29:011 Example problems on the first law of thermodynamics

1. 5000 J of heat are added to two moles of an ideal monatomic gas, initially at a temperature of 500 K, while the gas performs 7500 J of work. What is the final temperature of the gas?

Solution

$\Delta U = Q - W = 5000\,J - 7500\,J = -2500\,J$

$\Delta U = -2500\,J = (3/2)nR\Delta T = (3/2)(2)(8.31)\Delta T$

$\rightarrow \Delta T = -100\,K$

$\rightarrow T_f = 500\,K - 100\,K - 400\,K$

comment : the gas does more work than it takes in as heat,
so it must use 2500 J of its internal energy.

2. Compute the internal energy change and temperature change for the two processes involving 1 mole of an ideal monatomic gas.
(a) 1500 J of heat are added to the gas and the gas does no work and no work is done on the gas
(b) 1500 J of work are done on the gas and the gas does no work and no heat is added or taken away from the gas

Solution

(a)

$\Delta U = Q - W = 1500\,J - 0 = 1500\,J$

$\Delta U = 1500\,J = (3/2)nR\Delta T = (3/2)(1)(8.31)\Delta T$

$\rightarrow \Delta T = 120\,K$

(b)

$\Delta U = Q - W = 0 - (-1500\,J) = +1500\,J$

$\Delta U = 1500\,J = (3/2)nR\Delta T = (3/2)(1)(8.31)\Delta T$

$\rightarrow \Delta T = 120\,K$

Notice that in both processes, the change in internal energy is the same. We say that the internal energy is a "state function". A state function depends only on the state of the system and not on the process that brings the system to that particular state.