Lecture 7 (Thermodynamic Processes)

Physics 161-01 Spring 2012
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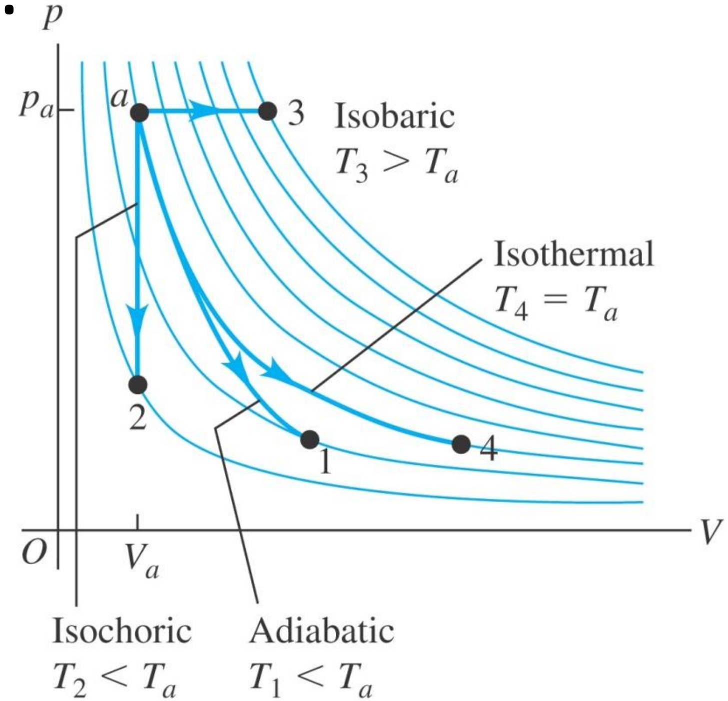
Thermodynamic Processes

- Any thermodynamic process is possible, however, for the purposes of our study, we will look at four specific processes:
  - Adiabatic = no heat transfer.
  - Isochoric = constant volume.
  - Isobaric = constant pressure.
  - Isothermal = constant temperature.



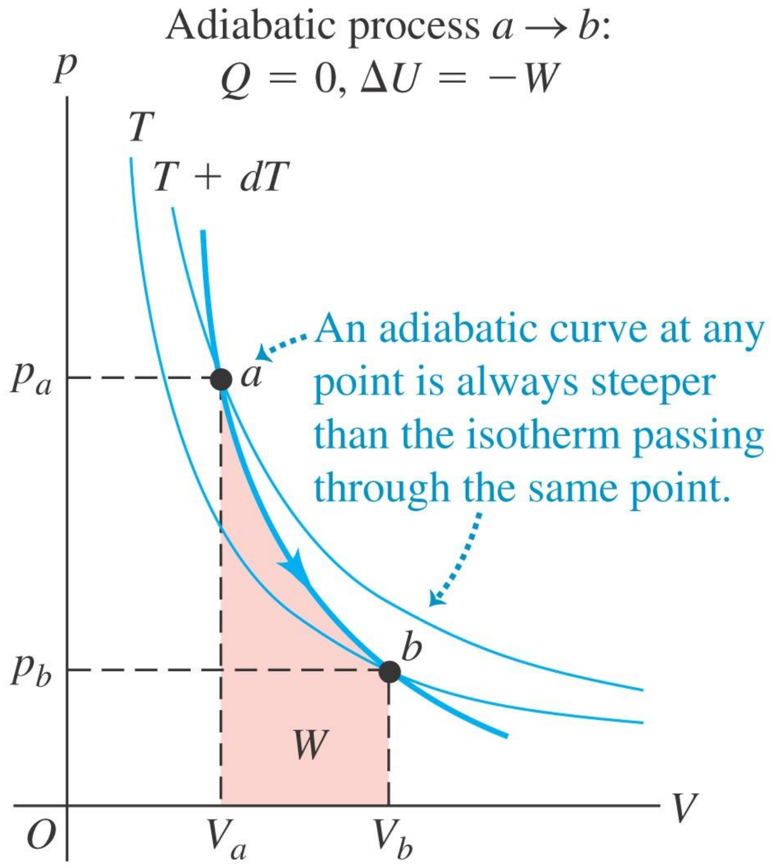
Adiabatic Processes

- No heat is transferred into or out of the system, so $Q = 0$.

