

Internal Energy, Heat, and Work

- First Law of Thermodynamics

$$\Delta U = Q + W$$

It's possible to increase the internal/thermal energy (temperature) of a gas by

- 1. heat transferred from the environment to the gas.*
- 2. work done by the environment on the gas.*
- 3. either of these.*
- 4. none of these.*

Expending the Energy Model

First Law of Thermodynamics

You could raise the temperature (the internal energy) of a system by:

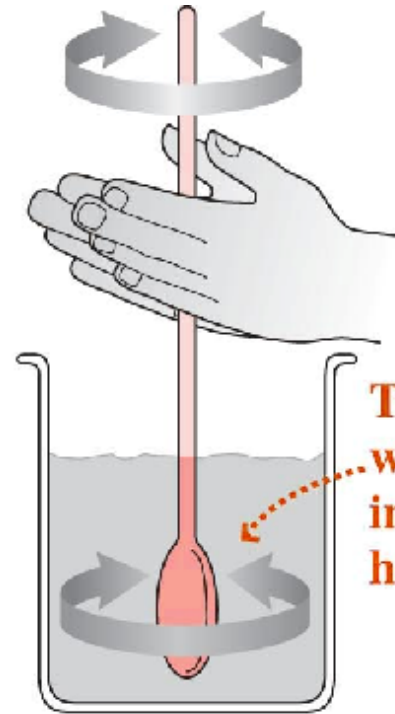
$$\Delta U = W_{onGas} + Q$$

Heat and work are essentially equivalent!

Heat from the flame raises water's internal energy and therefore its temperature.



(a)



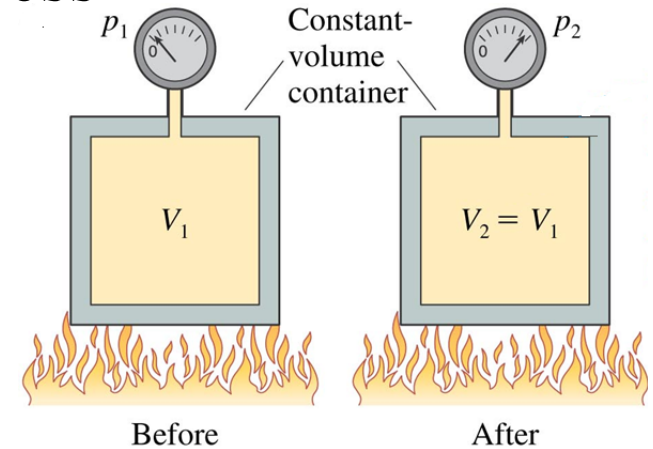
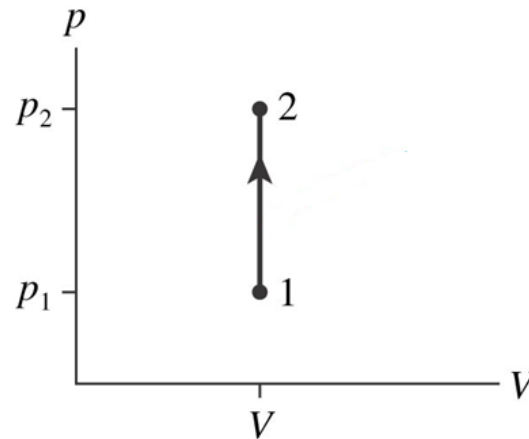
The spoon's mechanical work similarly raises internal energy and hence temperature.

(b)

