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

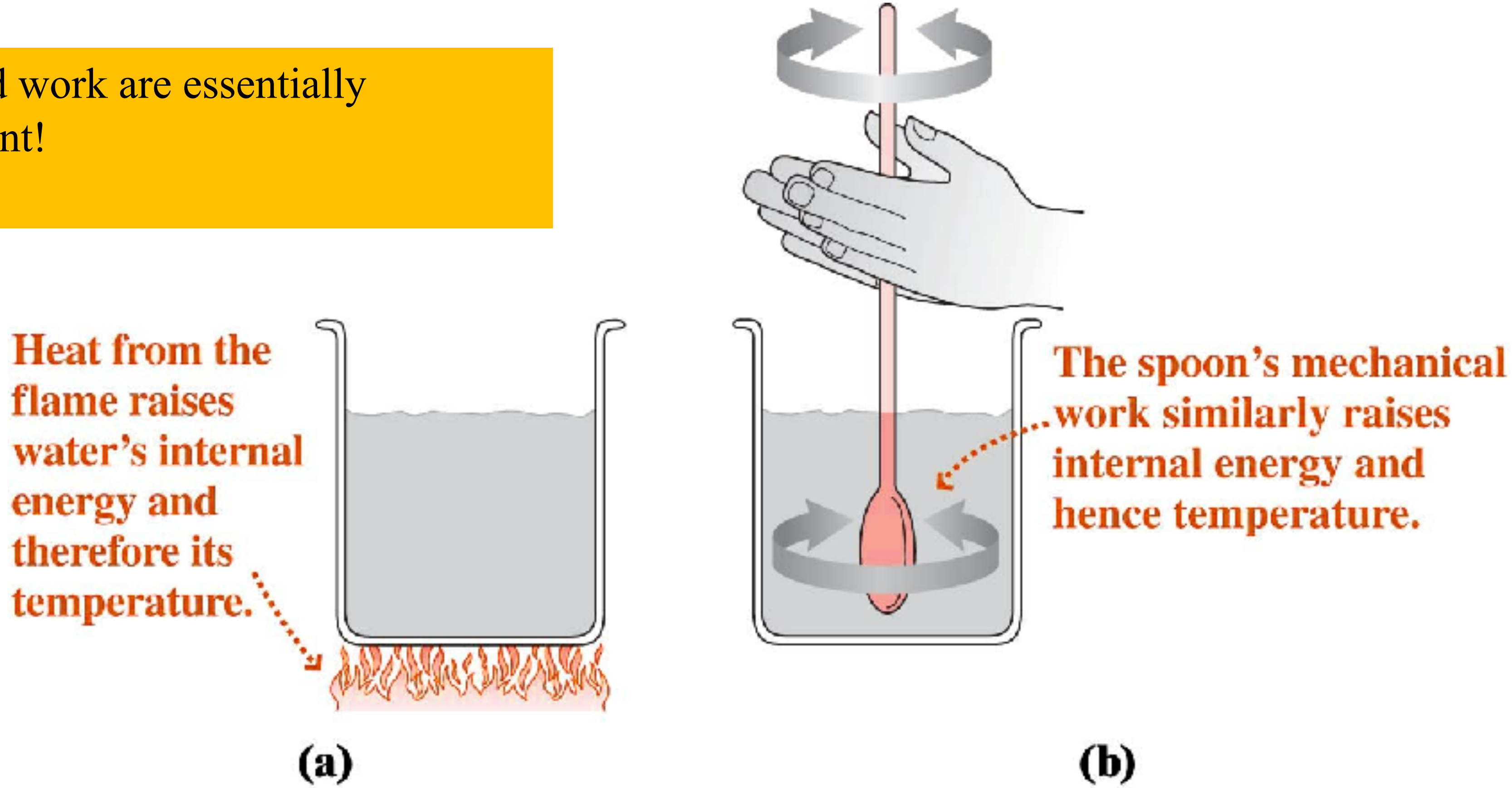
1. *heat transferred from the environment to the gas.*
2. *work done by the environment on the gas.*
3. *either of these.*
4. *none of these.*

