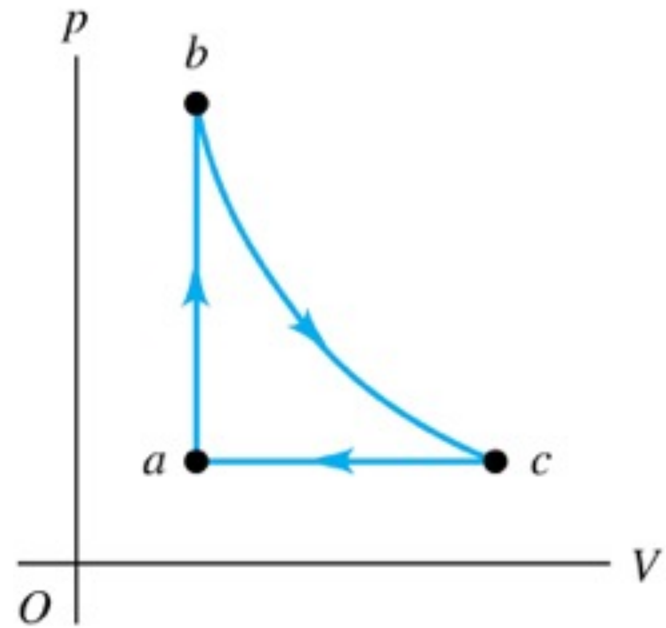
Lecture 7

PHYC 161 Fall 2016

Q20.2

An ideal gas is taken around the cycle shown in this *p*-*V* diagram, from *a* to *b* to *c* and back to *a*. Process $b \to c$ is *isothermal*. Which of the processes in this cycle could be *reversible*?



