Ideal Gas Processes (3 outta 4), 1st Law of Thermo, Phase Diagrams

Knight Ch. 19.1-19.6, 18.5

Physics 2C, Spring 2025

Agenda Today (April 21 and 24, 2025)

- Ideal Gas Processes (graph on pV diagram)
  - Isobaric, Isochoric, Isothermal
- 1st Law of Thermodynamics
  - Cons. Of Energy, Work in Thermodynamics
  - Find Q and W for each ideal gas process
- Phase Diagrams
- Calorimetry Problems (relating Q with ΔT)

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Ideal Gas: 3 Processes [*quasistatic*]

Let’s add heat to a gas three ways: constant P, constant V, constant T.

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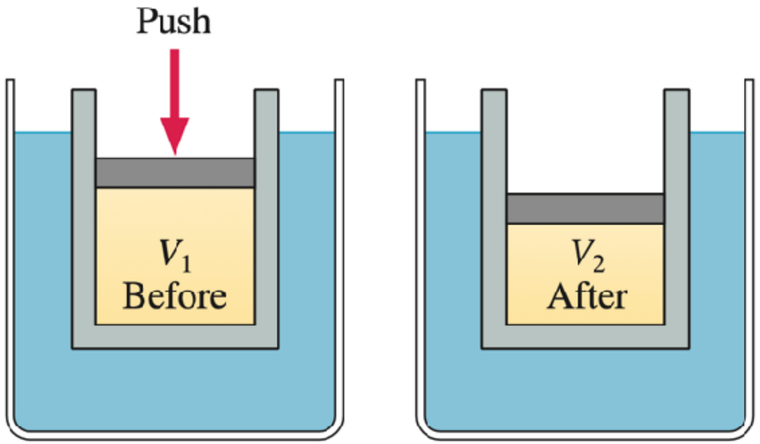

A person slowly pushes down on a piston, compressing a system of gas that is immersed in a large tub of water. Which of the following best describes this process?

A. Isobaric

B. Isochoric

C. Isothermal

Work, W

We follow the chemistry convention. Other textbooks define W with a plus sign, which is the work done *by* the gas on its surroundings.

We will always call this $W_{\text{by}} = \int_i^f p\,dV$

$$W = -\int_i^f p\,dV = \text{ work done on a system by its surroundings.}$$

Heat, Q

Heat is energy that flows due to a temperature difference alone.

FIGURE 19.11 The sign of heat.

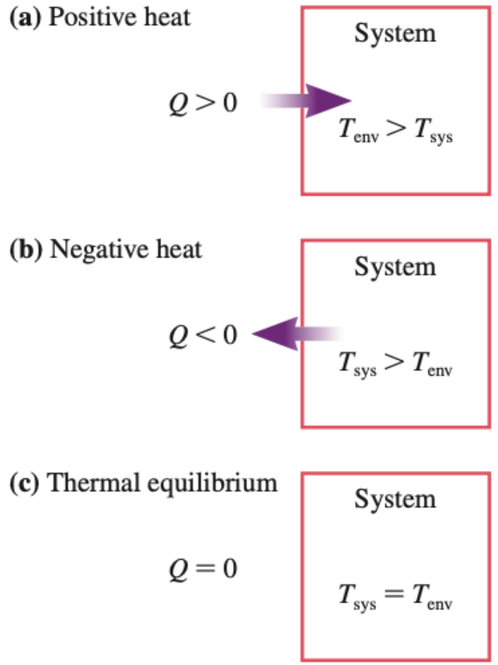

TABLE 19.1 Understanding work and heat

	Work	Heat
Interaction:	Mechanical	Thermal
Requires:	Force and displacement	Temperature difference
Process:	Macroscopic pushes and pulls	Microscopic collisions
Positive value:	$W > 0$ when a gas is compressed. Energy is transferred in.	$Q > 0$ when the environment is at a higher temperature than the system. Energy is transferred in.
Negative value:	$W < 0$ when a gas expands. Energy is transferred out.	$Q < 0$ when the system is at a higher temperature than the environment. Energy is transferred out.
Equilibrium:	A system is in mechanical equilibrium when there is no net force or torque on it.	A system is in thermal equilibrium when it is at the same temperature as the environment.

