Answer on Question #57537-Physics – Molecular Physics | Thermodynamics

A closed vessel having capacity 200 mL is filled with hydrogen gas at STP. Calculate:

(i) Number of moles of hydrogen gas filled in the vessel.

(ii) Pressure of hydrogen gas in the vessel at 273°C.

(iii) Root mean square velocity of hydrogen gas at STP.

(iv) The value of Cp and Cv for hydrogen gas.

Solution

(i) At standard temperature and pressure (STP) one mole of hydrogen gas occupies $22.4L$. Then, we can compose a proportion (because the vessel is filled with hydrogen gas at STP)

$$1\, mole\ of\ H_2 -\ 22.4L$$

$$n\ moles\ of\ H_2 -\ 200mL$$

From the proportion we obtain

$$n = \frac{200 \cdot 10^{-3}L \cdot 1mole}{22.4L} = 0.0089\, mol.$$

(ii) We can calculate the pressure of hydrogen gas in the vessel at 273°C from the ideal gas law

$$PV = nRT,$$

here, P is the pressure of the gas, V is the volume of the gas, n is the amount of substance of the gas which is measured in moles, $R = 8.314 \frac{(m^3 \cdot Pa)}{(mol \cdot K)}$ is the universal gas constant, T is the temperature of the gas.

Therefore, from the formula we get

$$P = \frac{nRT}{V} = \frac{0.0089mol \cdot 8.314 \frac{(m^3 \cdot Pa)}{(mol \cdot K)} \cdot (273 + 273.15K)}{200 \cdot 10^{-6}m^3} = 2.02 \cdot 10^5 Pa.$$

(iii) By the definition, the root mean square velocity is given by formula

$$c_{rms} = \sqrt{\frac{3kT}{m}}$$

here, $k = 1.38 \cdot 10^{-23} \frac{J}{K}$ is the Boltzmann constant, $T = 273K$ (standard temperature), $m = 3.347 \cdot 10^{-27}kg$ is the mass of the molecule of the hydrogen gas.

Then, the root mean square velocity of hydrogen gas at STP will be

$$c_{rms} = \sqrt{\frac{3 \cdot 1.38 \cdot 10^{-23} \frac{J}{K} \cdot 273K}{3.347 \cdot 10^{-27}kg}} = 1837.6 \frac{m}{s}.$$

(iv) Since H_2 is diatomic gas, the molar heat capacity at constant volume C_v will be

$$C_v = \frac{5}{2}R = \frac{5}{2}8.314\frac{J}{(mol\cdot K)} = 20.78\frac{J}{mol\cdot K}.$$

By the definition, the molar heat capacity at constant pressure will be

$$C_p = C_v + R = \frac{5}{2}R + R = \frac{7}{2}R = \frac{7}{2}\cdot 8.314\frac{J}{mol\cdot K} = 29.09\frac{J}{mol\cdot K}.$$