A. $a \to b$

B. $b \to c$

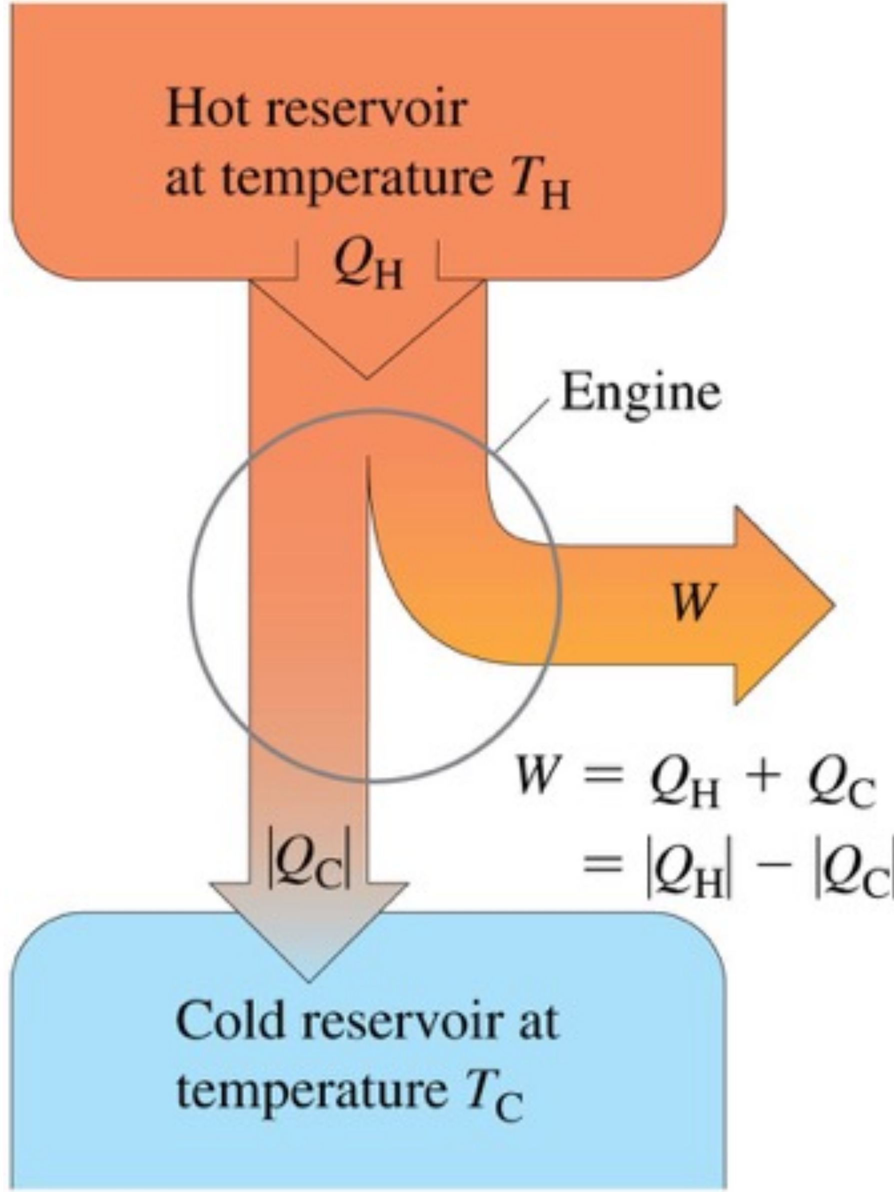
C. $c \to a$

D. two or more of A, B, and C

E. none of A, B, or C

Heat engines

- Simple heat engines operate on a *cyclic process* during which they absorb heat Q_H from a hot reservoir and discard some heat Q_C to a cold reservoir.
- Shown is a schematic energy-flow diagram for a heat engine.



