First-Law of Thermodynamics extra problems solutions

May 20, 2026

38. When a dilute gas expands quasi-statically from 0.50 to 4.0 L, it does 250 J of work. Assuming that the gas temperature remains constant at 300 K, (a) what is the change in the internal energy of the gas? (b) How much heat is absorbed by the gas in this process?

1. (a) Note that we are working with an ideal gas. For an ideal gas, its internal energy depends on temperature. Hence, if the temperature of the gas doesn't change, the internal energy of the gas doesn't change. Hence, in the process, we are considering internal energy of the gas doesn't change. That is, $dU = 0$. (b) We know from the first law, $dU = \delta Q - \delta W$. Here, $dU = 0$, hence, $\delta Q = \delta W$. As work done by the gas is 250J, $\delta Q = \delta W = 250J$. Hence, heat absorbed by the gas is 250J.

39. In an expansion of gas, 500 J of work are done by the gas. If the internal energy of the gas increased by 80 J in the expansion, how much heat does the gas absorb?

2. In the process described, $\delta W =$ work done by the gas $= 500J$ and $dU =$ change in the internal energy $= 80J$. From the first-law, $dU = \delta Q - \delta W$, implies $\delta Q = dU + \delta W = 80 + 500 = 580J$. Hence, heat absorbed by the gas is 580J.

40. An ideal gas expands quasi-statically and isothermally from a state with pressure p and volume V to a state with volume 4V. How much heat is added to the expanding gas?

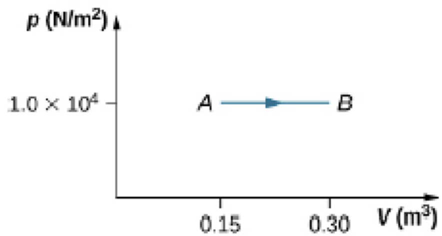
3. We have an isothermal process. In an isothermal process, internal energy doesn't change. Hence, $dU = 0$. That implies, from the first-law, $\delta Q = \delta W$. In the process mentioned in the question, volume of the gas increases from V, when pressure is p, to 4V. We know for the ideal gas $PV = nRT$. Hence, during the

isothermal expansion,

$$
\begin{aligned}
\delta W =& \text{work done by the gas} \\
=& \int_{V_1}^{V2} \frac{nRT}{V} dV \\
=& nRT \; ln\left(\frac{V_2}{V_1}\right) \\
=& nRT \; ln\left(\frac{4V}{V}\right) \\
=& nRT \; ln(4) \\
=& pV \; ln(4)
\end{aligned} \tag{1}
$$

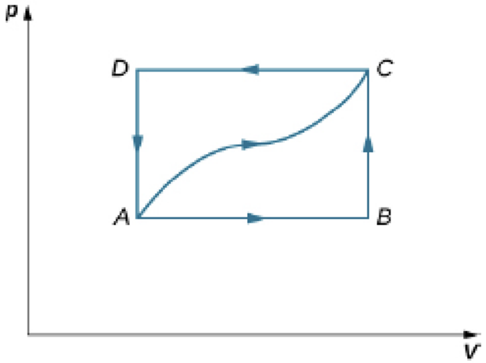
In the last line, we made use of $pV = nRT$ for initial pressure p and initial volume V. Hence heat added is $\delta Q = pV \; ln(4)$.

42. During the isobaric expansion from A to B represented below, 3,100 J of heat are added to the gas. What is the change in its internal energy?



4. We have an increase in the volume of the gas from 0.15 to 0.30 m^3, under a constant pressure $P = 10^4 N/m^2$. Hence, δW = work done by the gas $= P\Delta V = 10^4 \times (0.30 - 0.15) N \cdot m = 0.15 \times 10^4 J$. Then we also have δQ = heat absorbed by the gas $= 3100J$. Hence, the change in the internal energy is, $dU = \delta Q - \delta W = 3100 - 1500J = 1600J$.

45. When a gas expands along *AB* (see below), it does 20 J of work and absorbs 30 J of heat. When the gas expands along *AC*, it does 40 J of work and absorbs 70 J of heat. (a) How much heat does the gas exchange along *BC*? (b) When the gas makes the transition from *C* to *A* along *CDA*, 60 J of work are done on it from *C* to *D*. How much heat does it exchange along *CDA*?



5. We have δW_{AB} = work done during process A to B $= 20J$ and δQ_{AB} = heat absorbed during process A to B $= 30J$. Then $\delta W_{AC} = 40J$ and $\delta Q_{AC} = 70J$.

(a) Then we can write

$$\begin{aligned} dU_{AC} =& \text{internal energy difference between state A and C} \\ =& U_C - U_A \\ =& U_C - U_B + U_B - U_A \\ =& dU_{BC} + dU_{AB} \end{aligned}$$

Then using first law,

$$\begin{aligned} dU_{AC} =& dU_{BC} + dU_{AB} \\ \delta Q_{AC} - \delta W_{AC} =& \delta Q_{BC} - \delta W_{BC} + \delta Q_{AB} - \delta W_{AB} \end{aligned}$$

Because the volume of the gas doesn't change between B and C, $\delta W_{BC} = 0$. Then putting the above values for heat changes and work done, we get

$$\begin{aligned}\delta Q_{BC} =& 70 - 40 - 30 + 20 \\ =& 20J\end{aligned}$$

(b) We have δW_{CDA} = work done by the gas from C to A through D = $-60J$. Note the negative sign. The question mentions that $60J$ of work is done on the gas and hence work done by the gas will be opposite of it. Then we have from first-law

$$\begin{aligned}dU_{CA} =& \delta Q_{CDA} - \delta W_{CDA} \\ -dU_{AC} =& \delta Q_{CDA} + 60J \\ -\delta Q_{AC} + \delta W_{AC} =& \delta Q_{CDA} + 60J \\ \text{which implies} \qquad \delta Q_{CDA} =& -70 + 40 - 60J \\ \delta Q_{CDA} =& -90J\end{aligned}$$

Hence, gas loses $90J$ of heat.