1st Law of Thermodynamics

Two ways to charge the energy of a system:

$$\Delta E = Q + W$$

For an ideal gas, the total energy E is a monotonically-increasing function of the temperature.

In other words, the higher the temperature, the higher the total energy.

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Clicker/Poll Question

In an isothermal process, the gas does 50 J of work on its surroundings. How much energy in the form of heat was added to the gas?

A. A positive amount < 50 J
B. A positive amount = 50 J
C. A positive amount > 50 J
D. Zero joules
E. A negative amount

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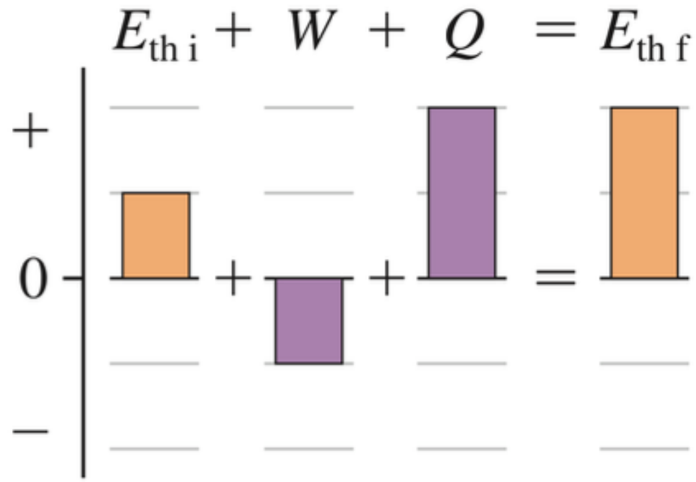
Clicker/Poll Question

In an isobaric process, the gas does 50 J of work on its surroundings. How much energy in the form of heat was added to the gas?

A. A positive amount < 50 J
B. A positive amount = 50 J
C. A positive amount > 50 J
D. Zero joules
E. A negative amount

Example

Take the following first-law bar chart and sketch a possible process on a pV diagram.



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A gas undergoes a process in which 30 J of heat is added to the gas yet its temperature goes down. Which of the below best describes what's going on with the volume of the gas?

A. The gas definitely expands.

B. The gas definitely contracts.

C. The gas could have expanded or contracted; there isn't enough info to say for certain.

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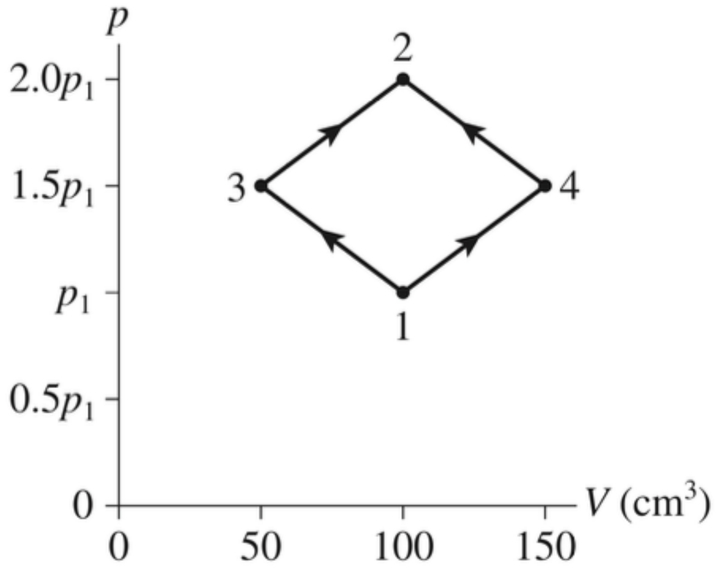
Clicker/Poll Question

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

	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

Example

The figure shows two processes by which 1.0g of Nitrogen gas moves from state 1 to state 2. The temperature of state 1 is 27 degrees C.

