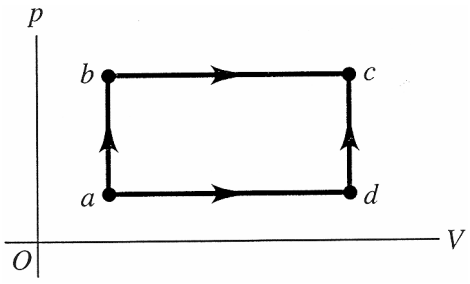
The figure shows four states of a thermodynamic system, a, b, c, and d. The volume of the system is V_a for both state a and state b, and is V_c for both state c and state d. The pressure of the system is p_a for both state a and state d, and is p_c for both state b and state c. The internal energies of the four states are U_a, U_b, U_c, and U_d. For each of the processes *ab*, *bc*, *ad*, and *dc*, find



a) the work done by the system during the process and
b) the heat flow into the system during the process.
c) The system can be taken from state a to state c along either path *abc* or path *ade*. Find the net heat flow into the system and the net work done by the system for each path. For which path is the net heat flow greater? For which path is the net work greater?
d) A friend tells you that the amounts of heat flow should be the same for both path *abc* and path *ade*, since the initial state (a) and final state (c) of the system are the same for both paths. How would you respond?

We will need the equation for work and the 1st Law of Thermodynamics,

$$W = p(V_2 - V_1) \quad and \quad DU = Q - W.$$

a) The work done by the system during the process: Along *ab* or *cd*, *W*=0. Along *bc*, $W_{bc} = p_c(V_c - V_a)$. Along *ad*, $W_{ad} = p_a(V_c - V_a)$.

b) The heat flow into the system during the process: $Q = \Delta U + W$.

$$DU_{ab} = U_b - U_a, so\ Q_{ab} = U_b - U_a + 0.$$
$$DU_{bc} = U_c - U_b, so\ Q_{bc} = (U_c - U_b) + p_c(V_c - V_a).$$
$$DU_{ad} = U_d - U_a, so\ Q_{ad} = (U_d - U_a) + p_a(V_c - V_a).$$
$$DU_{dc} = U_c - U_d, so\ Q_{dc} = (U_c - U_d) + 0.$$

c) From state a to state c along path *abc*:

$$W_{abc} = p_c(V_c - V_a). Q_{abc} = U_b - U_a + (U_c - U_b) + p_c(V_c - V_a) = (U_c - U_a) + p_c(V_c - V_a)$$

From state a to state c along path adc :

$$W_{adc} = p_a(V_c - V_a). Q_{adc} = (U_c - U_a) + p_a(V_c - V_a)$$

Assuming $p_c > p_a$, $Q_{abc} > Q_{adc}$, and $W_{abc} > W_{adc}$.

d) To understand this difference, start from the relationship $Q = W + \Delta U$. The internal energy change ΔU is path independent and so it is the same for path *abc* and path *adc*. The work done by the system is the area *under* the path in the *pV*-plane and is *not* the same for the two paths. Indeed, it is larger for path *abc*. Since ΔU is the same and *W* is different, *Q* must be different for the two paths. The heat flow *Q* is path dependent.