Physics 2C 1/30

(1) 1st Law

(2) Work and signs (!)

(3) ~~Heat~~ (Adiabatic) Free Expansion (though exp.)

---

(1) 1st Law

$$\Delta E_{th} = W + Q$$

- $E_{th} = E_{th}(T)$ is a state variable

- Work
  - Mechanical
  - Force + disp.
  - Macro.
  - $W > 0$: work done on gas
  - Equil: no forces

vs.

Heat
- Thermal
- Temp. diff
- Micro
- $Q > 0$: environment at higher T
- Equil: same T as envir.

$$W = -\int_{V_i}^{V_f} p\, dV$$

Note: isothermal $\Rightarrow \Delta E_{th} = 0 \Rightarrow W + Q = 0$

isochoric $\Rightarrow W = 0 \Rightarrow \Delta E_{th} = Q$

adiabatic $\Rightarrow Q = 0 \Rightarrow \Delta E_{th} = W$

$(\Delta T \neq 0!)$

WILEY

18.10.1. An insulated container is filled with a mixture of water and ice at zero °C. An electric heating element inside the container is used to add 1680 J of heat to the system while a paddle does 450 J of work by stirring. What is the increase in the internal energy of the ice-water system?

$\Delta E_{th} = Q + W$

$(+) \quad (+)$

a) 450 J

b) 1230 J

c) 1680 J

d) 2130 J

e) zero J

Q	W
(+)	(−)
(−)	(+)
0	(+)
(+)	0
(+)	(+)

WILEY

18.10.2. The internal energy of a system increases during some time interval. Which one of the following statements concerning this situation must be true?

$\Delta E_{th} = Q + W$

$(+)$

a) The increase in internal energy indicates that work was done on the system.

b) The increase in internal energy indicates that heat was added to the system.

c) The increase in internal energy indicates that work was done by the system.

d) The increase in internal energy indicates that heat was removed from the system.

e) The information given is insufficient to indicate the reason for the increase.

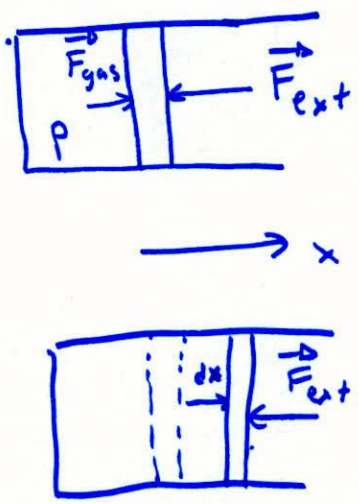
[V const]

A system undergoes an isochoric process in which its internal energy increases by 20 J. Which entry in the table below is correct? Draw pV first

	Heat	Work
A)	None	20 J done on system
B)	None	20 J done by system
C)	20 J removed from system	None
D)	20 J added to system	None
E)	40 J added to system	20 J done by system

(2) Work and signs

$$W = \int_{s_i}^{s_f} \vec{F}_s \cdot d\vec{s}$$



$dV = Adx$

$$(F_{ext})_x = -(F_{gas})_x = -pA$$

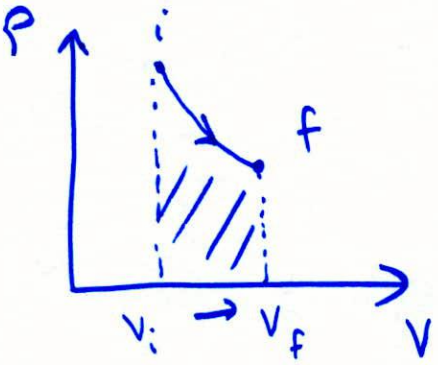
$$dW_{ext} = (F_{ext})_x dx = -pA\,dx$$

$$= -p\,dV$$

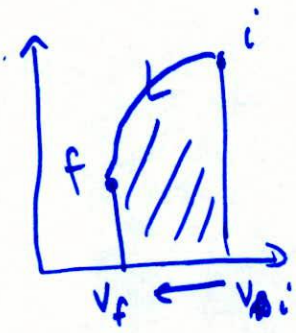
$$W_{ext} = -\int_{V_i}^{V_f} p\,dV$$

$W_{ext} > 0 \Rightarrow$ - work done on gas
- gas compresses $V_f < V_i$

$W_{ext} < 0 \Rightarrow$ - work done by gas
- gas expands $V_f > V_i$

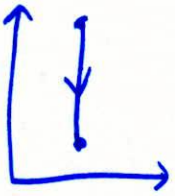


W = - area < 0



W = - area > 0

isochoric



$W = 0$

isobaric

$W = -p\Delta V$

isothermal

$$W = -nRT\ln\left(\frac{V_f}{V_i}\right)$$

$\Delta U = -W + Q$ (+)

