

習題七

19.11. IDENTIFY: Part *ab* is isochoric, but *bc* is not any of the familiar processes.

SET UP: $pV = nRT$ determines the Kelvin temperature of the gas. The work done in the process is the area under the curve in the pV diagram. Q is positive since heat goes into the gas. $1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$. $1 \text{ L} = 1 \times 10^{-3} \text{ m}^3$. $\Delta U = Q - W$.

EXECUTE: (a) The lowest T occurs when pV has its smallest value. This is at point *a*, and

$$T_a = \frac{p_a V_a}{nR} = \frac{(0.20 \text{ atm})(1.013 \times 10^5 \text{ Pa/atm})(2.0 \text{ L})(1.0 \times 10^{-3} \text{ m}^3/\text{L})}{(0.0175 \text{ mol})(8.315 \text{ J/mol}\cdot\text{K})} = 278 \text{ K.}$$

(b) *a* to *b*: $\Delta V = 0$ so $W = 0$.

b to *c*: The work done by the gas is positive since the volume increases. The magnitude of the work is the area under the curve so $W = \frac{1}{2}(0.50 \text{ atm} + 0.30 \text{ atm})(6.0 \text{ L} - 2.0 \text{ L})$ and

$$W = (1.6 \text{ L}\cdot\text{atm})(1 \times 10^{-3} \text{ m}^3/\text{L})(1.013 \times 10^5 \text{ Pa/atm}) = 162 \text{ J.}$$

(c) For *abc*, $W = 162 \text{ J}$. $\Delta U = Q - W = 215 \text{ J} - 162 \text{ J} = 53 \text{ J}$.

EVALUATE: 215 J of heat energy went into the gas. 53 J of energy stayed in the gas as increased internal energy and 162 J left the gas as work done by the gas on its surroundings.

19.18. IDENTIFY: For constant volume $Q = nC_V\Delta T$. For constant pressure, $Q = nC_p\Delta T$. For any process of an ideal gas, $\Delta U = nC_V\Delta T$.

SET UP: $R = 8.315 \text{ J/mol}\cdot\text{K}$. For helium, $C_V = 12.47 \text{ J/mol}\cdot\text{K}$ and $C_p = 20.78 \text{ J/mol}\cdot\text{K}$.

EXECUTE: (a) $Q = nC_V\Delta T = (0.0100 \text{ mol})(12.47 \text{ J/mol}\cdot\text{K})(40.0 \text{ K}) = 4.99 \text{ J}$. The pV -diagram is sketched in Figure 19.18a.

(b) $Q = nC_p\Delta T = (0.0100 \text{ mol})(20.78 \text{ J/mol}\cdot\text{K})(40.0 \text{ K}) = 8.31 \text{ J}$. The pV -diagram is sketched in Figure 19.18b.

(c) More heat is required for the constant pressure process. ΔU is the same in both cases. For constant volume $W = 0$ and for constant pressure $W > 0$. The additional heat energy required for constant pressure goes into expansion work.

(d) $\Delta U = nC_V\Delta T = 4.99 \text{ J}$ for both processes. ΔU is path independent and for an ideal gas depends only on ΔT .

EVALUATE: $C_p = C_V + R$, so $C_p > C_V$.

19.35

IDENTIFY and SET UP: For an ideal gas, $pV = nRT$. The work done is the area under the path in the pV -diagram.

EXECUTE: (a) The product pV increases and this indicates a temperature increase.

(b) The work is the area in the pV plane bounded by the blue line representing the process and the verticals at V_a and V_b . The area of this trapezoid is

$$\frac{1}{2}(p_b + p_a)(V_b - V_a) = \frac{1}{2}(2.53 \times 10^5 \text{ Pa})(0.0400 \text{ m}^3) = 5060 \text{ J.}$$

EVALUATE: The work done is the average pressure, $\frac{1}{2}(p_1 + p_2)$, times the volume increase.

19.38

IDENTIFY: Segment ab is isobaric, bc is isochoric, and ca is isothermal.