Expending the Energy Model
First Law of Thermodynamics

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

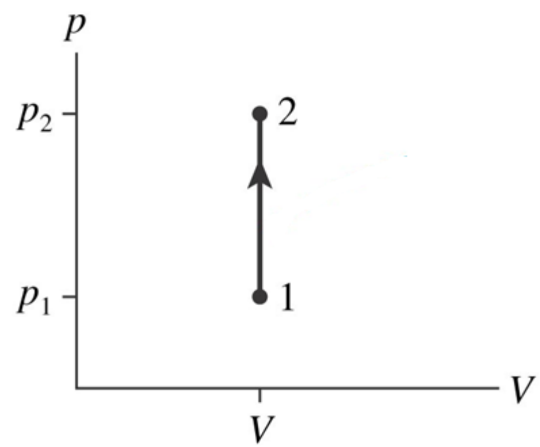
$$\Delta U = W_{onGas} + Q$$

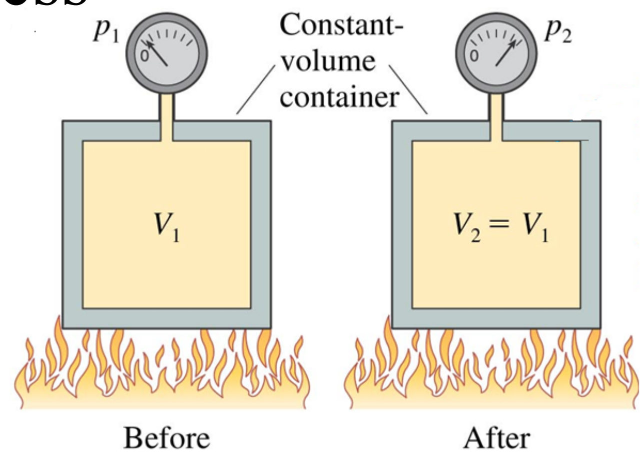
Heat and work are essentially equivalent!



First Law of Thermodynamics
Four special ideal-gas processes

(1) Isochoric (constant-volume) process





Q (J)	$W_{on\ gas}$(J)	ΔU (J)

First Law of Thermodynamics
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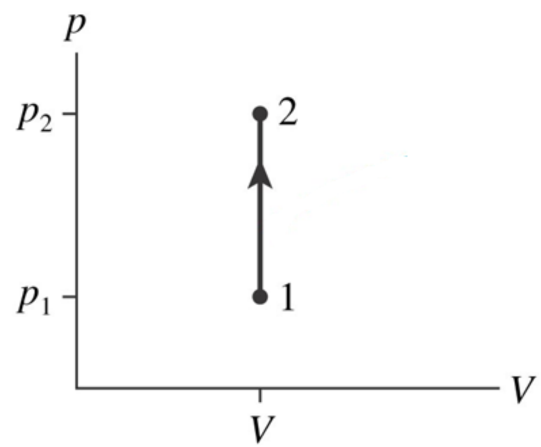
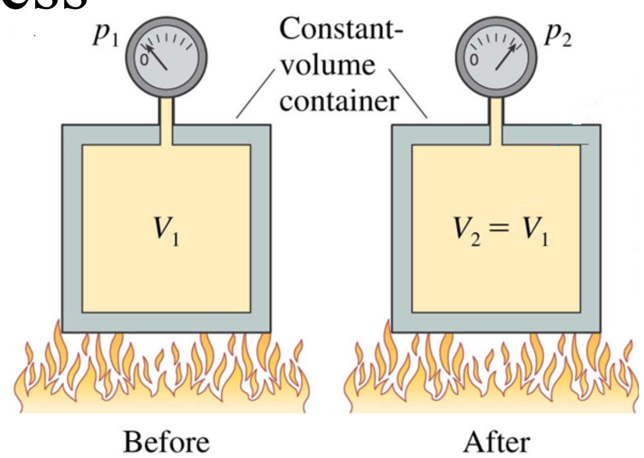
(1) Isochoric (constant-volume) process