WILEY

18.10.3. A gas is enclosed in a cylinder by a piston. The volume of the gas is then reduced to one half its original value by applying a force to the piston. Which one of the following statements concerning the internal energy of the gas is true?

a) The internal energy of the gas will decrease.

b) The internal energy of the gas will increase.

c) The internal energy of the gas will neither increase nor decrease.

d) The internal energy of the gas will equal the work done in moving the piston.

e) The internal energy of the gas may increase, decrease, or remain the same depending on the amount of heat that is gained or lost by the gas.

WILEY

18.11.1. Consider the pV diagram shown. There are eight points labeled and the choices below indicate possible multi-step processes. In which one of the processes does the work done have the largest absolute value?

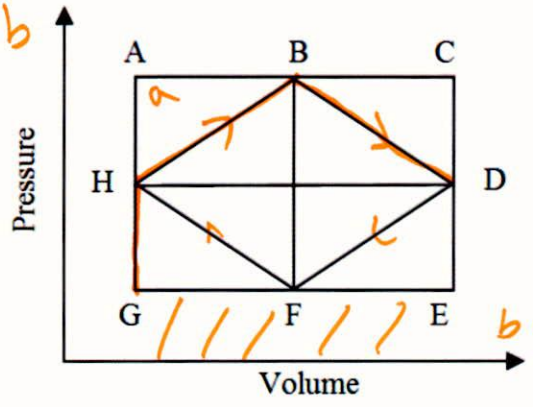
a) G–H–B–D $W = -6a - b$

b) G–F–B–D $-3a - b$

c) H–A–B–D $-7a - b$

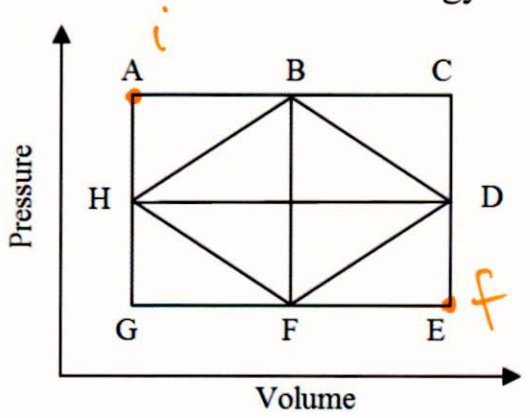
d) E–D–F–H $+2a + b$

e) C–B–F–G $+4a + b$



WILEY

18.11.2. Consider the pV diagram shown. There are eight points labeled and the choices below indicate possible multi-step processes. If the initial state of the system is at A and the final state is at E, which of the following paths between these two states results in the largest increase in internal energy of the system?



i

f

a) A–H–D–E

b) A–B–F–E

c) A–G–E

d) A–C–E

e) All paths between A and E are equivalent.

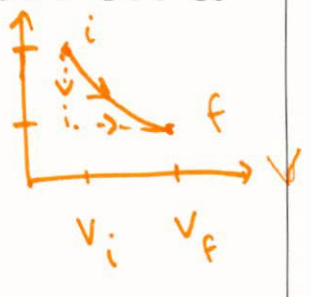
only thing that matters is final

isotherms

Based on the first-law bar chart below, sketch a possible path on a pV diagram.