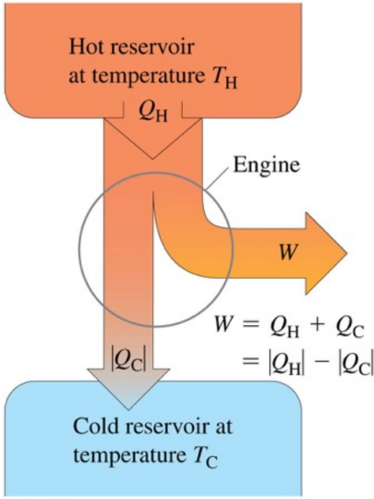
The efficiency of a heat engine

- The **thermal efficiency** ***e*** of a heat engine is the fraction of Q_H that is converted to work.

Thermal efficiency of an engine; Work done by engine; Heat rejected by engine; Heat absorbed by engine

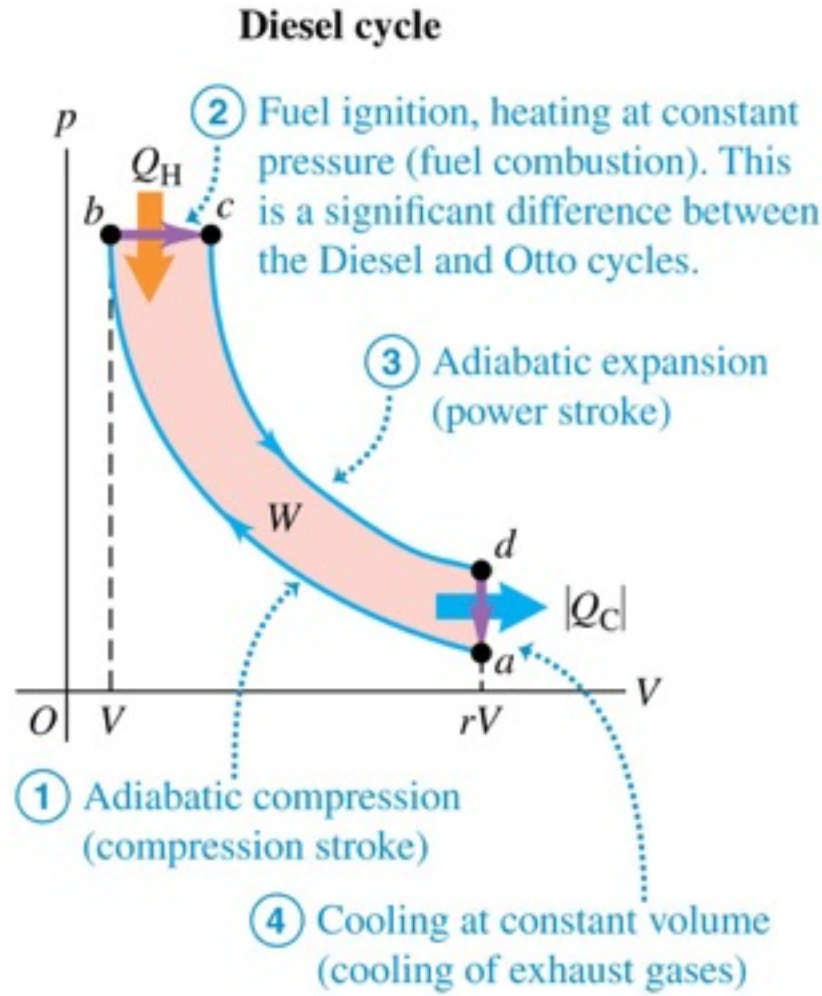
$$e = \frac{W}{Q_H} = 1 + \frac{Q_C}{Q_H} = 1 - \left|\frac{Q_C}{Q_H}\right|$$