$$\Delta U = Q - W \Rightarrow$$

$$\Delta U = -W = nC_V \Delta T$$

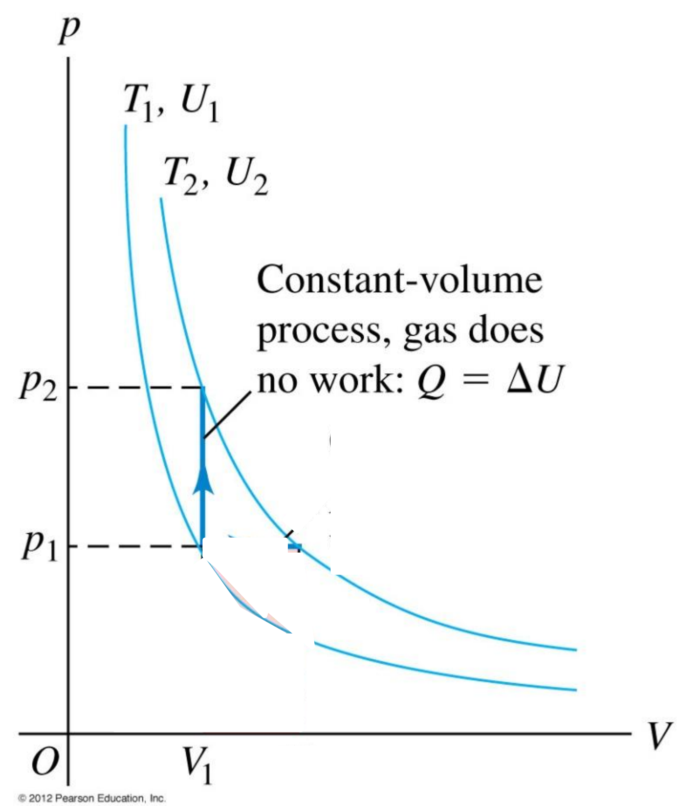
for an ideal gas



Isochoric Processes

- The volume remains constant, so $W = 0$.