First Law of Thermodynamics

Four special ideal-gas processes

(1) Isochoric (constant-volume) process

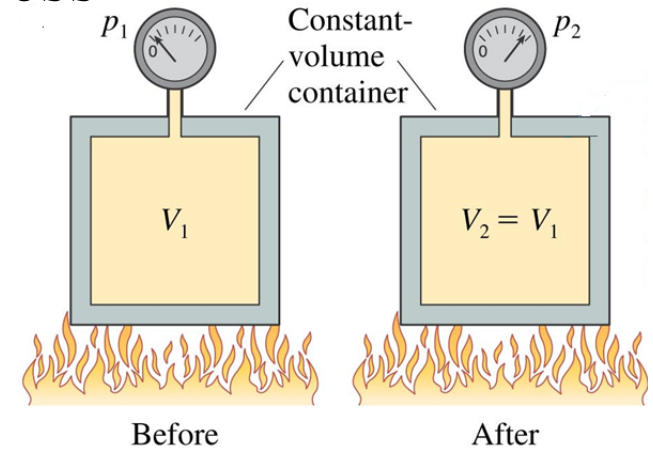
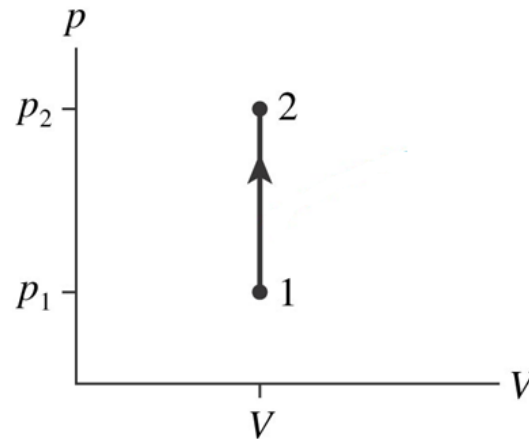


Q (J)	$W_{\text{on gas}}$ (J)	ΔU (J)

First Law of Thermodynamics

Four special ideal-gas processes

(1) Isochoric (constant-volume) process



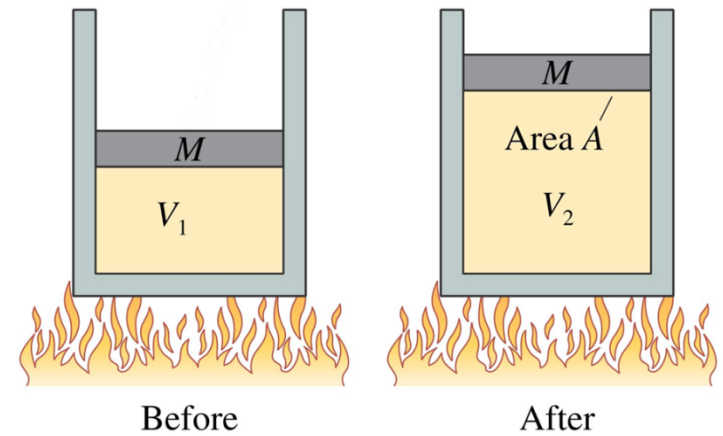
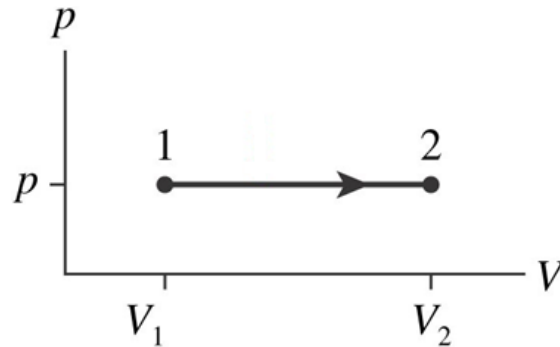
Q (J)	W _{on gas} (J)	ΔU (J)
+	0	+

$$\Delta V = 0 \Rightarrow W = 0$$

First Law of Thermodynamics

Four special ideal-gas processes

(2) Isobaric (constant pressure) process

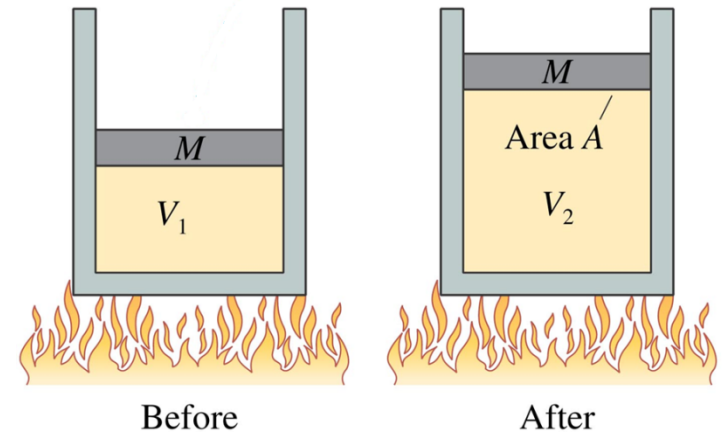
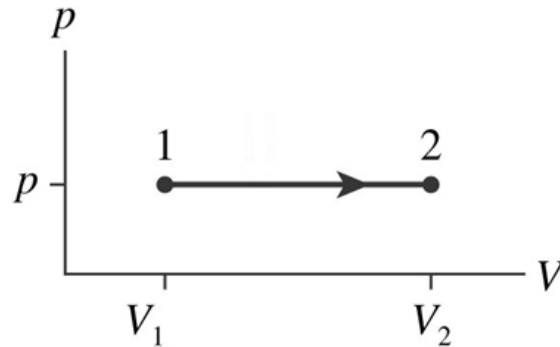


