Answer on Question 57164, Physics, Other

Question:

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℃.

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

(iv) The value of C_p and C_v 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:

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

(ii) We can calculate the pressure of hydrogen gas in the vessel at 273℃ 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:

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

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

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

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

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

Answer:

(i) $n = 0.0089 mol$.

(ii) $P = 2.02 \cdot 10^5 Pa$.

(iii) $c_{rms} = 1837.6 \frac{m}{s}$.

(iv) $C_v = 20.78 \frac{J}{mol \cdot K}$,

$C_p = 29.09 \frac{J}{mol \cdot K}$.