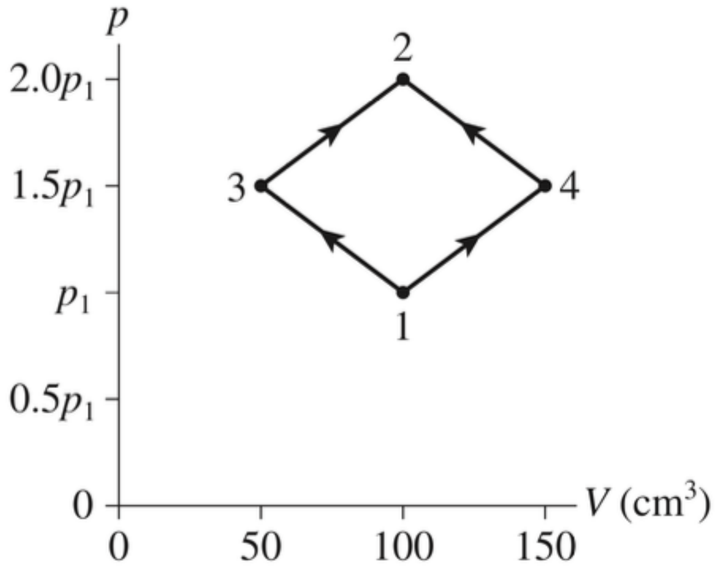


What is the net work done by the gas…

a) ...if going along the path $1 \rightarrow 3 \rightarrow 2$?

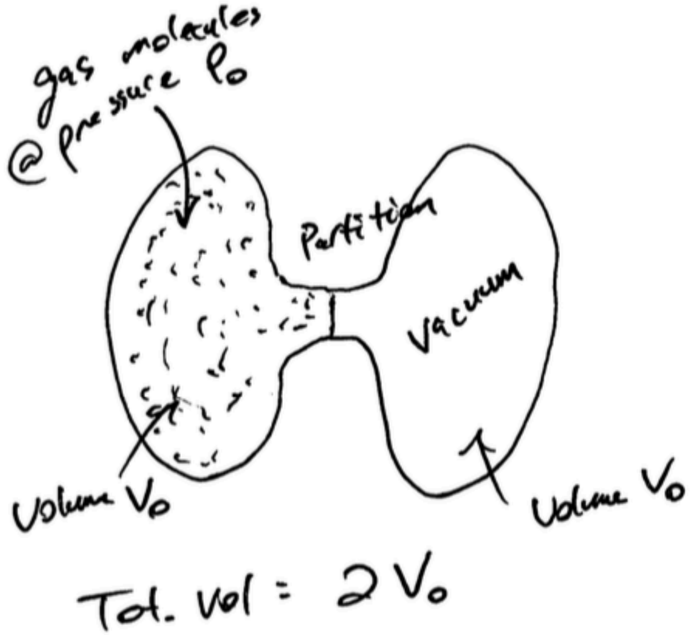
b) ...if going along the path $1 \rightarrow 4 \rightarrow 2$?

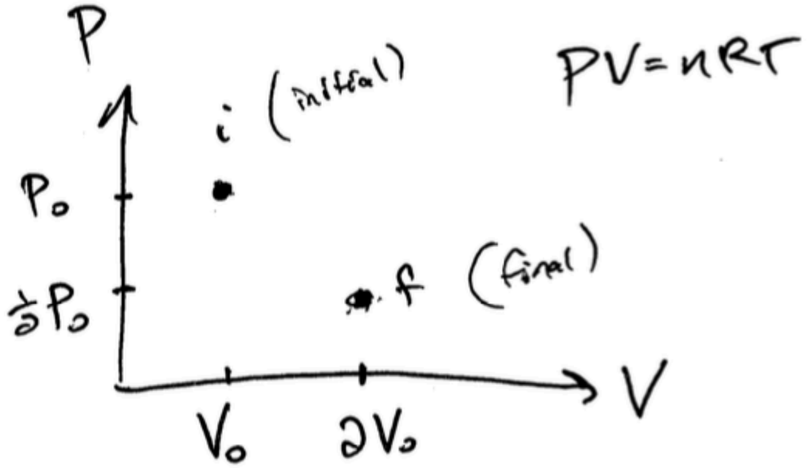
Example (continued)



Free Expansion: Non-Quasistatic process!

In a non-quasistatic process (intermediate states not in equilibrium), we can't draw a path on a pV diagram, and so Q and W can't be defined. ΔE can be defined though.