SET UP: He is a monatomic gas so $C_V = \frac{3}{2}R$ and $C_p = \frac{5}{2}R$. For any process of an ideal gas,

$$\Delta U = nC_V\Delta T. \text{ For an isothermal process of an ideal gas, } \Delta U = 0 \text{ so } Q = W = nRT \ln(V_2/V_1).$$

EXECUTE: (a) Apply $pV = nRT$ to states a and c . $T_a = T_c$ so nRT is constant and $p_a V_a = p_c V_c$.

$$p_a = p_c \left(\frac{V_c}{V_a} \right) = (2.0 \times 10^5 \text{ Pa}) \left(\frac{0.040 \text{ m}^3}{0.010 \text{ m}^3} \right) = 8.0 \times 10^5 \text{ Pa.}$$

$$(b) T_a = \frac{p_a V_a}{nR} = \frac{(8.0 \times 10^5 \text{ Pa})(0.010 \text{ m}^3)}{(3.25 \text{ mol})(8.315 \text{ J/mol}\cdot\text{K})} = 296 \text{ K;}$$

$$T_b = \frac{p_b V_b}{nR} = \frac{(8.0 \times 10^5 \text{ Pa})(0.040 \text{ m}^3)}{(3.25 \text{ mol})(8.315 \text{ J/mol}\cdot\text{K})} = 1184 \text{ K;}$$

$$T_c = \frac{p_c V_c}{nR} = \frac{(2.0 \times 10^5 \text{ Pa})(0.040 \text{ m}^3)}{(3.25 \text{ mol})(8.315 \text{ J/mol}\cdot\text{K})} = 296 \text{ K} = T_a.$$

(c) ab : $Q = nC_p\Delta T = (3.25 \text{ mol})\left(\frac{5}{2}\right)(8.315 \text{ J/mol}\cdot\text{K})(1184 \text{ K} - 296 \text{ K}) = 6.00 \times 10^4 \text{ J}$; heat enters the gas.

bc : $Q = nC_V\Delta T = (3.25 \text{ mol})\left(\frac{3}{2}\right)(8.315 \text{ J/mol}\cdot\text{K})(296 \text{ K} - 1184 \text{ K}) = -3.60 \times 10^4 \text{ J}$; heat leaves the gas.

ca : $Q = nRT \ln\left(\frac{V_a}{V_c}\right) = (3.25 \text{ mol})(8.315 \text{ J/mol}\cdot\text{K})(296 \text{ K}) \ln\left(\frac{0.010 \text{ m}^3}{0.040 \text{ m}^3}\right) = -1.11 \times 10^4 \text{ J}$; heat leaves the gas.

(d) ab : $\Delta U = nC_V\Delta T = (3.25 \text{ mol})\left(\frac{3}{2}\right)(8.315 \text{ J/mol}\cdot\text{K})(1184 \text{ K} - 296 \text{ K}) = 3.60 \times 10^4 \text{ J}$; the internal energy increased.

bc : $\Delta U = nC_V\Delta T = (3.25 \text{ mol})\left(\frac{3}{2}\right)(8.315 \text{ J/mol}\cdot\text{K})(296 \text{ K} - 1184 \text{ K}) = -3.60 \times 10^4 \text{ J}$; the internal energy decreased.

ca : $\Delta T = 0$ so $\Delta U = 0$.

EVALUATE: As we saw in (d), for any closed path on a pV diagram, $\Delta U = 0$ because we are back at the same values of P , V , and T .

19.41

IDENTIFY: Use $pV = nRT$ to calculate T_c/T_a . Calculate ΔU and W and use $\Delta U = Q - W$ to obtain Q .

SET UP: For path ac , the work done is the area under the line representing the process in the pV -diagram.

EXECUTE: (a)
$$\frac{T_c}{T_a} = \frac{p_c V_c}{p_a V_a} = \frac{(1.0 \times 10^5 \text{ J})(0.060 \text{ m}^3)}{(3.0 \times 10^5 \text{ J})(0.020 \text{ m}^3)} = 1.00. \quad T_c = T_a.$$

(b) Since $T_c = T_a$, $\Delta U = 0$ for process abc . For ab , $\Delta V = 0$ and $W_{ab} = 0$. For bc , p is constant and $W_{bc} = p\Delta V = (1.0 \times 10^5 \text{ Pa})(0.040 \text{ m}^3) = 4.0 \times 10^3 \text{ J}$. Therefore, $W_{abc} = +4.0 \times 10^3 \text{ J}$. Since $\Delta U = 0$, $Q = W = +4.0 \times 10^3 \text{ J}$. $4.0 \times 10^3 \text{ J}$ of heat flows into the gas during process abc .

(c)
$$W = \frac{1}{2}(3.0 \times 10^5 \text{ Pa} + 1.0 \times 10^5 \text{ Pa})(0.040 \text{ m}^3) = +8.0 \times 10^3 \text{ J}. \quad Q_{ac} = W_{ac} = +8.0 \times 10^3 \text{ J}.$$

EVALUATE: The work done is path dependent and is greater for process ac than for process abc , even though the initial and final states are the same.