Q (J)	$W_{\text{on gas}}$ (J)	ΔU (J)

First Law of Thermodynamics

Four special ideal-gas processes

(2) Isobaric (constant pressure) process



Q (J)	$W_{\text{on gas}}(\text{J})$	ΔU (J)
+	-	+

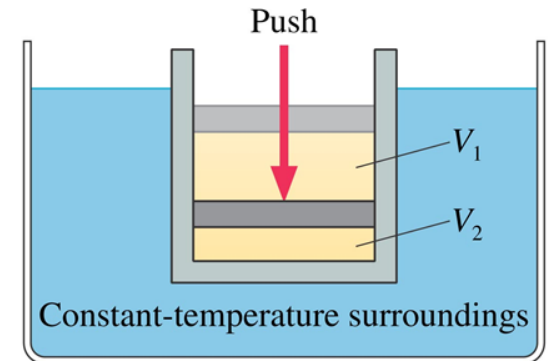
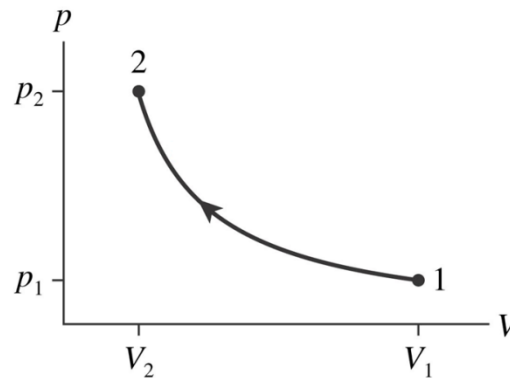
$$\Delta P = 0 \Rightarrow W = -P\Delta V$$

First Law of Thermodynamics

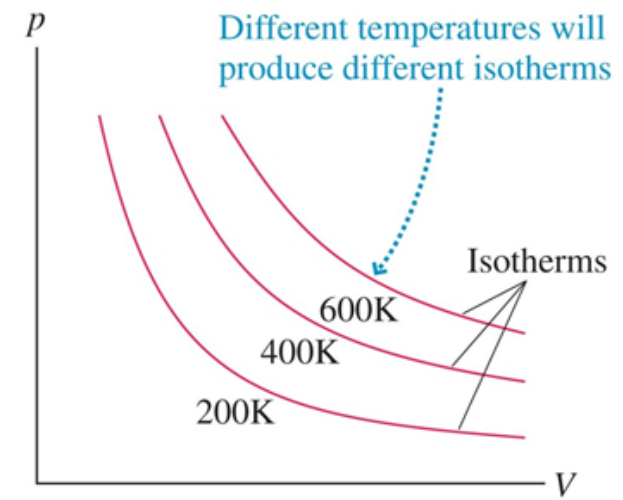
Four special ideal-gas processes

(3) Isothermal (constant temperature) process

Is it possible to cool the gas (heat to flow out), and the temperature of the gas stays the same?



Q (J)	$W_{\text{on gas}}(\text{J})$	ΔU (J)



