CH353 – Physical Chemistry I
Spring 2013, Unique 52575

$C_v = \frac{3}{2}R$; $C_p = \frac{5}{2}R$

Quiz 2, Friday 8 February 2013

1.0 mole of a monatomic ideal gas is expanded from an initial volume of 10.0 L at a pressure of 2.0 atm to a final volume of 30.0 L, at which point the pressure is 1.0 atm. This expansion can be conducted along two possible paths. For path 1, the system is heated at constant pressure to achieve the final volume, then cooled at constant volume to achieve the final pressure. For path 2, the system is cooled at constant volume to achieve the final pressure, then heated at constant pressure to achieve the final volume.

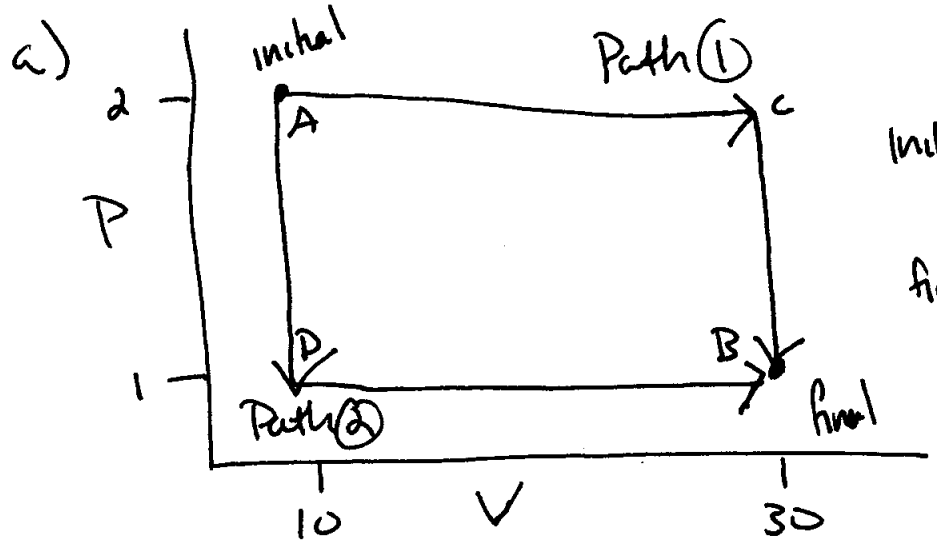
a) Draw a graph representing the initial and final states, and the two different paths connecting them. There are many ways to do this, but it would probably make sense for the axes of your graph to represent volume and pressure.

b) Determine ΔU, w, and q along path 1.

c) Determine ΔU, w, and q along path 2.

d) Compare ΔU, w, and q between these two paths, highlighting any similarities or differences.

e) If you wanted your system to perform the maximum amount of work on the surroundings, which path would you chose and why?



Call these points A–D

Initial state (A): $P_A = 2.0$ atm

$V_A = 10.0$ L

final state (B) $P_B = 1.0$ atm

$V_B = 30.0$ L

$T_A = \frac{P_A V_A}{nR}$ $T_B = \frac{P_B V_B}{nR}$

b) path ①: $w_{AC} = -P_{ext}\Delta V = -P_A(V_B - V_A)$

$w_{CB} = -P_{ext}\Delta V = 0$

$w_① = w_{AC} + w_{CB} = -P_A(V_B - V_A) = \boxed{-4050\,J = w_①}$

$q_{AC} = q_P = nC_p\Delta T = n\left(\frac{5}{2}R\right)(T_C - T_A)$

$q_{CB} = q_V = nC_v\Delta T = n\left(\frac{3}{2}R\right)(T_B - T_C)$

$q_① = q_{AC} + q_{CB} = \boxed{5570\,J = q_①}$

$\boxed{\Delta U_① = q_① + w_① = 1520\,J}$

c) path ②: $w_{AD} = -P_{ext}\Delta V = 0$

$w_{DB} = -P_{ext}\Delta V = -P_B(V_B - V_D)$

$w_② = w_{AD} + w_{DB} = -P_B(V_B - V_D) = \boxed{-2030\,J = w_②}$

$q_{AD} = q_V = nC_v\Delta T = n\left(\frac{3}{2}R\right)(T_D - T_A)$

$q_{DB} = q_P = nC_p\Delta T = n\left(\frac{5}{2}R\right)(T_B - T_D)$

$q_② = q_{AD} + q_{DB} = \boxed{3550\,J = q_②}$

$\boxed{\Delta U_② = 1520\,J}$

d) $w_① > w_②$ (i.e. System can do more work)

$q_① > q_②$

$\Delta U_① = \Delta U_②$ as expected (state function)

e) use path ① to get the most work out of the system