$$\Delta U = Q - W \Rightarrow$$
$$\Delta U = Q$$

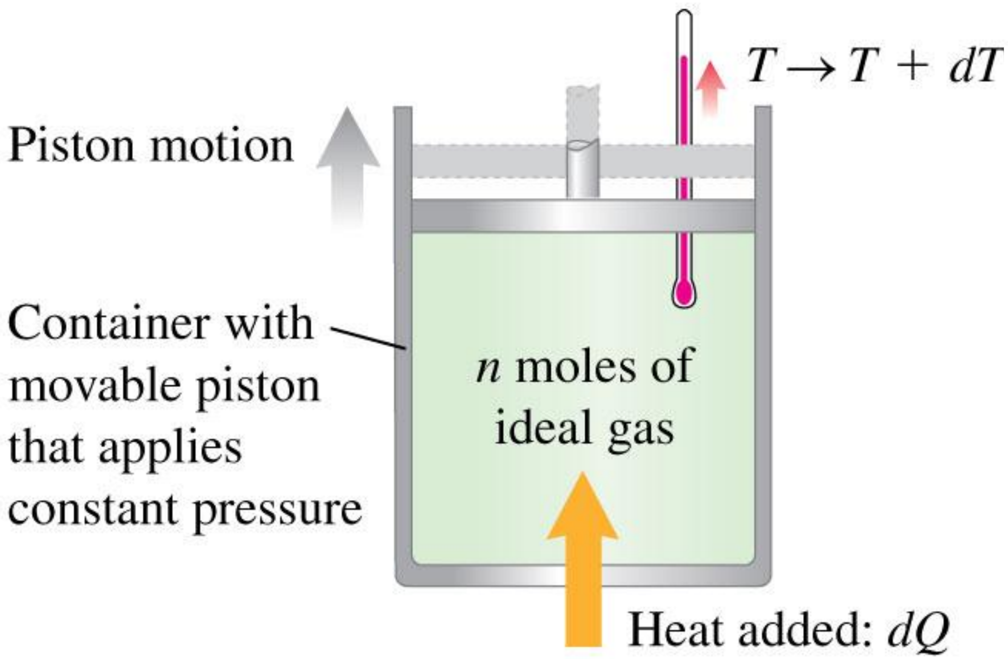


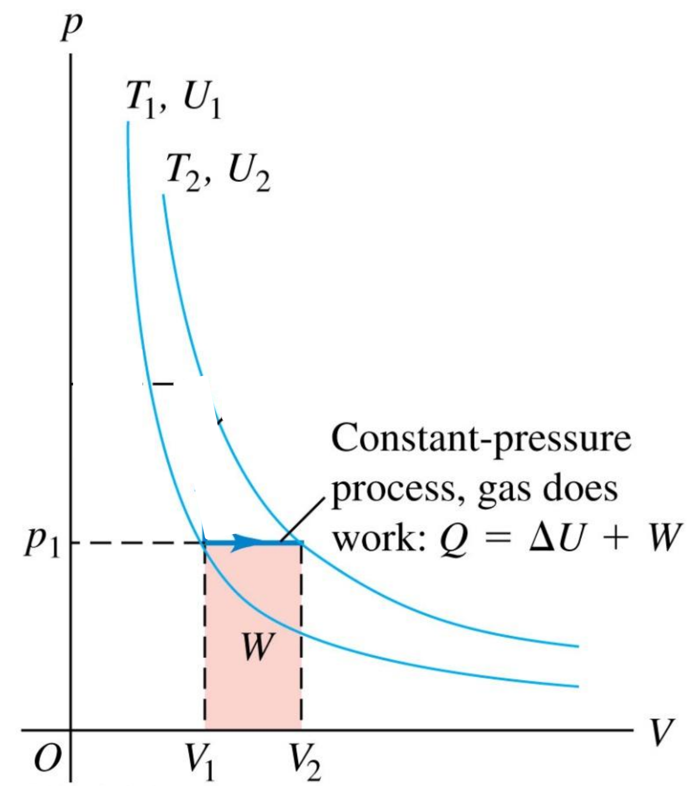
Isobaric Processes

- The pressure remains constant, so
  - $W = p(V_2 - V_1)$.

$$\Delta U = Q - W \Rightarrow$$

$$\Delta U = Q - p\left(V_2 - V_1\right)$$

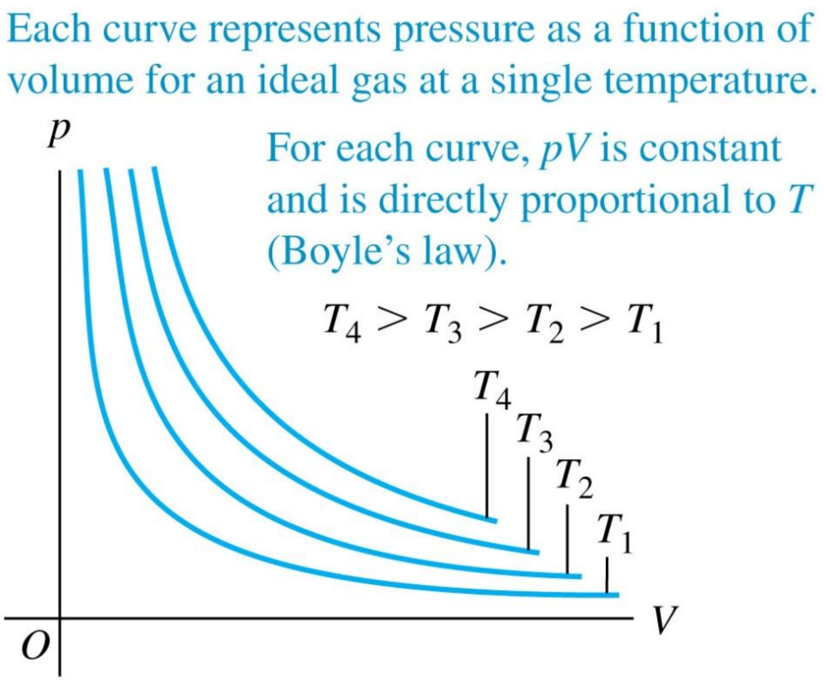




Isothermal Processes

- The temperature remains constant.
- For an ideal gas, the internal energy only depends upon temperature, so:

$$\Delta U = Q - W = 0 \Rightarrow$$
$$Q = W$$



Internal Energy of an Ideal Gas

- Because an ideal gas has no interactions between the particles, the internal energy of an ideal gas depends only on its temperature, not on its pressure or volume.