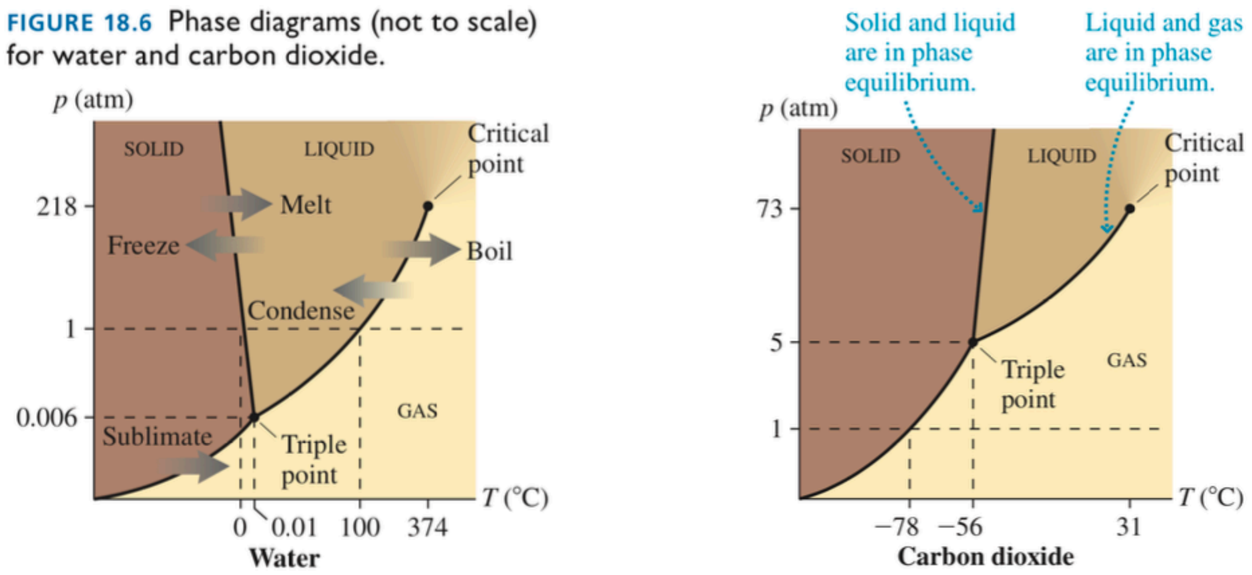


i : Partition closed

f = after partition opened.

Phase Diagrams: Phase as a function of p,T

A plot of p vs T with regions showing phases is called a “phase diagram”



Clicker/Poll Question

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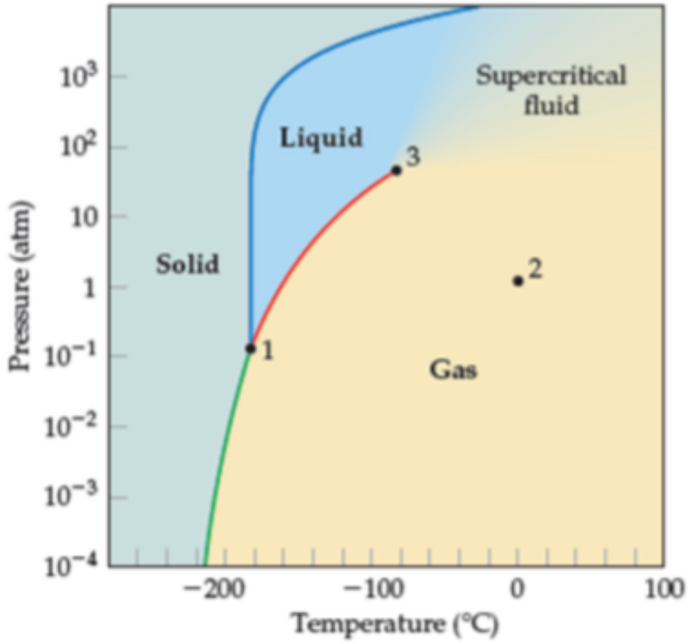
Which of the following is NOT true?

A. The material is a fluid at 1atm & room temp.
B. The material sublimates at atmospheric pressure.
C. The maximum density of the material is in its solid phase.
D. N/A (all of the above are true).