- *e* is what you get divided by what you pay for.
- This is always less than unity, an all-too-familiar experience!



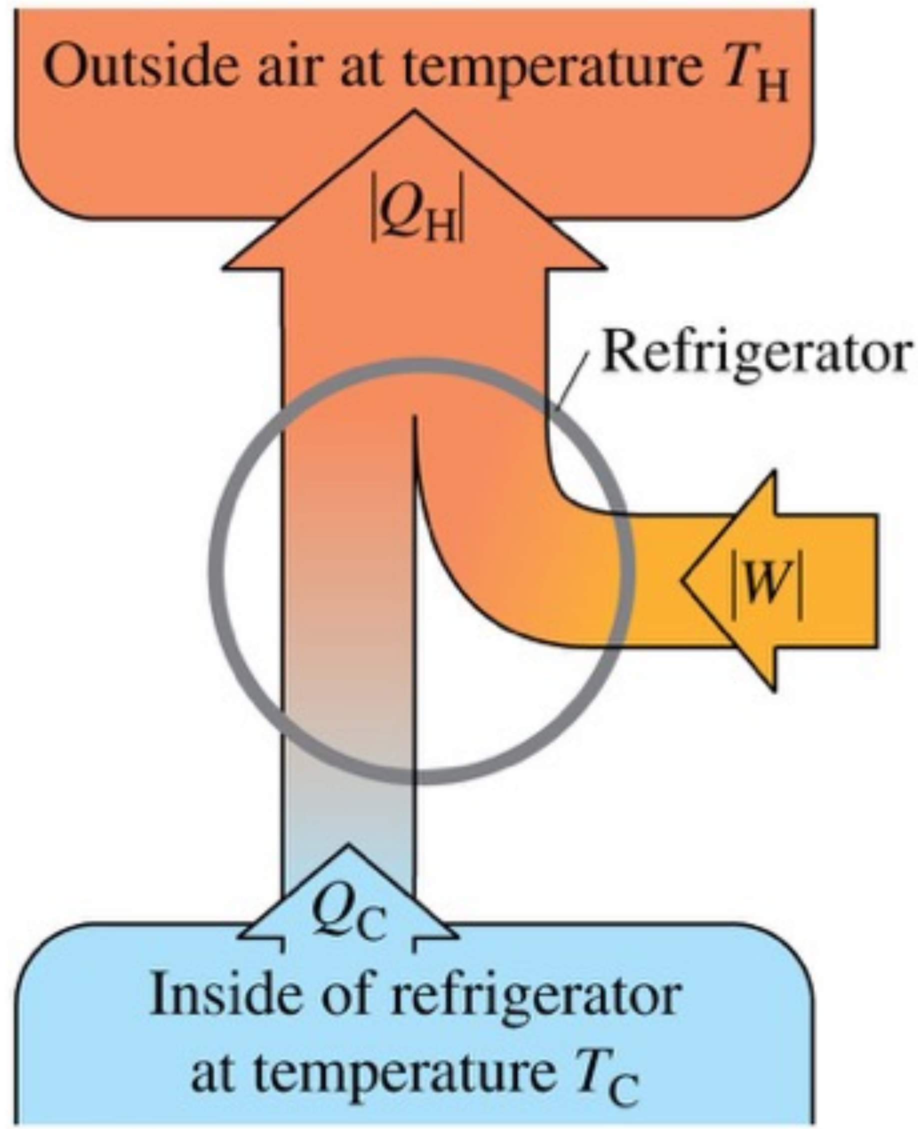
pV-diagram of the Diesel cycle

- Starting at point *a*, air is compressed adiabatically to point *b*, heated at constant pressure to point *c*, expanded adiabatically to point *d*, and cooled at constant volume to point *a*.
- Because there is no fuel in the cylinder during the compression stroke, pre-ignition cannot occur, and the compression ratio *r* can be much higher than for a gasoline engine.
- This improves efficiency.