CPS 7-1

In an isothermal expansion of an ideal gas, the amount of heat that flows into the gas

A. is greater than the amount of work done by the gas.

B. equals the amount of work done by the gas.

C. is less than the amount of work done by the gas, but greater than zero.

D. is zero.

E. is negative (heat flows *out of* the gas).

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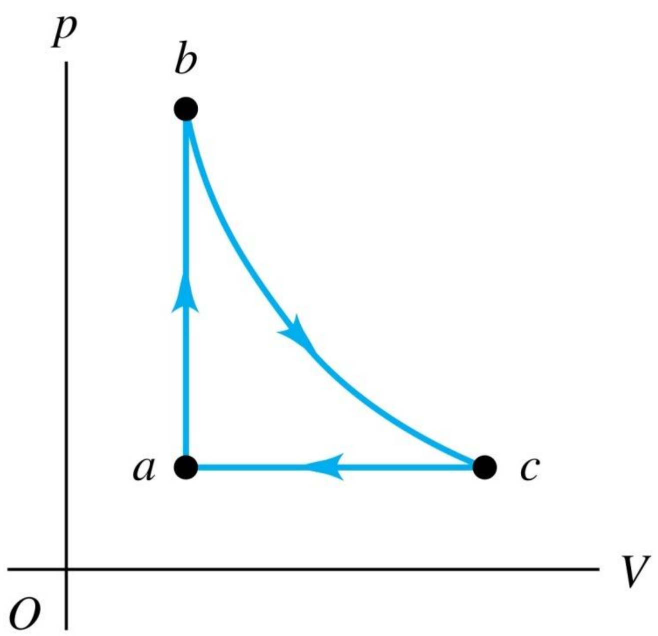
CPS 7-2

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.



For process $a \to b$,

A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

C. $Q = 0$ and $\Delta U > 0$.

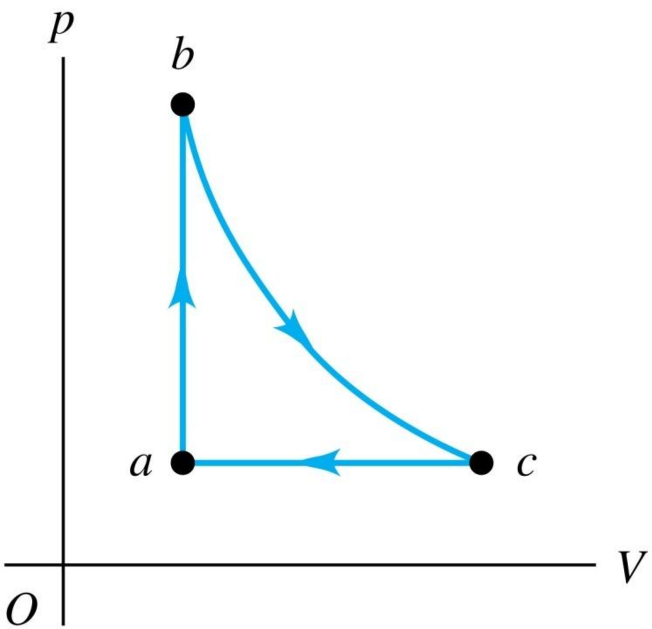
D. $Q = 0$ and $\Delta U < 0$.

E. $Q < 0$ and $\Delta U < 0$.

CPS 7-2

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 $b \rightarrow c$ is isothermal.