First Law of Thermodynamics

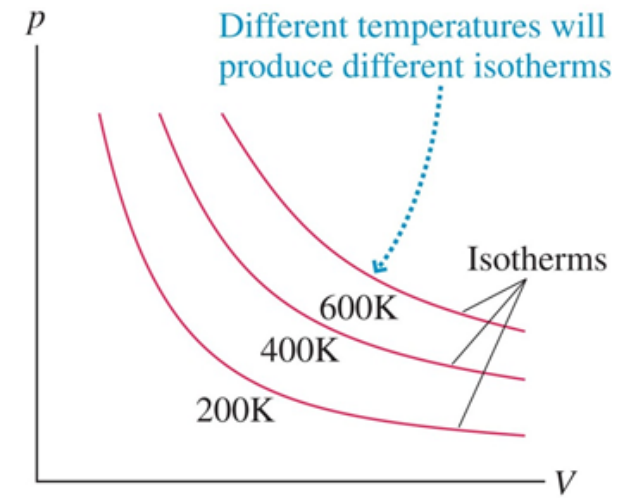
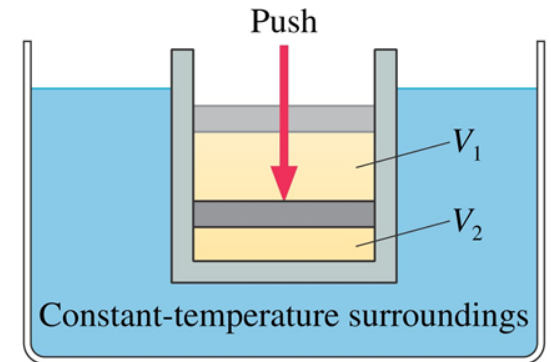
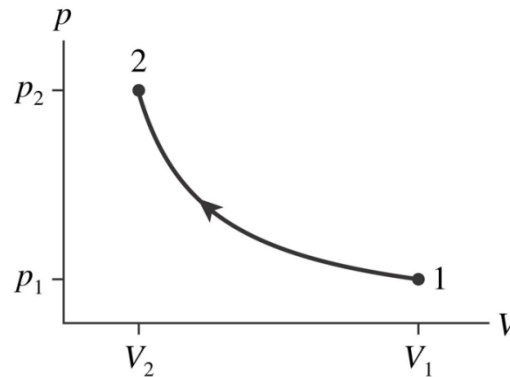
Four special ideal-gas processes

(3) Isothermal (constant temperature) process

Is it possible to cool the gas (heat to flow out), and the temperature of the gas stays the same?

$$\Delta T = 0 \Rightarrow \Delta U = 0$$

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

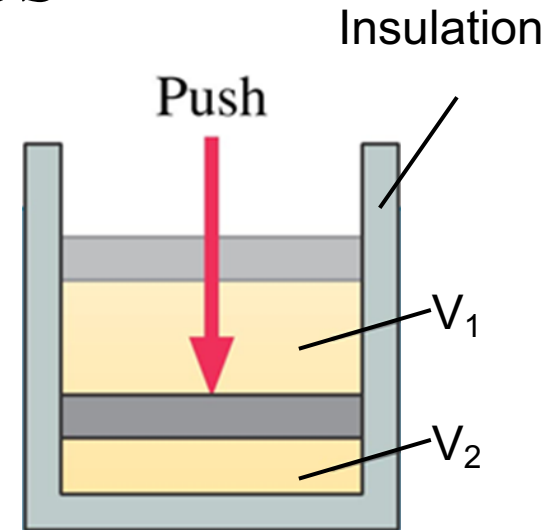


Q (J)	W _{on gas} (J)	ΔU (J)
–	+	0

Adiabatic Process

- We have already learned:

- Isobaric process $\Delta P=0 \Rightarrow W=-P\Delta V$
- Isochoric process $\Delta V=0 \Rightarrow W=0$
- Isothermal process $\Delta T=0 \Rightarrow \Delta U=0$



- An adiabatic process

- A process in which no heat energy is transferred between the system and environment.
- $Q=0 \rightarrow \Delta U=W$
- Warning: This does not mean $\Delta T=0$.
- Well insulated or happens very quickly

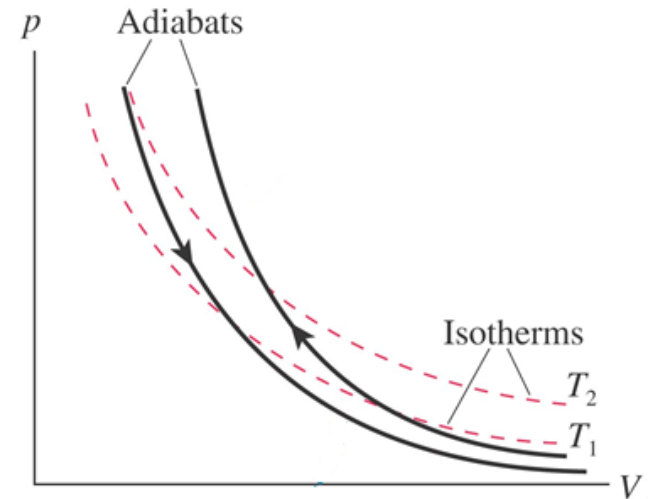
First Law of Thermodynamics

Four special ideal-gas processes

(4) Adiabatic ($Q = 0$) process

It's possible to increase the temperature of a gas without adding heat to it?

