Chapter 18 Problem 29 †

Given
$W = 2.5\ kJ$

Solution
a) Find the temperature change for one mole of an ideal monatomic gas during the adiabatic process.

In an adiabatic process there is no heat flow into or out of the system. From the 1st Law of Thermodynamics

$$\Delta U = Q - W$$

it can be concluded that

$$\Delta U = -W$$

Since 2.5 kJ of work is being done on the gas, the work is negative and the change of internal energy is positive.

$$\Delta U = -W = -(-2.5\ kJ) = 2.5\ kJ$$

For an ideal monatomic gas, the molar heat capacity is $C_V = \frac{3}{2}nR$. Therefore, the change of internal energy is

$$\Delta U = \tfrac{3}{2}nR\Delta T$$

Solving for the change in temperature gives

$$\Delta T = \frac{\Delta U}{\frac{3}{2}nR} = \frac{2\Delta U}{3nR}$$

Substituting in the appropriate values gives

$$\Delta T = \frac{2(2500\ J)}{3(1.0\ mol)(8.31\ J/mol \cdot K)} = 201\ K$$

b) Find the temperature change for one mole of an ideal diatomic gas during the adiabatic process.

The change of internal energy will be the same as in part a. However, for a diatomic gas the relationship between change of internal energy and temperature change is

$$\Delta U = \tfrac{5}{2}nR\Delta T$$

Solving for the change in temperature gives

$$\Delta T = \frac{2\Delta U}{5nR} = \frac{2(2500\ J)}{5(1.0\ mol)(8.31\ J/mol \cdot K)} = 120\ K$$

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† Problem from Essential University Physics, Wolfson