Refrigerators

- A **refrigerator** takes heat from a cold place (inside the refrigerator) and gives it off to a warmer place (the room). An *input* of mechanical work is required to do this.
- A refrigerator is essentially a heat engine operating in reverse.
- Shown is an energy-flow diagram of a refrigerator.



The second law of thermodynamics

- The *second law of thermodynamics* can be stated in several ways:

✓ **It is impossible for any system to undergo a process in which it absorbs heat from a reservoir at a single temperature and converts the heat completely into mechanical work, with the system ending in the same state in which it began.**

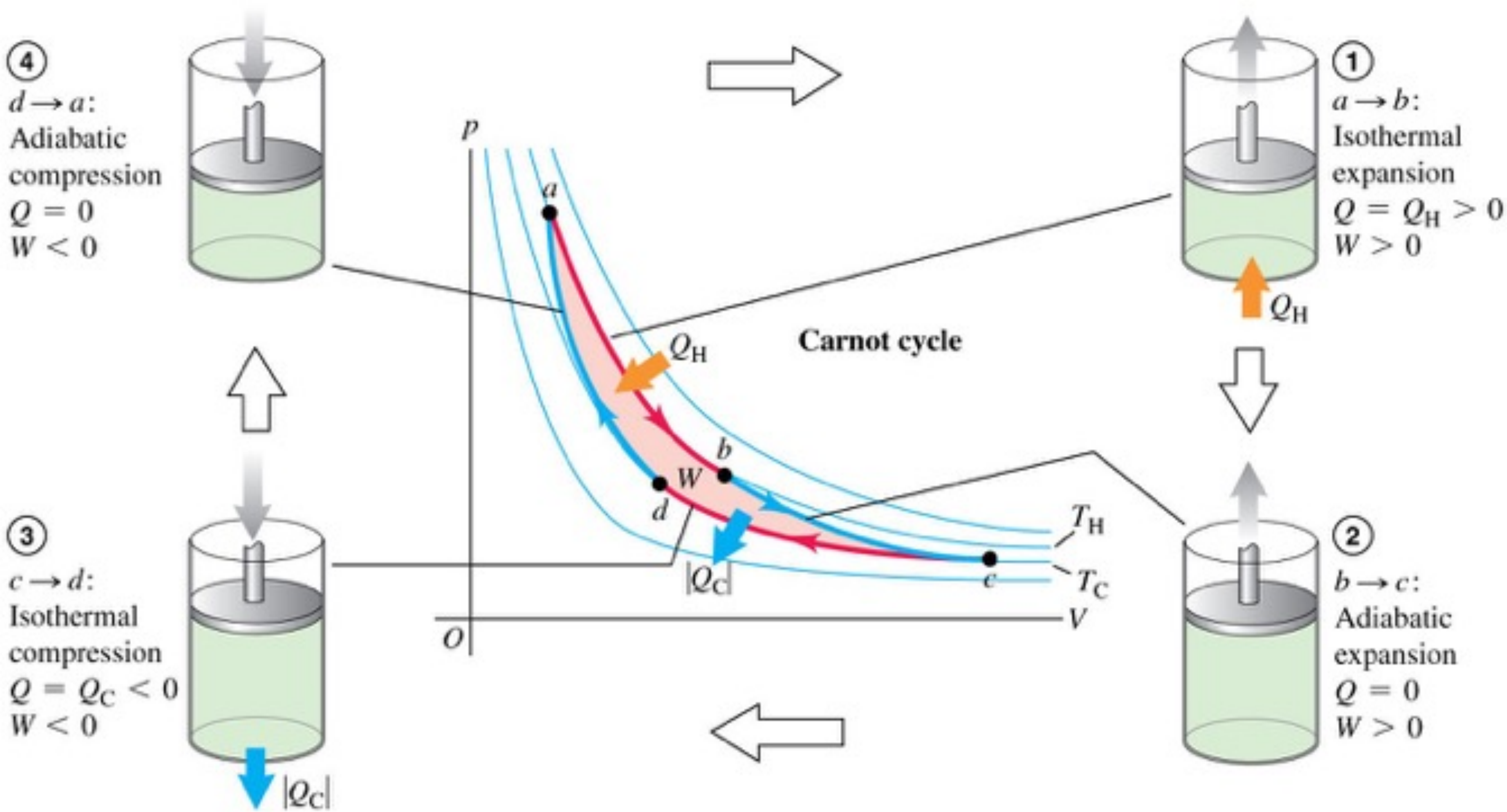
- We will call this the "engine" statement of the second law.