For process $a \rightarrow b$,



A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

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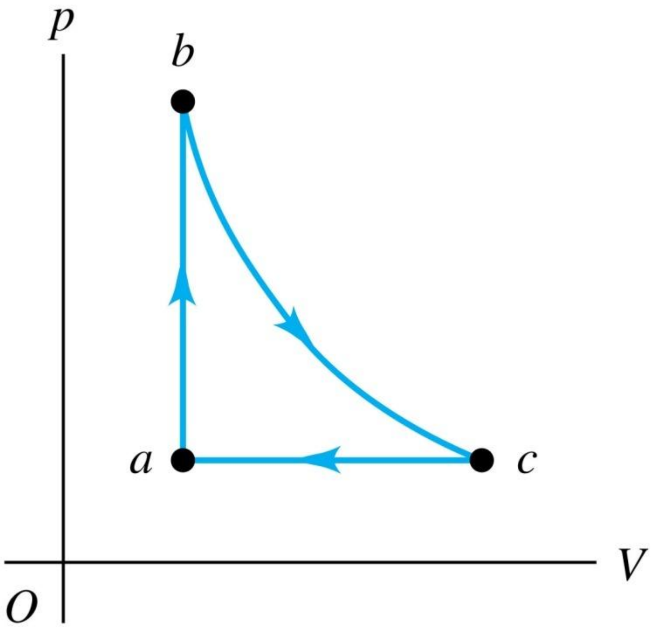
CPS 7-3

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.

For process $b \rightarrow c$,



A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

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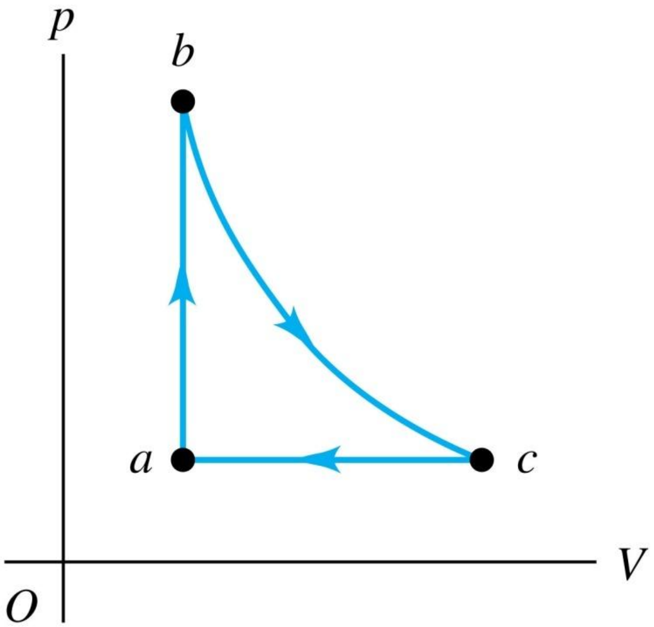
For process $b \rightarrow c$,



A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

C. $Q = 0$ and $\Delta U > 0$.

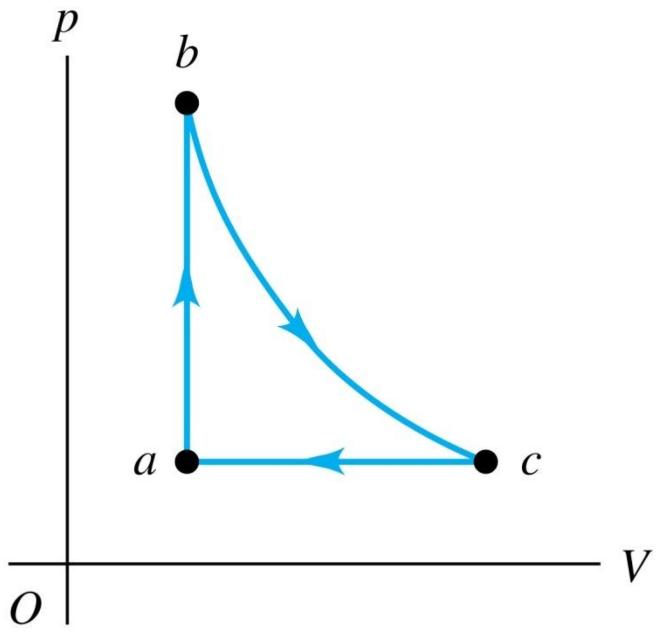
D. $Q = 0$ and $\Delta U < 0$.

E. $Q < 0$ and $\Delta U < 0$.

CPS 7-4

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.

