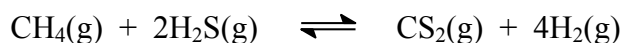


- Methane, CH₄, reacts with hydrogen sulfide, H₂S, according to the following equilibrium:



In an experiment 1.00 mol of CH₄, 2.00 mol of H₂S, 1.00 mol of CS₂ and 2.00 mol of H₂ are mixed in a 250 mL vessel at 960 °C. At this temperature, $K_c = 0.034$ (based on a standard state of 1 mol L⁻¹).

Calculate the reaction quotient, Q , and hence predict in which direction the reaction will proceed to reach equilibrium? Explain your answer.

Marks
5

Using concentration = number of moles / volume, the concentrations when the gases are mixed are:

$$[\text{CH}_4(\text{g})] = 1.00 \text{ mol} / 0.250 \text{ L} = 4.00 \text{ mol L}^{-1}$$

$$[\text{H}_2\text{S}(\text{g})] = 2.00 \text{ mol} / 0.250 \text{ L} = 8.00 \text{ mol L}^{-1}$$

$$[\text{CS}_2(\text{g})] = 1.00 \text{ mol} / 0.250 \text{ L} = 4.00 \text{ mol L}^{-1}$$

$$[\text{H}_2(\text{g})] = 2.00 \text{ mol} / 0.250 \text{ L} = 8.00 \text{ mol L}^{-1}$$

From the chemical equation, the reaction quotient is:

$$Q = \frac{[\text{CS}_2(\text{g})][\text{H}_2(\text{g})]^4}{[\text{CH}_4(\text{g})][\text{H}_2\text{S}(\text{g})]^2} = \frac{(4.00)(8.00)^4}{(4.00)(8.00)^2} = 64.0$$

As $Q > K_c$, therefore the reaction will shift to the left until $Q = K_c$.

Show that the system is at equilibrium when $[\text{CH}_4(\text{g})] = 5.56 \text{ M}$.

A reaction table can be constructed to calculate the equilibrium concentrations:

	CH ₄ (g) +	2H ₂ S(g)	⇌	CS ₂ (g) +	4H ₂ (g)
Initial	4.00	8.00		4.00	8.00
Change	+x	+2x		-x	-4x
Equilibrium	4.00 + x	8.00 + 2x		4.00 - x	8.00 - 4x

If $[\text{CH}_4(\text{g})]_{\text{equilibrium}} = 5.56 \text{ M}$ then $4.00 + x = 5.56 \text{ M}$ and $x = 1.56 \text{ M}$. Hence:

$$[\text{CH}_4(\text{g})]_{\text{equilibrium}} = (4.00 + x) \text{ M} = 5.56 \text{ M}$$

$$[\text{H}_2\text{S}(\text{g})]_{\text{equilibrium}} = (8.00 + 2x) \text{ M} = 11.12 \text{ M}$$

$$[\text{CS}_2(\text{g})]_{\text{equilibrium}} = (4.00 - x) \text{ M} = 2.44 \text{ M}$$

$$[\text{H}_2(\text{g})]_{\text{equilibrium}} = (8.00 - 4x) \text{ M} = 1.76 \text{ M}$$

With these concentrations:

$$K_c = \frac{[\text{CS}_2(\text{g})][\text{H}_2(\text{g})]^4}{[\text{CH}_4(\text{g})][\text{H}_2\text{S}(\text{g})]^2} = \frac{(2.44)(1.76)^4}{(5.56)(11.12)^2} = 0.034$$