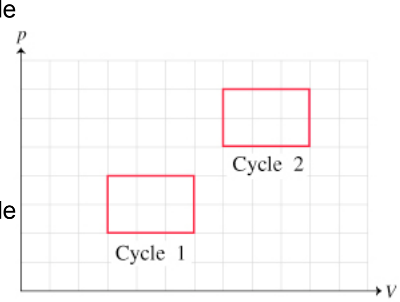
First Law of Thermodynamics

Two closed thermodynamic cycles

Two closed thermodynamic cycles for an ideal gas are depicted on the pV diagram.

Imagine processing the gas clockwise through Cycle 1 once. Determine whether the change in internal energy of the gas in the entire cycle is positive, negative, or zero.

- $\Delta U_{1clockwise} = 0$ internal energy only depends on initial and final states



Imagine processing the gas clockwise through Cycle 1. Determine whether the work done on the gas in the entire cycle is positive, negative, or zero.

- $W_{1clockwise} < 0$ negative to the right, positive to the left, zero along the vertical sides (isochoric). W = - area of rectangle.

Imagine processing the gas clockwise through Cycle 1. Determine whether the heat energy transferred to the gas in the entire cycle is positive, negative, or zero.

$Q_{1clockwise} > 0$ positive because W is negative and $\Delta U = W + Q = 0$

Demo:steam engine

A triangular thermodynamic cycle

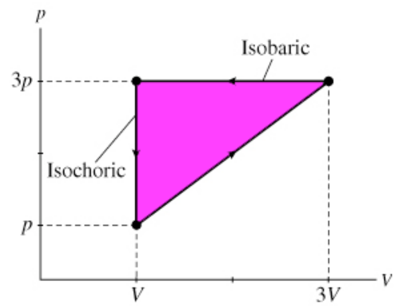
A cylinder with initial volume V contains a sample of gas at pressure p. The gas is heated in such a way that its pressure is directly proportional to its volume. After the gas reaches the volume 3V and pressure 3p it is cooled isobarically to its original volume V. The gas is then cooled isochorically until i returns to the original volume and pressure.

Find the work W done on the gas during the entire process

It is reasonable to use the ideal-gas model in this problem if :

2. The temperature is well above the condensation point.
3. The density of the gas is low.

The processes involved can be assumed to be quasi-static if: 1. They happen slowly.



The work done on the gas during: its expansion from V → 3V is: negative
the isobaric process is: positive
the isochoric process is: zero

A triangular thermodynamic cycle

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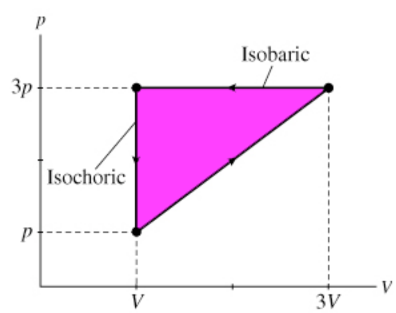


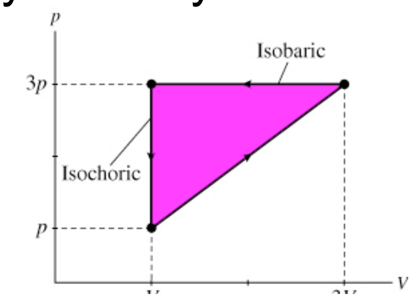
Let us now calculate the total work done on the goes during the cycle

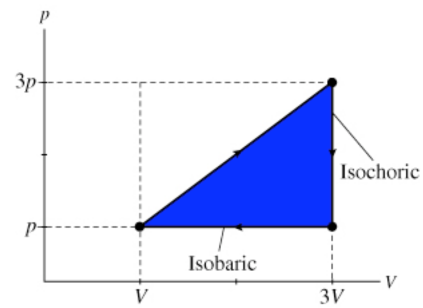
W_1 = -(2pV+2p2V/2) = -2pV-2pV = -4pV
W_2 = 2V3p = 6pV
W_3 = 0
$W = W_1 + W_2 + W_3 = 2$ pV
2 pV = area of the triangle in magenta
If the direction of the process was reversed, the overall work would be negative:
W = - area = - 2 pV