For process $c \to a$,



A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

C. $Q = 0$ and $\Delta U > 0$.

D. $Q = 0$ and $\Delta U < 0$.

E. $Q < 0$ and $\Delta U < 0$.

CPS 7-4

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.

For process $c \rightarrow a$,

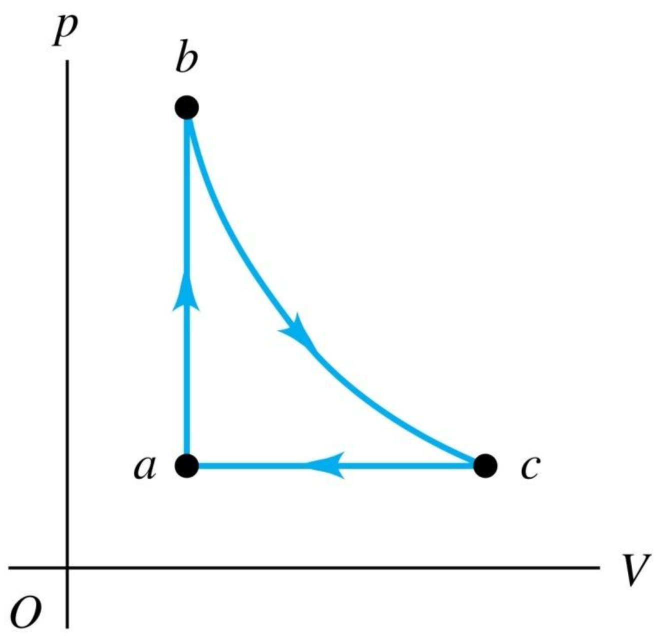
A. $Q > 0$ and $\Delta U > 0$.

B. $Q > 0$ and $\Delta U = 0$.

C. $Q = 0$ and $\Delta U > 0$.

D. $Q = 0$ and $\Delta U < 0$.

E. $Q < 0$ and $\Delta U < 0$.



CPS 7-5

An ideal gas begins in a thermodynamic state *a*. When the temperature of the gas is raised from T_1 to a higher temperature T_2 at a constant *volume*, a positive amount of heat Q_{12} flows into the gas. If the same gas begins in state *a* and has its temperature raised from T_1 to T_2 at a constant *pressure*, the amount of heat that flows into the gas is

A. greater than Q_{12}.

B. equal to Q_{12}.

C. less than Q_{12}, but greater than zero.

D. zero.

E. negative (heat flows *out of* the system).

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✓ A. greater than Q_{12}.

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D. zero.

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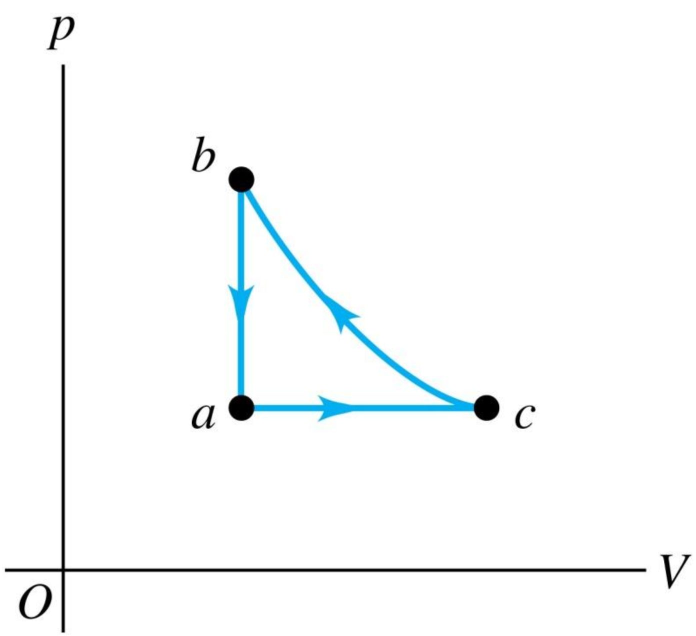
CPS 7-6

An ideal gas is taken around the cycle shown in this p-V diagram, from a to c to b and back to a. Process $c \rightarrow b$ is adiabatic.



