Hydrogen cyanide, HCN(g), is prepared commercially by the reaction of methane, CH₄(g), ammonia, NH₃(g), and oxygen, O₂(g), at high temperature. The other product is gaseous water. Write a chemical equation for the reaction.

\[
\text{CH}_4(\text{g}) + \text{NH}_3(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{HCN}(\text{g}) + 3\text{H}_2\text{O}(\text{l})
\]

What volume of HCN(g) can be obtained from 20.0 L of CH₄(g), 20.0 L of NH₃(g) and 20.0 L of O₂(g)? The volumes of all gases are measured at the same temperature and pressure.

From the ideal gas law, \(pV = nRT\), the number of moles is directly proportional to the volume of the substance, if the same temperature and pressure are used. As the volumes of CH₄(g), NH₃(g) and O₂(g) are the same, the number of moles of each is also the same.

From the chemical equation, 1.5 mol of O₂(g) is required for every 1 mol of CH₄(g) and every 1 mol of NH₃(g). As the number of moles of O₂(g) is equal to the number of moles of CH₄(g) and NH₃(g), the limiting reagent is O₂(g).

From the chemical equation, 1 mol of HCN(g) is made from every 1.5 mol of O₂(g). Each mole of O₂(g) will lead to \(\frac{2}{3}\) mol of HCN(g). Hence, the volume of HCN(g) = \(\frac{2}{3} \times 20.0 \text{ L} = 13.3 \text{ L}\).

Answer: 13.3 L

The reaction of carbon disulfide with chlorine is as follows.

\[
\text{CS}_2(\text{g}) + 3\text{Cl}_2(\text{g}) \leftrightarrow \text{CCl}_4(\text{g}) + \text{S}_2\text{Cl}_2(\text{g}) \quad \Delta H_{298} = -238 \text{ kJ mol}^{-1}
\]

In which direction will the reaction move when the following changes are made to the system initially at equilibrium?

(a) The pressure on the system is doubled by halving the volume.

As the reaction involves 4 mol of gas \(\rightarrow\) 2 mol of gas, increasing the pressure favours products (Le Chatelier’s principle). The reaction will shift to the right.

(b) CCl₄ is removed.

Removing product will lead to the reaction shifting to produce more product (Le Chatelier’s principle). The reaction will shift to the right.

(c) The system is heated.

The reaction is exothermic. Increasing the temperature will cause the reaction to reduce the amount of the exothermic reaction (Le Chatelier’s principle). The reaction will shift to the left.