CHEM2011 Chapter 1 problems

Jerry Wu

February 8, 2023

Question 1a,b

One mole of an ideal **monoatomic** gas initially at $300k$ and pressure of $15.0atm$ expands to a final pressure of $1.00atm$. The expansion can occur via any of five different paths. For each case, calculate the value of q, w, ΔU and ΔH.

a) Isothermal and reversible

Solution::

Assume $T_2 = T_1 \implies \Delta T = 0$ by isothermal. Because $\Delta T = 0$, we have that $\Delta H = 0$ and $\Delta U = 0$ as a consequence. So, $\Delta U = q + w = 0 \implies w = -q$. We can now find the value of w by using the formula::

$$w = -nRT\ln(\frac{P_1}{P_2}) = -(1)(8.314)(300)\ln(\frac{15}{1}) = -6.75E - 3J \implies q = 6.75E - 3J$$

b) Isothermal and irreversible

Solution::

ΔU and ΔH are still 0 since $\Delta T = 0$. Because this process is irreversible, $P_2 = P_{external}$. So we have that

$$w = -P_2\Delta V = -P_2(V_2 - V_1)$$

Apply ideal gas law to find V_1 and V_2.

$$V_1 = \frac{nRT}{P_1} = \frac{(1)(0.08206)(300)}{15} = 1.641L, V_2 = \frac{nRT}{P_2} = 24.62L$$

We can now find our work for the irreversible process.

$$w = -1(24.62 - 1.641)(\frac{101.325J}{1Latm}) = -2.33E3J \implies q = 2.33E3J$$

c) Isothermal and irreversible in a 2 step process. **Step 1::** $P = 7atm$, **Step 2::** P=1atm.

Solution::

The process is still isothermal, so assume $\Delta T, \Delta U, \Delta H = 0$ and $q = -w$.
Let $P' = 7atm$ denote the intermediate pressure between the two steps. So we want to find the work berween V_1 and V' along with V' and V_2.

$$V_1 = 1.641L, V' = \frac{(1)(0.08206)(300)}{7} = 3.52L, V_2 = 24.62L$$

Now let us calculate the work done for both steps.

$$w = w_1 + w_2 = -P_2\Delta V = -((7)(3.52 - 1.641) + (1)(24.62 - 3.52)) \approx -34.251Latm(\frac{101.325}{Latm})$$

Question 4

The constant pressure heat capacity of an ideal gas, $A \in \mathbb{C}$ was found to vary with temperature according to the expression

$$\bar{C}_P = 22.17 + 0.32T inunitsof JK^{-1}mol^{-1}$$

a) Calculate $q, w, \Delta U, \Delta H$ when the temperature of $2mol$ of A is raised from $0°C \to 50°C(273K \to 323K)$. Assume $P \equiv const.$

Solution::

First, we can find ΔH.

$$\Delta H = \int_{273}^{323} C_P dT = n\int_{273}^{323} \bar{C}_P dT = (2)\int_{273}^{323} 21.17 + 0.32T = 2\left[21.17T + \frac{0.32}{2}T^2\right]_{273}^{323}$$

$$= 2\left[\left(22.17(323) + \frac{0.32}{2}(323)^2\right) - \left(22.17(273) + \frac{0.32}{2}(273)^2\right)\right] = 11753J = 11.75kJ$$

Because we assumed $P \equiv const$, $\Delta H = q = 11.75kJ$. Now we find ΔU.

$$\Delta U = \Delta H - \Delta(PV) = \Delta H - nR\Delta T = 11753 - (2)(8.314)(323 - 273) = 10.92kJ$$

And so, $w = \Delta U - q$.

$$w = 10.92kJ - 11.75kJ = -0.83kJ$$

Because work is negative, work was done by the system, whereby we have an expansion.

b) Now assume $V \equiv const$.

Solution

Because $V \equiv const$, we can carry over our ΔH and ΔU values since they're only dependent on temperature.
When volume is constant, $w = 0$ since there is no expansion or compression. This implies that $q = \Delta U = 10.92kJ$.