Q (J)	$W_{\text{on gas}}$ (J)	ΔU (J)



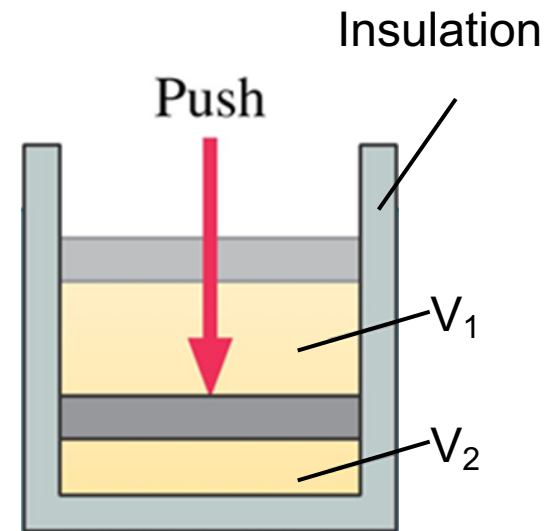
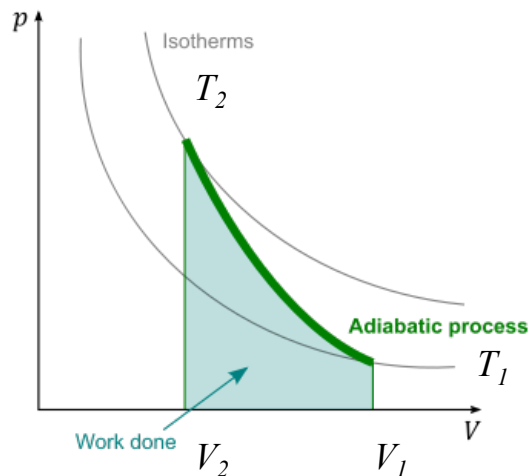
First Law of Thermodynamics

Four special ideal-gas processes

(4) Adiabatic ($Q = 0$) process

$$Q=0 \rightarrow \Delta U=W$$

It's possible to increase the temperature of a gas without adding heat to it?



Q (J)	$W_{\text{on gas}}$ (J)	ΔU (J)
0	+	+

0.02 moles of O₂ gas begins at a pressure of 2.0 atm and a volume of 300 cm³. It's then compressed to a final volume of 100 cm³. Its final pressure is 6.0 atm.

a) Represent the initial and final states on a PV diagram.

b) Find the initial and final temperatures.

c) What kind of process is this?

$$W_{onGas} = -\int_{V_i}^{V_f} P dV$$

d) Is the work done on the gas positive, negative or zero?

e) What is the work done on the gas?

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

f) Find Q and ΔU for the process.

$$PV = nRT$$

State	P	V	T
Initial			
Final			

Do the table of states (P , V , T) and a PV diagram

0.02 moles of O_2 gas begins at a pressure of 2.0 atm and a volume of 300 cm^3 . It's then compressed to a final volume of 100 cm^3 . Its final pressure is 6.0 atm.

a) Represent the initial and final states on a PV diagram.

b) Find the initial and final temperatures. $T_f = T_i = 365.7 \text{ K}$

c) What kind of process is this? **isothermal** $W_{\text{onGas}} = -\int_{V_i}^{V_f} P dV$

d) Is the work done on the gas positive, negative or zero? **positive**

e) What is the work done on the gas? $W_{\text{ongas}} = +66.77 \text{ J}$ $W_{\text{onGas}} = -nRT \ln\left(\frac{V_f}{V_i}\right)$

f) **Find Q and ΔU for the process.**

State	P	V	T
Initial	2.0 atm	300 cm^3	?
Final	6.0 atm	100 cm^3	?

$$PV = nRT$$

