Answer on Question #42963-Physics-Molecular Physics-Thermodynamics

A 600 g of helium gas occupy 2 liters at 80 c suddenly expanded (adiabatic) to volume 3 liter calculate

$$m = 600g = 0.6\,kg, V_1 = 2\cdot 10^{-3}m^3, V_2 = 3\cdot 10^{-3}m^3, T = (80+273)K = 353\,K.$$

1-molar heat capacities at constant volume and at constant pressure and gamma constant

Solution

Helium is a monoatomic gas. Its molar heat capacities at constant volume is

$$c_V = \frac{3}{2}R = 12.5\frac{J}{molK}.$$

Its molar heat capacities at constant pressure is

$$c_p = c_V + R = \frac{5}{2}R = 20.8\frac{J}{molK}.$$

Its gamma constant is

$$\gamma = \frac{c_p}{c_V} = \frac{\frac{5}{2}R}{\frac{3}{2}R} = \frac{5}{3} \approx 1.67.$$

2-intial pressure

Solution

From the ideal gas law ($pV = \frac{m}{M}RT$)

$$p_1V_1 = \frac{m}{M}RT_1 \to p_1 = \frac{mRT_1}{MV_1} = \frac{0.6\,kg\cdot 8.31\frac{J}{molK}\cdot 353\,K}{4\cdot 10^{-3}\frac{\text{kg}}{\text{mol}}\cdot 2\cdot 10^{-3}m^3} = 2.2\cdot 10^8 Pa.$$

3-final temperature and pressure

Solution

For adiabatic process

$$p_1V_1^\gamma = p_2V_2^\gamma \to p_2 = p_1\left(\frac{V_1}{V_2}\right)^\gamma = 2.2\cdot 10^8 Pa\left(\frac{2\cdot 10^{-3}m^3}{3\cdot 10^{-3}m^3}\right)^{\frac{5}{3}} = 1.1\cdot 10^8 Pa.$$

From the ideal gas law ($pV = \frac{m}{M}RT$) final temperature is

$$T_2 = \frac{p_2V_2}{p_1V_1}T_1 = \frac{1}{2}\cdot\frac{3}{2}\cdot 353\,K = 265\,K.$$

4-change in root mean square velocity

Solution

The root mean square velocity is $v_{rms} = \sqrt{\frac{3kT}{m}}$. The change in root mean square velocity is

$$\Delta v_{rms} = \sqrt{\frac{3RT_2}{M}} - \sqrt{\frac{3RT_1}{M}} = \sqrt{\frac{3RT_1}{M}}\left(\sqrt{\frac{T_2}{T_1}} - 1\right) = \sqrt{\frac{3 \cdot 8.31 \frac{J}{molK} \cdot 353\ K}{4 \cdot 10^{-3}\, \frac{\text{kg}}{\text{mol}}}}\left(\sqrt{\frac{3}{4}} - 1\right) = -199\ \frac{m}{s}.$$

5-change in mean kinetic energy of molecule

Solution

The mean kinetic energy of molecule is $\frac{3}{2}kT$. The change in mean kinetic energy of molecule is

$$\frac{3}{2}k\Delta T = \frac{3}{2} \cdot 1.38 \cdot 10^{-23}\frac{J}{K}(265 - 353)K = -1.82 \cdot 10^{-21} J.$$

6-change in molar kinetic energy

Solution

The molar kinetic energy is $\frac{3}{2}RT$. The change in molar kinetic energy is

$$\frac{3}{2}R\Delta T = c_V\Delta T = 12.5\frac{J}{molK} \cdot (265 - 353)K = -1.1\frac{kJ}{mol}.$$

7-change in internal energy and its sign

Solution

$$\Delta U = \frac{m}{M}c_V\Delta T = \frac{0.6kg}{4 \cdot 10^{-3}\, \frac{\text{kg}}{\text{mol}}} \cdot 12.5\frac{J}{molK} \cdot (265 - 353)K = -165\ kJ.$$

8-the mechanical work

Solution

For adiabatic process work done by gas is

$$W = -\Delta U = 165\ kJ.$$

9-what does this work?

Answer

W is positive, that’s why adiabatically expanding helium gas does work on its environment.