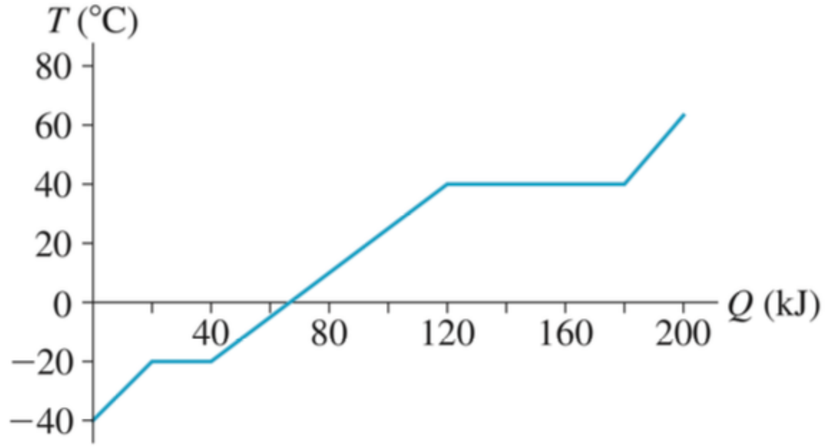
Calorimetry (Q vs. T)

- If a substance doesn't change phase, $Q = mc\Delta T$ ($= nC\Delta T$).
- If a substance undergoes a phase change, then $Q = mL$ is the heat involved in the phase change.

Example

An experiment measures the temperature of a 500 g substance while steadily supplying heat to it. The figure shows the results of the experiment. What are the

(a) specific heat of the solid phase,
(b) specific heat of the liquid phase,
(c) melting and boiling temperatures,
(d) heats of fusion and vaporization?



Example (continued)

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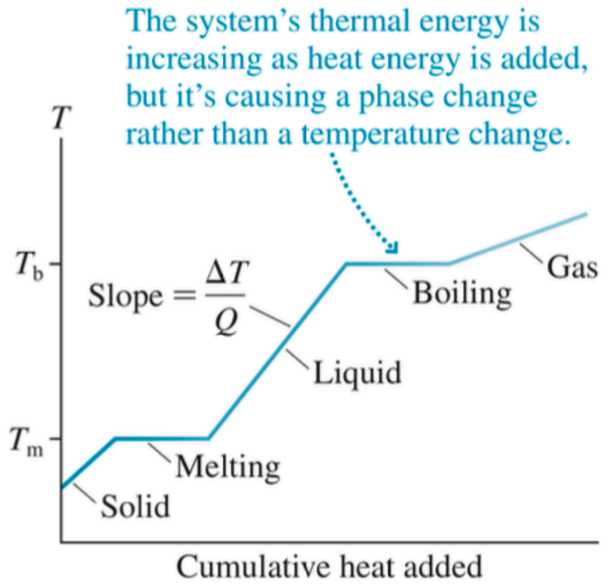
Clicker/Poll Question

Suppose you have 1 Joule of energy to give to a substance via heat. A temperature vs. heat-added graph for the substance is given. Which phase should you give the energy to the object to get the largest ΔT?

A. Solid
B. Liquid
C. Gas
D. ???

FIGURE 19.13 The temperature of a system that is heated at a steady rate.



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Clicker/Poll Question

The specific heat of water is 4.19 kJ/(kg·K) and the heat of fusion of water is 333 kJ/kg. Suppose you have 1kg of ice at its melting point and 1kg of water at temperature T_i. What should T_i be so that when mixed you have a pool of water (in equilibrium) at its freezing point?

A. 7°C
B. 13°C
C. 20°C
D. 93°C
E. None of the above is close

Try it yourself…

TABLE 19.2 Specific heats and molar specific heats of solids and liquids

Substance	c (J/kg K)	C (J/mol K)
Solids		
Aluminum	900	24.3
Copper	385	24.4
Iron	449	25.1
Gold	129	25.4
Lead	128	26.5
Ice	2090	37.6
Liquids		
Ethyl alcohol	2400	110.4
Mercury	140	28.1
Water	4190	75.4

30 g of copper pellets are removed from a 300°C oven and immediately dropped into 100 mL of water at 20°C in an insulated cup. What will the new water temperature be?