

Exercise walk-through

9.2

Thermodynamics (full B.4, HL)

International Baccalaureate · IB Diploma · Physics · HL

Thermodynamics · 3.1

Reasoning

State a sign convention before using the first law. Here change in internal energy equals heat into the system minus work done by the system. Expansion work can reduce internal energy when no heat enters. Identify whether a process is isothermal, adiabatic or at constant volume. On a pressure-volume graph, area under the process curve gives work done by the gas. The path matters for work even when endpoints match.

Constant volume heating

- 1 Set the model** Supply 500 J to 2.0 mol of monatomic ideal gas in a rigid container. Take work done by the gas as positive.
- 2 Calculate** $W = 0$, so $Q = \Delta U + W$ gives $\Delta U = 500$ J. Then $\Delta T = 500 / (1.5(2.0)(8.31)) = 20$ K.

Decision

There is no boundary work at constant volume. For entropy, use reversible heat transfer divided by absolute temperature, or a reversible path between the states.

Exercises 2.1-2.3

2.1 State the first law with the sign convention. [2]

2.2 Calculate the work done by a gas expanding $5.0 \times 10^{-3} \text{ m}^3$ at a constant $2.0 \times 10^5 \text{ Pa}$. [2]

2.3 Calculate the entropy change of a reservoir at 300 K that loses 600 J. [2]

Exercises 2.1·2.3

2.1 State the first law with the sign convention. [2]

2.1 $Q = \Delta U + W$; Q is the heat supplied to the system, W the work done by the system.

2.2 Calculate the work done by a gas expanding $5.0 \times 10^{-3} \text{ m}^3$ at a constant $2.0 \times 10^5 \text{ Pa}$. [2]

2.2 $W = P\Delta V = 2.0 \times 10^5 \times 5.0 \times 10^{-3} = 1.0 \times 10^3 \text{ J}$.

2.3 Calculate the entropy change of a reservoir at 300 K that loses 600 J. [2]

2.3 $\Delta S = -600/300 = -2.0 \text{ J/K}$ – the reservoir loses entropy.

Exercises 2.4·3.1

2.4 Name the four processes that keep one variable fixed. [4]

2.5 State the Carnot efficiency for $T_h = 500$ K, $T_c = 300$ K. [2]

3.1 2.0 mol of a monatomic ideal gas is heated at constant volume from 300 K to 360 K. Calculate ΔU and the heat supplied, and state W . [4]

Exercises 2.4·3.1

2.4 Name the four processes that keep one variable fixed. [4]

2.4 Isovolumetric (constant V), isobaric (constant P), isothermal (constant T), adiabatic (no heat exchange).

2.5 State the Carnot efficiency for $T_h = 500$ K, $T_c = 300$ K. [2]

2.5 $\eta = 1 - 300/500 = 0.40$.

3.1 2.0 mol of a monatomic ideal gas is heated at constant volume from 300 K to 360 K. Calculate ΔU and the heat supplied, and state W. [4]

3.1 $\Delta T = 60$ K; $\Delta U = 1.5 \times 2.0 \times 8.31 \times 60 = 1.496 \times 10^3 \approx 1.5 \times 10^3$ J; at constant V, $W = 0$, so $Q = \Delta U = 1.5 \times 10^3$ J.

Exercises 3.2-3.3

3.2 A heat engine takes in 800 J per cycle and does 200 J of useful work. Calculate the efficiency, the maximum possible efficiency if the hot reservoir is at 600 K and the cold at 300 K, and comment on the comparison. [4]

3.3 A refrigerator's interior (an open, non-isolated system) has its entropy decrease. Explain why this does not violate the second law. [3]

Exercises 3.2-3.3

3.2 A heat engine takes in 800 J per cycle and does 200 J of useful work. Calculate the efficiency, the maximum possible efficiency if the hot reservoir is at 600 K and the cold at 300 K, and comment on the comparison. [4]

3.2 $\eta = 200/800 = 0.25$; $\eta_{\text{Carnot}} = 1 - 300/600 = 0.50$; the engine runs at half the Carnot limit – allowed, since Carnot is an upper bound, not a requirement.

3.3 A refrigerator's interior (an open, non-isolated system) has its entropy decrease. Explain why this does not violate the second law. [3]

3.3 The second law applies to isolated systems; the refrigerator plus its power source and surroundings form the relevant isolated system; the heat pumped out and the work consumed raise the surroundings' entropy by at least as much as the interior's decrease.