For process $c \rightarrow b$,

A. $Q > 0$, $W > 0$, and $\Delta U = 0$.

B. $Q > 0$, $W > 0$, and $\Delta U > 0$.

C. $Q = 0$, $W > 0$, and $\Delta U < 0$.

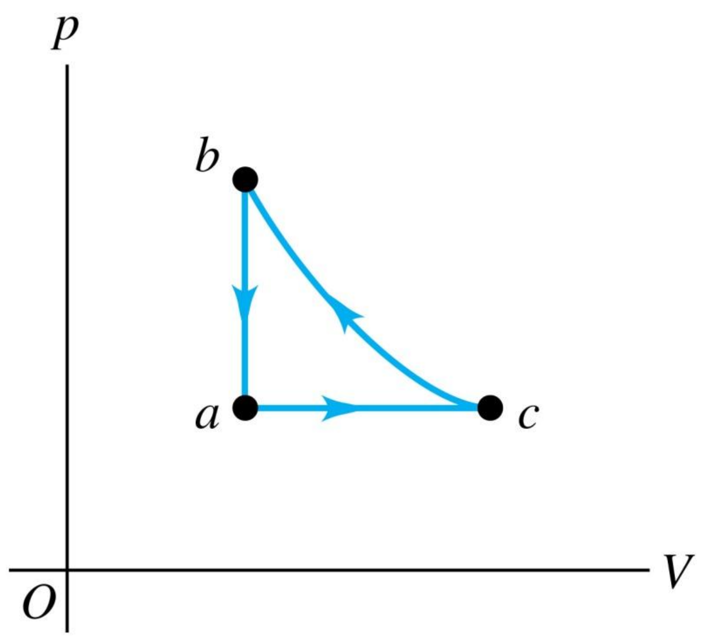
D. $Q = 0$, $W < 0$, and $\Delta U > 0$.

E. $Q < 0$, $W < 0$, and $\Delta U = 0$.

CPS 7-6

An ideal gas is taken around the cycle shown in this *p*-*V* diagram, from *a* to *c* to *b* and back to *a*. Process $c \rightarrow b$ is adiabatic.

For process $c \rightarrow b$,



A. $Q > 0$, $W > 0$, and $\Delta U = 0$.

B. $Q > 0$, $W > 0$, and $\Delta U > 0$.

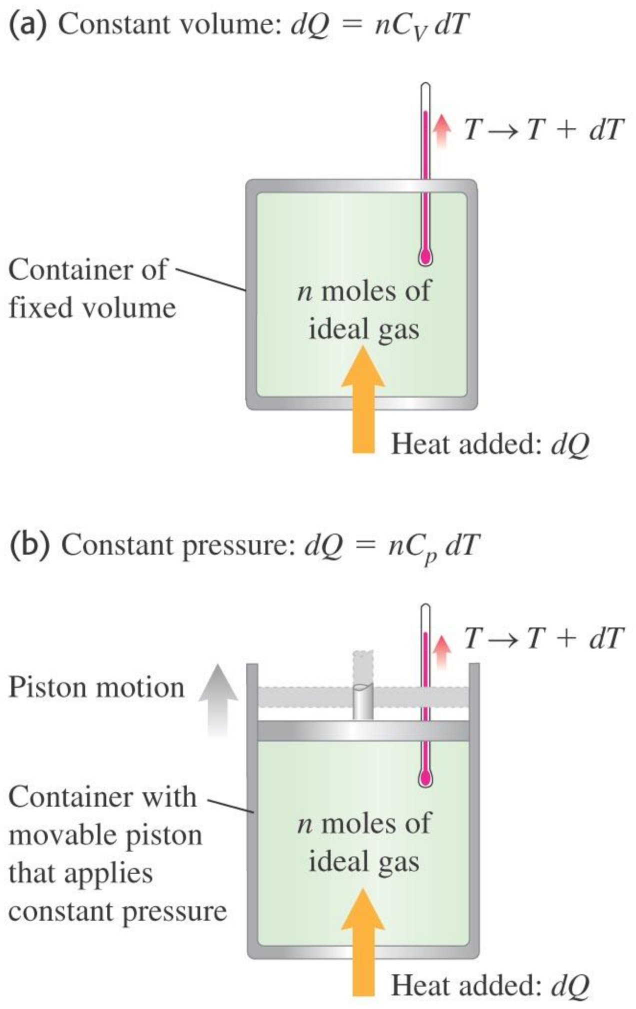
C. $Q = 0$, $W > 0$, and $\Delta U < 0$.