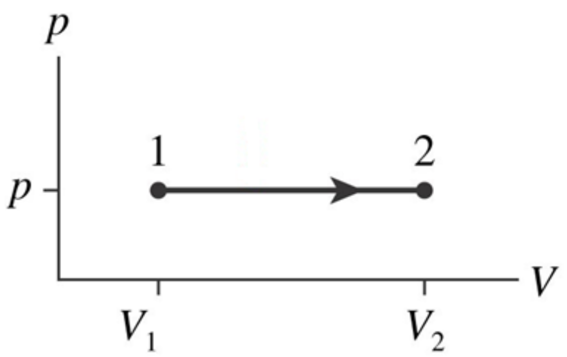


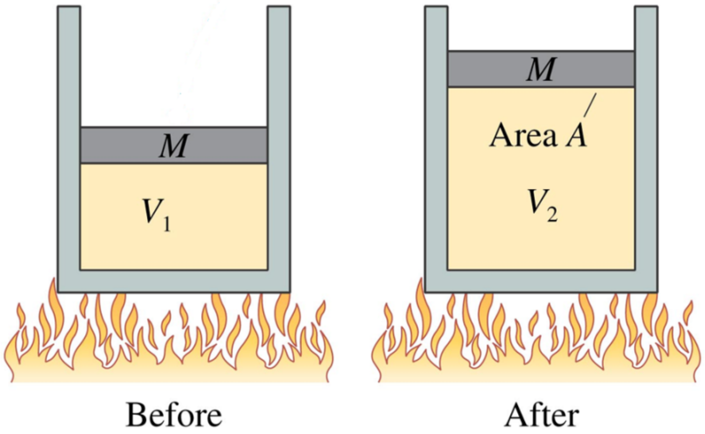
Q (J)	$W_{on\ gas}$(J)	ΔU (J)
+	0	+

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

First Law of Thermodynamics
Four special ideal-gas processes

(2) Isobaric (constant pressure) process





Q (J)	**$W_{on\ gas}$(J)**	**ΔU (J)**

First Law of Thermodynamics
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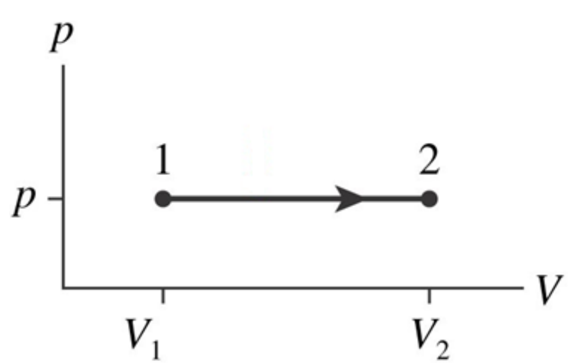
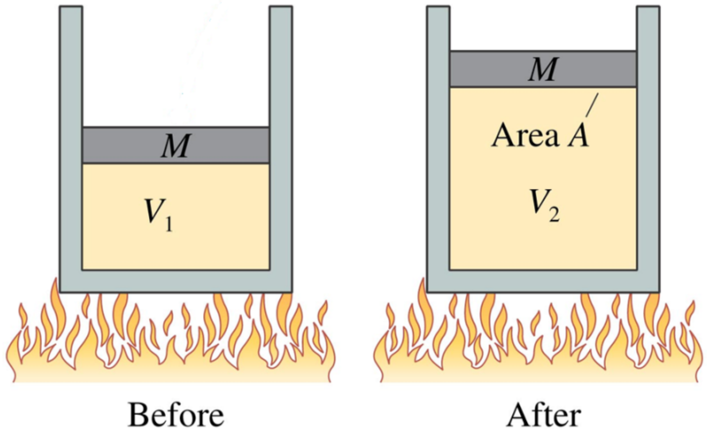
(2) Isobaric (constant pressure) process