A triangular thermodynamic cycle

If the gas cycle was reordered, so that the isochoric process came before the isobaric process, as in the bottom diagram shaded in blue, the work done on the gas during the entire new cycle would be:

1. positive
2. negative
3. zero





Demo: IR parabolic mirrors

Compression of a Jaguar XK8 cylinder

A Jaguar XK8 convertible has an eight-cylinder engine. At the beginning of its compression stroke, one of the cylinders contains 499 cm^3 of air at atmospheric pressure 1.01×10^5 Pa and a temperature of 27.0°C.
At the end of the stroke, the air has been compressed to a volume of 46.2 cm^3 and the gauge pressure has increased to 2.72×10^6 Pa.

What is the final temperature of the gas in an engine cylinder after the compression stroke?

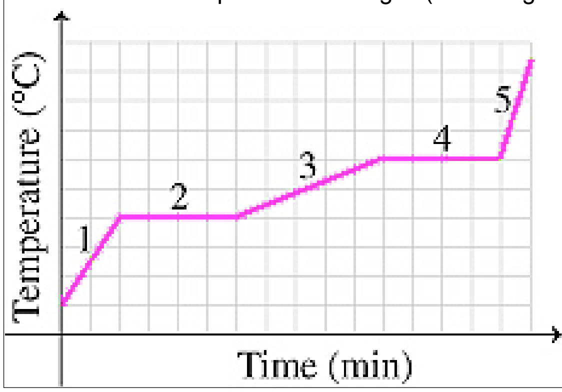
T_2 = 510°C
The increase in gas temperature caused by this compression stroke is one of the reasons why a car engine gets so hot when it is running.

Demo: freezing by evaporation

specific heat, latent heat, and temperature versus time graphs

The graph shows how the temperature of an initially solid sample changes as time goes by when it is placed above a flame that delivers a constant heating power (that is, a fixed amount of energy input in the form of heat per second). The process occurs in five distinct steps:

1. Increase the temperature of the solid until it reaches its melting temperature.
2. Melt the solid to form a liquid, maintaining a constant temperature.
3. Increase the temperature of the liquid until it reaches its boiling temperature.
4. Boil away all the liquid to form a gas, maintaining a constant temperature.
5. Increase the temperature of the gas (assuming that the gaseous sample is confined).



Use the graph to rank the sizes of the following:

A. specific heat of the solid, c_S
B. specific heat of the liquid, c_L
C. specific heat of the gas, c_G

The smaller the specific heat, the more quickly the temperature can change, so the steeper the slope on a temperature versus time graph.

Thus: $c_L > c_S > c_G$

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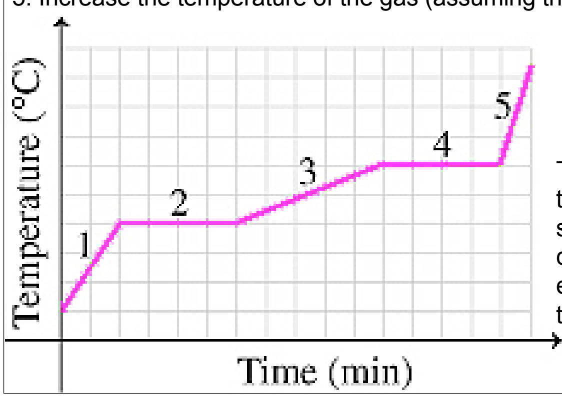

Use the graph to rank the sizes of the following:

1. latent heat of fusion, L_F
2. latent heat of vaporization, L_V

The two latent heats are related to the (horizontal) durations of sections 2 and 4 on the graph. You can rank the latent heats by estimating which phase change takes longer to accomplish.

Thus: $L_F = L_V$ water $\begin{cases} L_V = 2256 \text{ J/g} \\ L_F = 334 \text{ J/g} \end{cases}$