$\Delta E_{th} = W + Q$

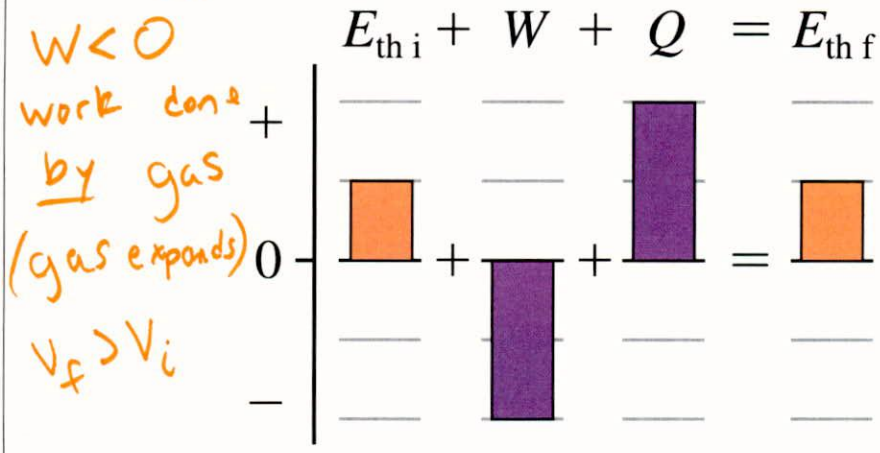
$\Delta E_{th} = 0 \Rightarrow$ same isotherm



$W < 0$

work done by gas (gas expands)

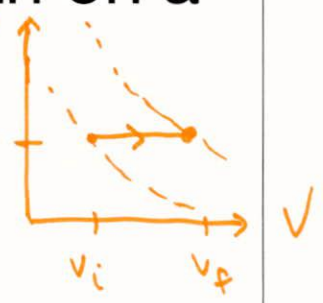
$V_f > V_i$



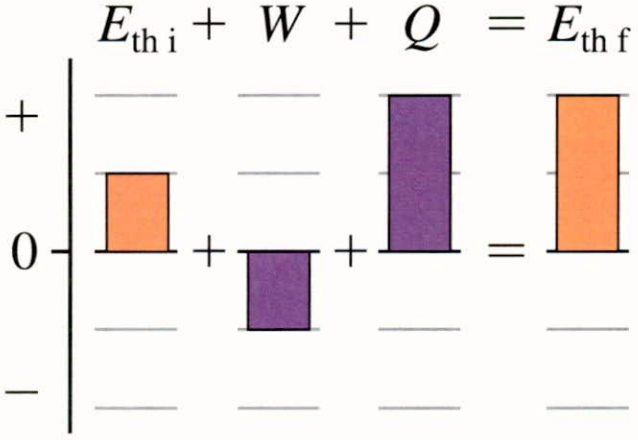
Based on the first-law bar chart below, sketch a possible path on a pV diagram.

$\Delta E_{th} = W + Q$

$\Delta E_{th} > 0 \Rightarrow$ higher isotherm

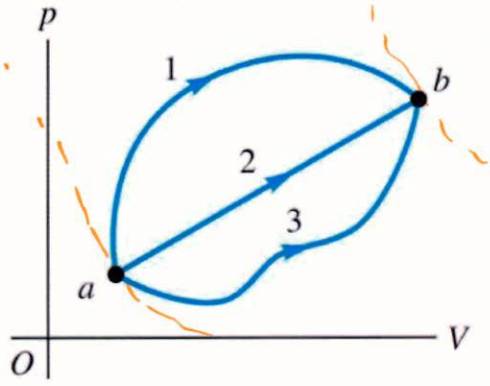


$W < 0$ gas expands $V_f > V_i$



The following figure shows three paths on a pV diagram along which a gas is taken from state a to state b. Rank the paths according to the change in thermal energy ΔU for the gas from greatest to least.

A) 1 > 2 > 3
B) 3 > 2 > 1
C) 1 = 2 = 3
D) Unable to tell

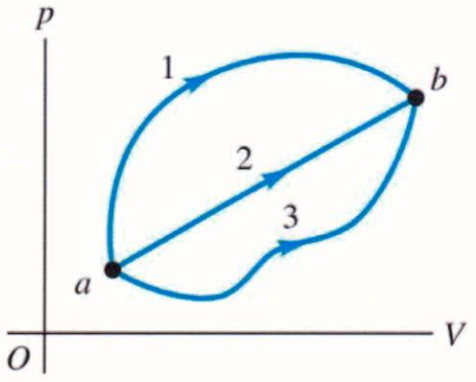


Same initial/final isotherms

The following figure shows three paths on a pV diagram along which a gas is taken from state a to state b. Rank the paths according to the heat added to the gas Q from greatest to least.

