Hydrogen can be made as shown: \[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons 3\text{H}_2(g) + \text{CO}(g) \quad \Delta H = +206 \text{ kJ mol}^{-1} \]

5.0 moles of methane was mixed with 5.0 moles of steam. At equilibrium, there was found to be 6.0 moles of hydrogen. The total pressure was 1500 kPa.

a Write an expression for \( K_p \) for this equilibrium. \[ K_p = \frac{(p \text{H}_2)^3 \times (p \text{CO})}{(p \text{CH}_4) \times (p \text{H}_2\text{O})} \]

b State the units of \( K_p \). kPa\(^2\)

c Calculate the moles of each gas at equilibrium.

- hydrogen = 6.0
- carbon monoxide = 2.0
- methane = 3.0
- steam = 3.0

d Calculate the partial pressure of each gas.

- hydrogen = \( \frac{6.0}{14.0} \times 1500 = 642.9 \text{ kPa} \)
- carbon monoxide = \( \frac{2.0}{14.0} \times 1500 = 214.3 \text{ kPa} \)
- methane = \( \frac{3.0}{14.0} \times 1500 = 321.4 \text{ kPa} \)
- steam = \( \frac{3.0}{14.0} \times 1500 = 321.4 \text{ kPa} \)

e Calculate \( K_p \) for this equilibrium.

\[ K_p = \frac{(p \text{H}_2)^3 \times (p \text{CO})}{(p \text{CH}_4) \times (p \text{H}_2\text{O})} = \frac{(642.9)^3 \times (214.3)}{(321.4) \times (321.4)} = 5.51 \times 10^5 \text{ kPa}^2 \]

f Explain what would happen to the position of the equilibrium and the value of \( K_p \) if the temperature of gases was increased?

- equilibrium position moves right in endothermic direction to oppose increase in temperature
- \( K_p \) increases

g Explain what would happen to the position of the equilibrium and the value of \( K_p \) if the total pressure of gases was increased?

- equilibrium position moves left to side with fewer gas molecules to oppose increase in pressure
- no change in \( K_p \)

h Calculate \( K_p \) and state the units for this equilibrium at the same temperature and pressure as the original mixture at the start of the question.

\[ 3\text{H}_2(g) + \text{CO}(g) \rightleftharpoons \text{CH}_4(g) + \text{H}_2\text{O}(g) \]

\[ K_p = \frac{1}{5.51 \times 10^5} = 1.81 \times 10^{-6} \text{ kPa}^{-2} \]