$$\bar{c}_v^* = \frac{3}{2}\bar{R} + 0 + 0 = \frac{3}{2}\bar{R} \qquad \bar{s}^* = \bar{R}\left\{\frac{5}{2} + \ln\left[\frac{(kT)^{5/2}}{p}\left(\frac{2\pi m^*}{h}\right)^{3/2}\right]\right\}$$

The enthalpy and specific heat at constant pressure are

$$\bar{h}^* = \bar{u}^* + \bar{R}T = \frac{5}{2}\bar{R}T \qquad \bar{c}_p^* = \bar{c}_v^* + \bar{R} = \frac{5}{2}\bar{R}$$

Exercise 17. Use the functions of Table IIIC-1 and the values of Table IIIC-2 to determine c_p for nitrogen at atmospheric pressure at the temperature levels 50, 300, 600, 1500, 3500, and 5000 K. Compare the results to the recommended "near room temperature" value, Table ID-1. Draw conclusions with respect to the effectiveness of the calculation and the contribution of each mode.

The results of Exmp. 10 and Exer. 17 demonstrate the meaning and limitation of the "near room temperature" specific heat values recommended for monatomic and diatomic gases, see Table ID-1. The recommendation for monatomic gases [$\bar{c}_v^* = (3/2)\cdot\bar{R}$, $\bar{c}_p^* = (5/2)\cdot\bar{R}$, and $\gamma^* = 1.67$] is simply the translational contribution. Since there is no molecular rotation or vibration in monatomic gases this approximation is valid for perfect gas states until the electronic mode is initiated, $T \sim 10^4$K. The recommendation for diatomic gases [$\bar{c}_v^* = (5/2)\cdot\bar{R}$, $\bar{c}_p^* = (7/2)\cdot\bar{R}$, $\gamma^* = 1.4$] is the sum of the translational and fully excited rotational mode contributions. All diatomic molecules except hydrogen and deuterium have fully excited rotational modes at all achievable gaseous states. (Even these exceptions occur only at their lowest gaseous temperatures.) Thus in practice "near room temperature" means from the lowest gaseous temperatures until the vibrational mode is energized, viz., at temperatures above $T \sim \theta_v/8$.

Exercise 18. Determine $\bar{c}_p^*$ for methane at 200, 400, 800, 1600, and 3200 K.

Ans. 15. In the low-temperature limit, $\theta_v/T \Rightarrow \infty$ and $\exp(\theta_v/T) - 1 \Rightarrow \exp(\theta_v/T)$

$$\bar{c}_{v,v} \Rightarrow \bar{R}\left(\frac{\theta_v}{T}\right)^2 e^{-\theta_v/T} \Rightarrow 0$$

In the high-temperature limit, $\theta_v/T \Rightarrow 0$ and $\exp(\theta_v/T) \Rightarrow 1 + (\theta_v/T)$. So

$$\bar{c}_{v,v} = \bar{R}\left(\frac{\theta_v}{T}\right)^2 \frac{[1 + (\theta_v/T)]}{[1 + (\theta_v/T) - 1]^2} \Rightarrow \bar{R}$$

Ans. 16. The required constants are listed in Table IA-2.

$$k = 1.380\cdot 10^{-23}\text{J/(part K)}, \qquad h = 6.625\cdot 10^{-34}\text{Js/part}, \qquad e = 1.602\cdot 10^{-19}\text{C/part},$$

$$m_e^* = 9.109\cdot 10^{-28}\text{g/part}, \qquad \varepsilon_o = 8.854\cdot 10^{-12}\text{C/(Vm)}$$

$$\theta_{el,H} = \frac{1.602^4\cdot 10^{-76}\text{C}^4\cdot 9.109\cdot 10^{-31}\text{kg}\cdot(1\ \text{J/CV})^2}{8\cdot(8.854)^2\cdot 10^{-24}\text{C}^2/(\text{Vm})^2\cdot(6.625)^2\cdot 10^{-68}(\text{J s})^2\cdot 1.380\cdot 10^{-23}\text{J/K}}$$

$$= 1.579\cdot 10^5\text{K}$$