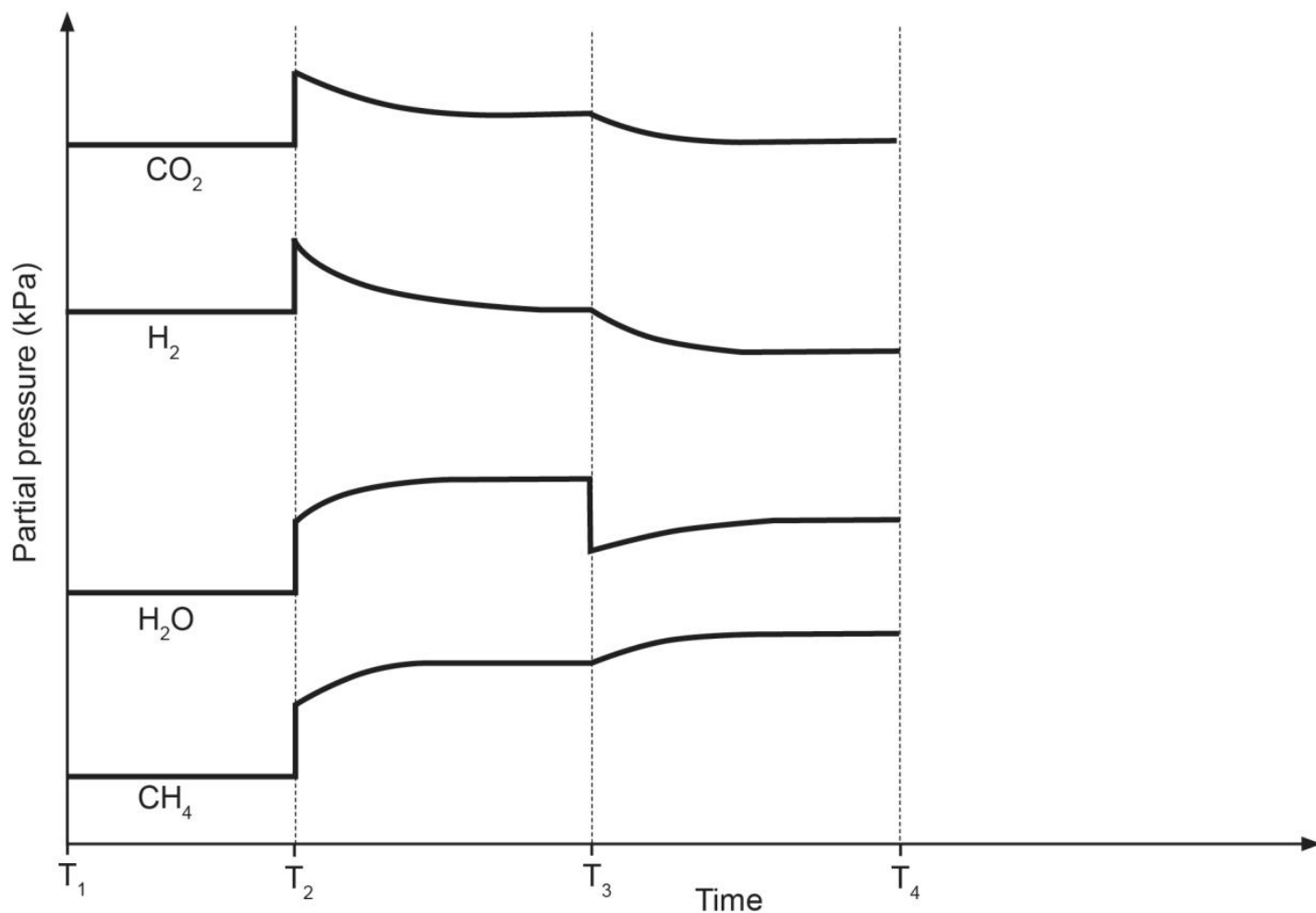
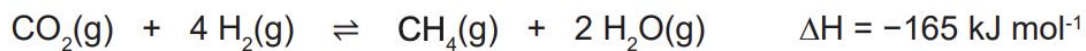
The carbon dioxide would be obtained from the Martian atmosphere and the hydrogen from the hydrolysis of water extracted from either the Martian subsoil or atmosphere. The resulting methane could be used as rocket fuel while the water could be electrolysed to produce hydrogen and oxygen. The hydrogen could be fed back into the reaction vessel and the oxygen used for breathing apparatus.

- (a) With reference to rates of reaction, equilibrium and economic considerations, explain why the above conditions are considered optimal for the Sabatier reaction. In your response, address any compromises in conditions. (7 marks)

- (b) Predict the effect of each of the following changes on the methane yield in the Sabatier reaction. (5 marks)

Imposed change	Effect on methane yield (circle your answer)		
a suitable catalyst is added	increase	decrease	no effect
the volume of the reaction vessel is increased	increase	decrease	no effect
the temperature is increased	increase	decrease	no effect
methane is removed through a special valve as soon as it forms	increase	decrease	no effect
the partial pressure of carbon dioxide is decreased	increase	decrease	no effect

Graphs can be drawn to show the effects of imposed changes on equilibrium systems. The graph below shows the effects of some changes that might be made to the reacting system in a flexible vessel.



With reference to the above graph, answer the following questions.

(c) (i) What happened at T_1 ? (1 mark)

(ii) Identify the change imposed at each time in the table below. (2 marks)

Time	Change imposed on the system
T_2	
T_3	

(iii) The temperature of the reaction vessel was decreased at T_4 . Sketch on the graph above to show how this affected the partial pressures of all species present. Include any changes to scale and continue until a new equilibrium is established. (3 marks)