Teacher notes
Topic B

Molar specific heat capacities

For an ideal gas we may define the molar heat capacity as the amount of energy required to change the temperature of one mole of the gas by one degree: then, $Q = nc\Delta T$. However, we must distinguish the case when heat is given to the gas at constant pressure from that where the heat is provided at constant volume. This defines the molar specific heat capacity at constant pressure, c_P , and at constant volume, c_V .

If the heat is given at constant pressure,

$$\begin{aligned} Q &= nc_P\Delta T \\ &= \Delta U + W \quad \text{(first law of thermodynamics)} \end{aligned}$$

$$nc_P\Delta T = \frac{3}{2}Rn\Delta T + P\Delta V$$

$$c_P = \frac{3}{2}R + \frac{P\Delta V}{n\Delta T}$$

From the ideal gas law,

$$PV = nRT \Rightarrow P\Delta V = nR\Delta T$$

$$\Rightarrow \frac{P\Delta V}{n\Delta T} = R$$

Hence $c_P = \frac{3}{2}R + R = \frac{5}{2}R$.

At constant volume,

$$\begin{aligned} Q &= nc_V\Delta T \\ &= \Delta U + W \end{aligned}$$

$$nc_V\Delta T = \frac{3}{2}Rn\Delta T + 0$$

$$c_V = \frac{3}{2}R$$

Thus,

$$c_P - c_V = R$$

Numerically, $c_V = \frac{3}{2}R = 12.25\ \text{J mol}^{-1}\text{K}^{-1}$ and $c_P = \frac{5}{2}R = 20.77\ \text{J mol}^{-1}\text{K}^{-1}$.

The table gives the experimental values for the molar heat capacities of the noble gases at 300 K, in excellent agreement with the prediction.

	c_V	c_P
Helium	12.5 J mol^{-1} K^{-1}	20.8 J mol^{-1} K^{-1}
Neon	12.5 J mol^{-1} K^{-1}	20.8 J mol^{-1} K^{-1}
Argon	12.5 J mol^{-1} K^{-1}	20.8 J mol^{-1} K^{-1}
Krypton	12.5 J mol^{-1} K^{-1}	20.9 J mol^{-1} K^{-1}
Xenon	12.5 J mol^{-1} K^{-1}	21.0 J mol^{-1} K^{-1}