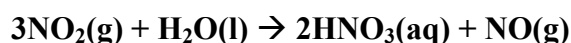


Marks
8

- One of the causes of acid rain is a reaction occurring in the upper atmosphere between gaseous NO_2 and water to produce nitric acid and gaseous NO . Write a balanced chemical equation for this reaction.



As part of their school project on acid rain, some high school students collected a sample of rain (220 mL) and measured the pH value of the solution, reporting the value as $\text{pH} = 3.9$. Assuming that the rain sample does not contain any acids other than nitric acid, calculate the volume of gaseous NO_2 that would have been consumed in the upper atmosphere (where temperature = -56°C and pressure = 11.6 kPa) to produce the sample of rain collected by the students.

By definition,

$$\text{pH} = -\log_{10}[\text{H}^+] \quad \text{or} \quad [\text{H}^+] = 10^{-\text{pH}}$$

$\text{pH} = 3.9$ therefore corresponds to $[\text{H}^+] = 10^{-3.9} \text{ M}$.

The number of moles of H^+ in the sample of 220 mL is,

$$\begin{aligned} \text{number of moles} &= \text{volume (in L)} \times \text{molarity (in mol L}^{-1}\text{)} \\ &= 0.220 \text{ L} \times 10^{-3.9} \text{ M} = 2.8 \times 10^{-5} \text{ mol} \end{aligned}$$

As nitric acid is a strong acid, this is also the number of moles of nitric acid present. From the chemical equation, *two* moles of nitric acid are produced from every *three* moles of NO_2 . Therefore, the number of moles of NO_2 used is:

$$\text{number of moles} = \frac{3}{2} \times 2.8 \times 10^{-5} \text{ mol} = 4.2 \times 10^{-5} \text{ mol}$$

The volume of this number of moles of gas at 11.6 kPa and -56°C ($= 217 \text{ K}$) is given by the ideal gas law:

$$pV = nRT$$

so,

$$\begin{aligned} V &= \frac{nRT}{P} = \frac{(4.2 \times 10^{-5} \text{ mol})(8.314 \text{ J}^{-1} \text{ K}^{-1} \text{ mol}^{-1})(217 \text{ K})}{11.6 \times 10^3 \text{ Pa}} \\ &= 6.5 \times 10^{-6} \text{ m}^3 = 6.5 \times 10^{-3} \text{ L} \end{aligned}$$

(Note the use of $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ as pressure is given in Pascal provides the answer in m^3)

ANSWER: $6.5 \times 10^{-3} \text{ L}$