✓ **It is impossible for any process to have as its sole result the transfer of heat from a cooler to a hotter body.**

- We'll call this the "refrigerator" statement of the second law.

The Carnot cycle

- A *Carnot cycle* has two adiabatic segments and two isothermal segments.



The Carnot engine

- The Carnot cycle consists of the following steps:
  1. The gas expands isothermally at temperature T_H, absorbing heat Q_H.
  2. It expands adiabatically until its temperature drops to T_C.
  3. It is compressed isothermally at T_C, rejecting heat $|Q_C|$.
  4. It is compressed adiabatically back to its initial state at temperature T_H.
- The efficiency of a Carnot engine is:

Efficiency of a Carnot engine

$$e_{\text{Carnot}} = 1 - \frac{T_C}{T_H} = \frac{T_H - T_C}{T_H}$$

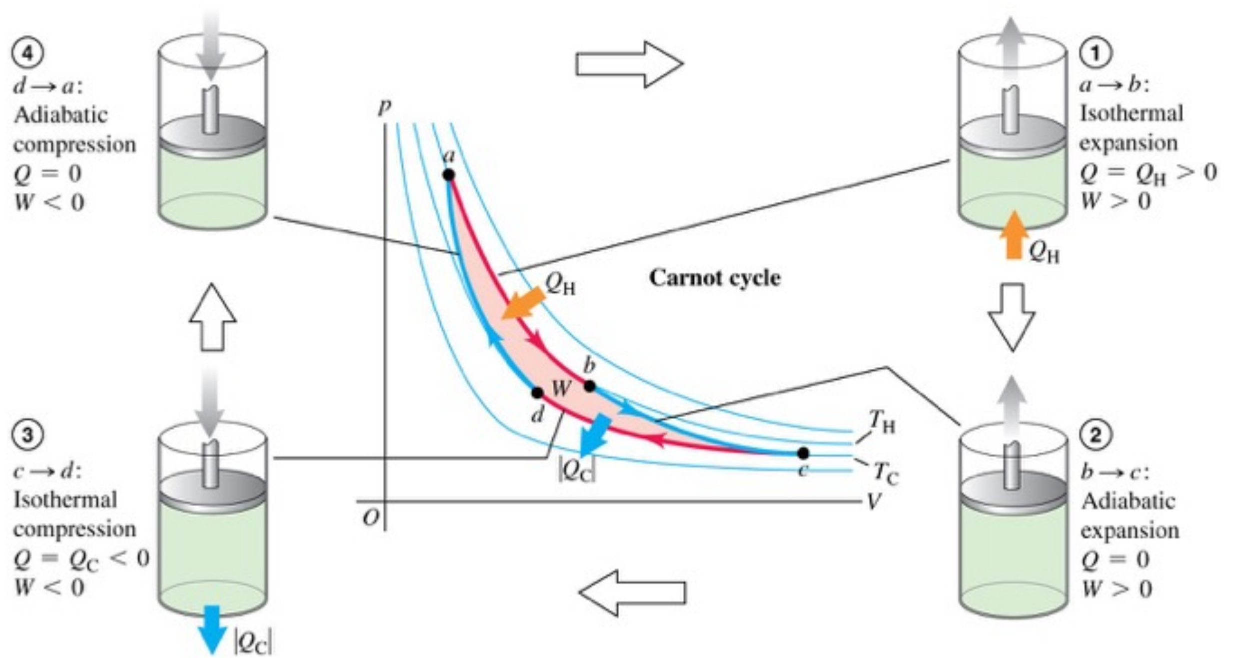
Temperature of cold reservoir

Temperature of hot reservoir

Ex 20.13 Carnot

EXAMPLE 20.3 ANALYZING A CARNOT ENGINE II

Suppose 0.200 mol of an ideal diatomic gas ($\gamma = 1.40$) undergoes a Carnot cycle between 227°C and 27°C, starting at $p_a = 10.0 \times 10^5$ Pa at point a in the pV-diagram of Fig. 20.13. The volume doubles during the isothermal expansion step $a \rightarrow b$. (a) Find the pressure and volume at points a, b, c, and d. (b) Find Q, W, and ΔU for each step and for the entire cycle. (c) Find the efficiency directly from the results of part (b), and compare with the value calculated from Eq. (20.14).



Entropy and the second law

- The second law of thermodynamics can be stated in terms of entropy:

✓ **No process is possible in which the total entropy decreases, when all systems taking part in the process are included.**

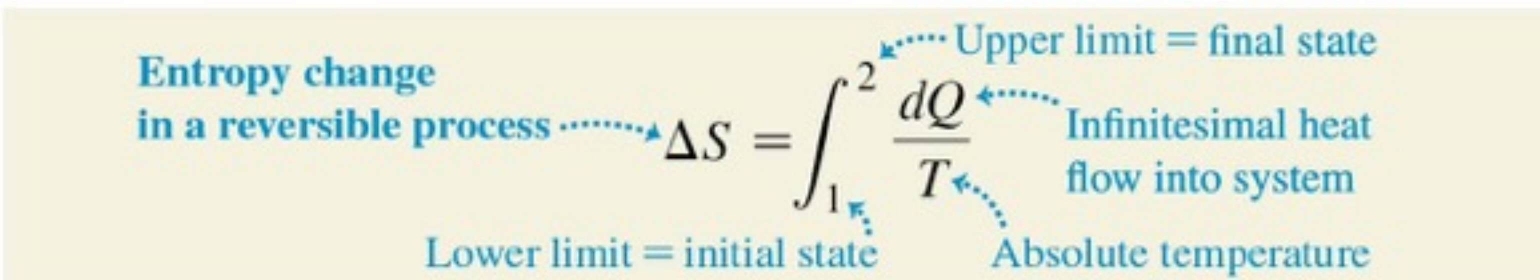
- The entropy of the ink–water system *increases* as the ink mixes with the water.

Entropy in reversible processes

- We introduce the symbol *S* for the entropy of the system, and we define the infinitesimal entropy change *dS* during an infinitesimal reversible process at absolute temperature *T* as:

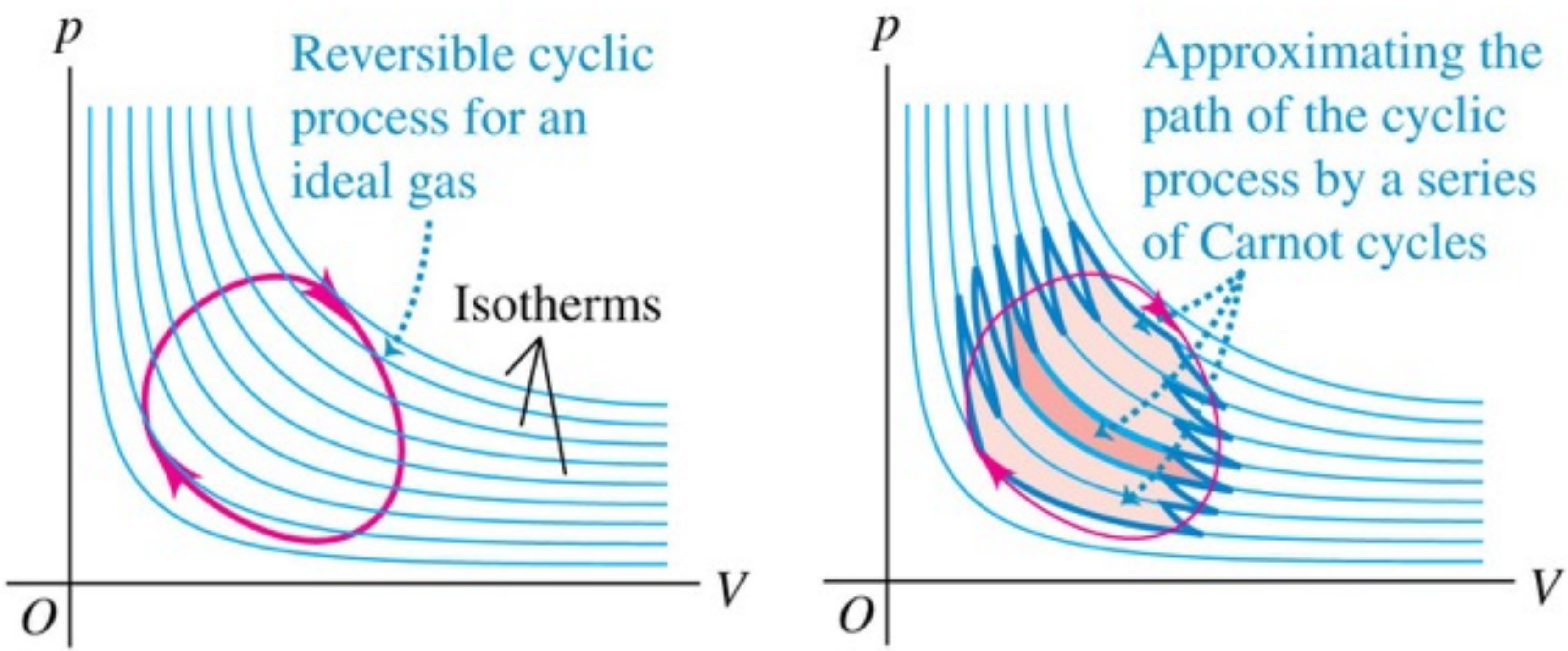
$$dS = \frac{dQ}{T} \quad \text{(infinitesimal reversible process)}$$

- The total entropy change over any reversible process is:



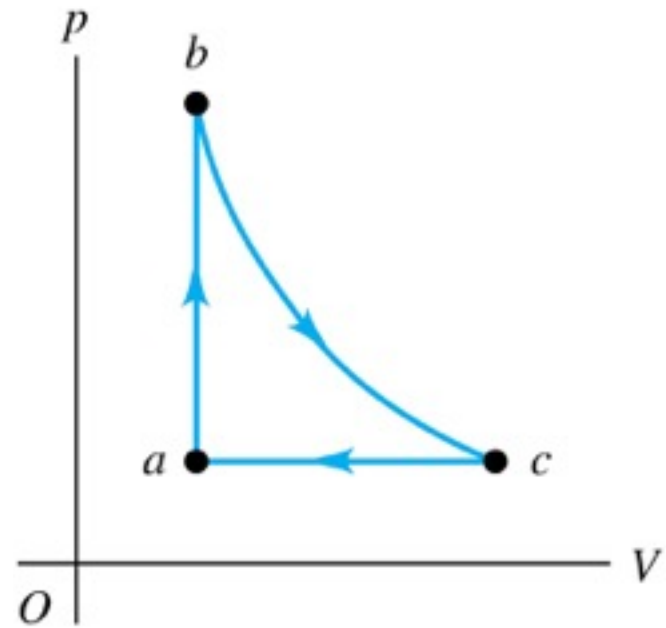
Entropy in cyclic processes

- The total entropy change in one cycle of any Carnot engine is zero.
- This result can be generalized to show that the total entropy change during *any* reversible cyclic process is zero.



Q20.9

An ideal gas is taken around the cycle shown in this *p*-*V* diagram, from *a* to *b* to *c* and back to *a*. Process $b \rightarrow c$ is *isothermal*. What can you conclude about the net entropy change of the *gas* during the cycle?



A. It is positive.

B. It is negative.

C. It is zero.

D. Two of A, B, and C are possible.

E. All three of A, B, and C are possible.