$\Delta E_{th} = W + Q$
$(+) \quad (-) \quad (+)$

A) 1 > 2 > 3
B) 3 > 2 > 1
C) 1 = 2 = 3
D) Unable to tell



$\Delta E_{th} > 0$ and is same

$W < 0$ and is different: $|W_1| > |W_2| > |W_3|$

$Q > 0$ and has to balance $Q_1 > Q_2 > Q_3$

The figure shows two processes by which 1.0 g of Nitrogen gas moves from state 1 to state 2.
The temperature of state 1 is 27°C.
Let p_1 = 1 atm. What is the net work done on the gas…

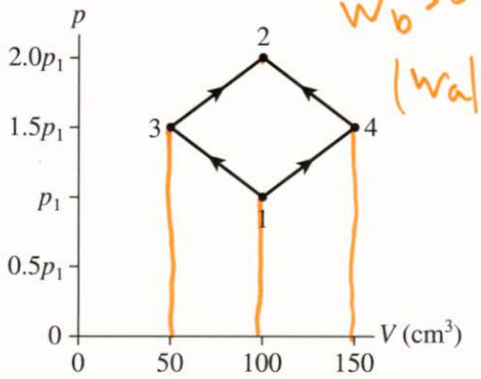
i) … if going 1→3→2
ii) … if going 1→4→2

A) $W_a > W_b$
B) $W_b > W_a$
C) $W_b = W_a$

$W_a < 0$

$W_b > 0$

$|W_a| = |W_b|$



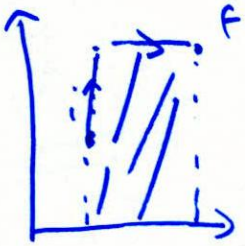
$\Delta E_{th} = W + Q$

$(-) = (-)\ (+)$

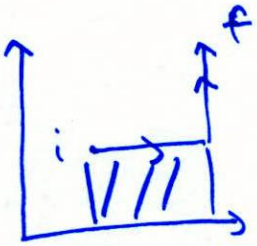
A gas undergoes a process in which 30 J of heat is added to the gas yet its temperature goes down. Which of the options below best describes the change in volume of the gas?

A) The gas expands
B) The gas contracts
C) The gas may have expanded or contracted; there isn't enough info.

Work done depends on path taken

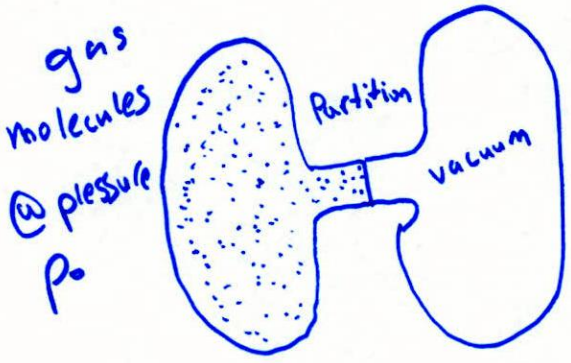


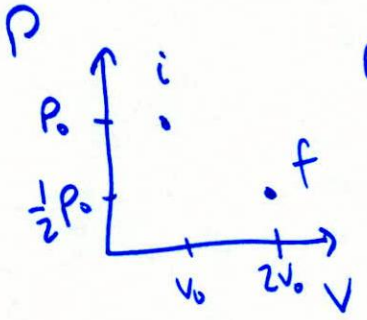
vs.



---

(3) Free Expansion





$pV = nRT$

i : partition closed

f : after partition opened

$\Delta E_{th} = Q + W$

(zero) = (zero) + (zero)

Irreversible

WILEY

18.11.3. An insulated container with rigid walls has two compartments within. One compartment contains n moles of an ideal gas and the other compartment has been evacuated. A valve connecting the two chambers is opened at time $t = 0$ s. Which one of the following statements concerning this situation is true?

a) There is no change in the internal energy of the gas.

b) There is no change in the pressure of the gas.

c) The temperature of the gas decreases with time.

d) Work is done by the gas as it fills the previously evacuated compartment.

e) The gas will remain in the first compartment unless heat is added to the system.