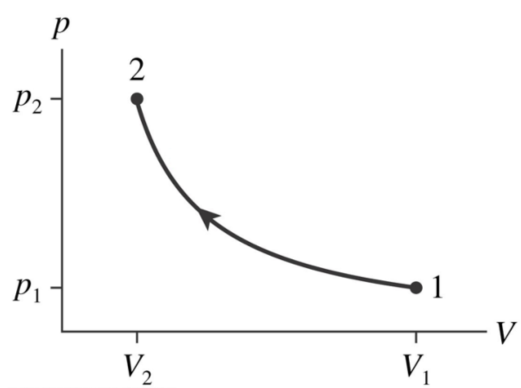
Q (J)	$W_{on\ gas}$(J)	ΔU (J)
+	−	+

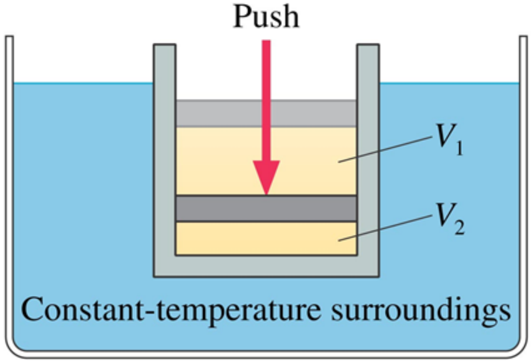
$\Delta P=0 \Rightarrow W=-P\Delta V$

First Law of Thermodynamics
Four special ideal-gas processes

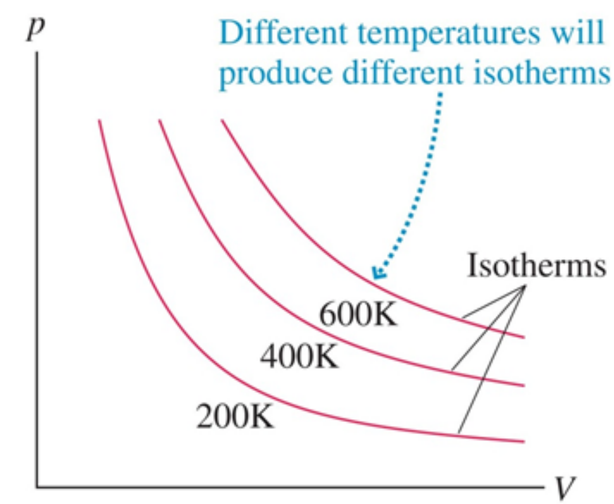
(3) Isothermal (constant temperature) process

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





Q (J)	$W_{on\ gas}$(J)	ΔU (J)



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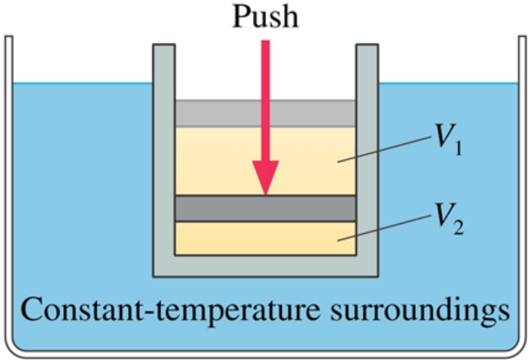
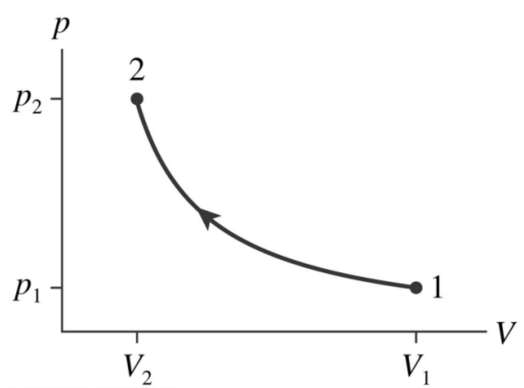
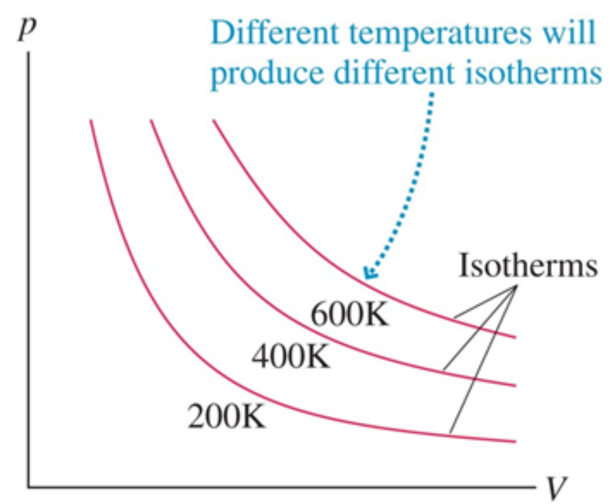


$\Delta T=0 \Rightarrow \Delta U=0$

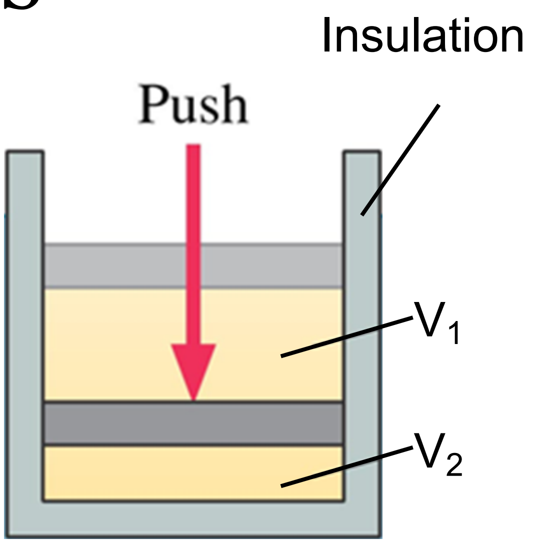
$$W_{onGas} = -nRT\ln\left(\frac{V_f}{V_i}\right)$$



