

19.1 Gas processes, entropy and reversible cycles

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS entropy production • coefficient of performance

Objective

Apply first-law work and heat signs to gas processes; Compare reversible entropy balances and P–V cycle areas; Distinguish engine efficiency from refrigerator coefficient of performance. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Use $\Delta U = Q - W$, with heat entering and work done by the gas positive. Quasistatic work is $\int P dV$. Ideal-gas U depends on temperature: constant volume gives $Q = \Delta U$; isothermal gives $Q = W$; adiabatic gives $Q = 0$. A complete cycle has $\Delta U = 0$, hence net $Q = \text{net } W$.

Reversible isothermal paths have PV constant; with constant heat capacities, adiabatic paths have PV^γ constant and fall more steeply. Isobaric paths are horizontal. Clockwise P–V cycles give positive work: rectangle area $\Delta P \Delta V$, triangle area half that. Convert litres to m^3 .

Reversible heat transfer gives $dS = \delta Q_{\text{rev}}/T$. Total system-plus-environment entropy change is zero, but system entropy can change: isothermal expansion gives $nR \ln(V_2/V_1)$, balanced by reservoir entropy loss. Irreversibility produces nonnegative total entropy; reversible does not mean isothermal or zero work.

Carnot engine efficiency is $1 - T_C/T_H$. Refrigerator $\text{COP} = Q_C/W = T_C/(T_H - T_C)$; heat-pump $\text{COP} = T_H/(T_H - T_C)$, using kelvin. On a reversible T–S rectangle, isothermal heat is $T \Delta S$ and work magnitude is the area. Refrigerator COP can exceed one because it moves heat while consuming work.

■ Worked method

A reversible refrigerator transfers entropy ΔS from T_c to T_h .

$$Q_c = T_c \Delta S = (270 \text{ K})(3.0 \text{ J/K}) = 810 \text{ J}.$$

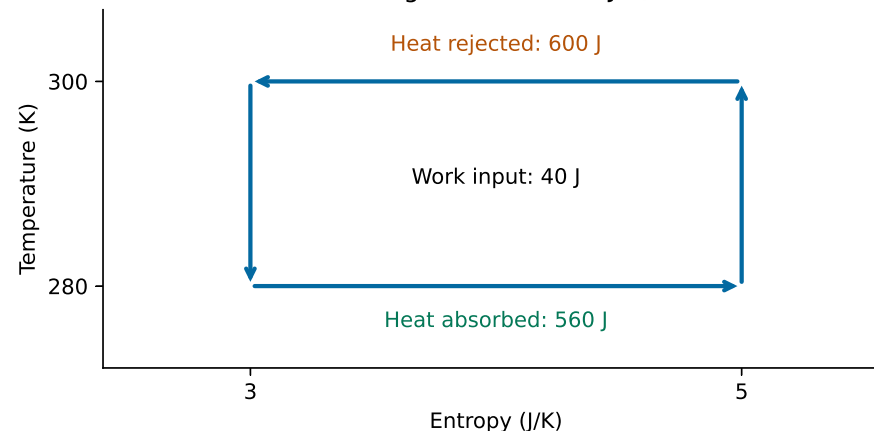
$$Q_h = T_h \Delta S = (300 \text{ K})(3.0 \text{ J/K}) = 900 \text{ J}.$$

$$W_{\text{in}} = Q_h - Q_c = 900 \text{ J} - 810 \text{ J} = 90 \text{ J}.$$

$$\text{COP} = Q_c/W_{\text{in}} = (810 \text{ J})/(90 \text{ J}) = 9.$$

COP above one is possible because heat is moved, rather than all produced from work.

Reversible refrigerator: $\Delta S = 2 \text{ J/K}$; $\text{COP} = 14$



2 Practice

2.1 Choose one answer. In a reversible process of a system and its environment, which must hold? [1]

- **A** The system entropy is constant
- **B** Temperature is constant
- **C** Total entropy change is zero
- **D** Work is zero
- **E** Internal energy is constant

2.2 Choose one answer. A reversible refrigerator has $T_C = 270 \text{ K}$ and $T_H = 300 \text{ K}$. Its COP is: [1]

- **A** 0.1
- **B** 0.9
- **C** 1
- **D** 9
- **E** 10

[2]

[2]

[5]