D. $Q = 0$, $W < 0$, and $\Delta U > 0$.

E. $Q < 0$, $W < 0$, and $\Delta U = 0$.

Heat Capacities of an Ideal Gas

- C_V is the *molar heat capacity at constant volume*.
- C_p is the *molar heat capacity at constant pressure*.



Heat Capacities of an Ideal Gas

- Figure 19.19 at the right shows that to produce the same temperature change, more heat is required at constant pressure than at constant volume since ΔU is the same in both cases.

- This means that $C_p > C_V$.

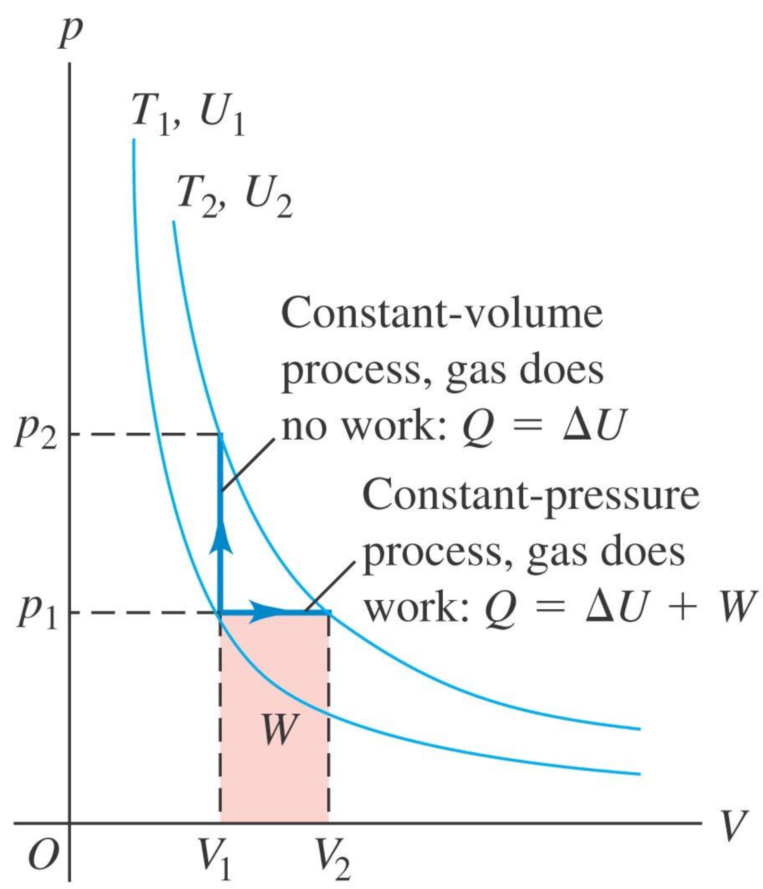
- $C_p = C_V + R$.

monatomic:

$$C_V = \frac{3}{2}R$$

diatomic:

$$C_V = \frac{5}{2}R$$



Ratios of Heat Capacities of an Ideal Gas

- The *ratio of heat capacities* is $\gamma = C_p/C_V$. For ideal gases, $\gamma = 1.67$ (monatomic) and $\gamma = 1.40$ (diatomic).
- Table 19.1 shows that theory and experiment are in good agreement for monatomic and diatomic gases.

Table 19.1 Molar Heat Capacities of Gases at Low Pressure

Type of Gas	Gas	C_V (J/mol · K)	C_p (J/mol · K)	$C_p - C_V$ (J/mol · K)	$\gamma = C_p/C_V$
Monatomic	He	12.47	20.78	8.31	1.67
	Ar	12.47	20.78	8.31	1.67
Diatomic	H_2	20.42	28.74	8.32	1.41
	N_2	20.76	29.07	8.31	1.40
	O_2	20.85	29.17	8.31	1.40
	CO	20.85	29.16	8.31	1.40
Polyatomic	CO_2	28.46	36.94	8.48	1.30
	SO_2	31.39	40.37	8.98	1.29
	H_2S	25.95	34.60	8.65	1.33