Q (J)	$W_{on\ gas}$(J)	ΔU (J)
−	+	0



Adiabatic Process

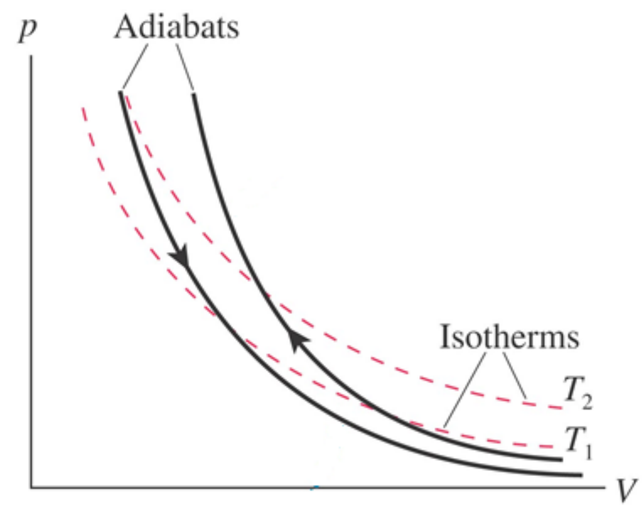


- We have already learned:
  - Isobaric process $\Delta P=0 \Rightarrow W=-P\Delta V$
  - Isochoric process $\Delta V=0 \Rightarrow W=0$
  - Isothermal process $\Delta T=0 \Rightarrow \Delta U=0$
- An adiabatic process
  - A process in which no heat energy is transferred between the system and environment.
  - Q=0 → $\Delta U=W$
  - Warning: This does not mean ΔT=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?



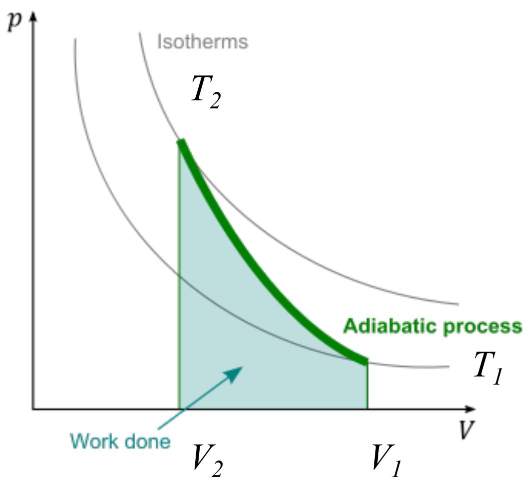
Q (J)	$W_{on\ gas}$(J)	ΔU (J)

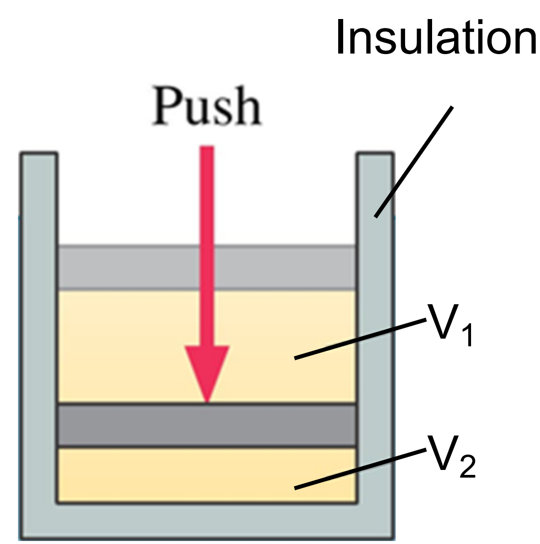
First Law of Thermodynamics
Four special ideal-gas processes

(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)	$W_{on\ gas}$(J)	ΔU (J)
0	+	+

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.

c) What kind of process is this? Isothermal

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

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

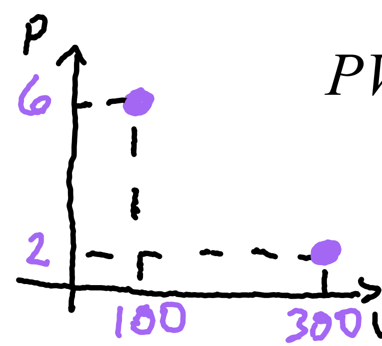
e) What is the work done on the gas? 6677 J

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

f) Find Q and ΔU for the process.

$\Delta U = Q + W$ $\quad \Delta U = 0$

$Q = -W = -66.77\text{J}$



$$PV = nRT$$

State	*P*	*V*	*T*
Initial	2atm	300cm^3	365.7 K
Final	6atm	100 cm^3	365.7 K

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. $T_f = T_i = 365.7$ K

c) What kind of process is this? isothermal

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

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

e) What is the work done on the gas? $W_{ongas} = +66.77$J

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

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	?

$$PV = nRT$$