Thermodynamic transitions

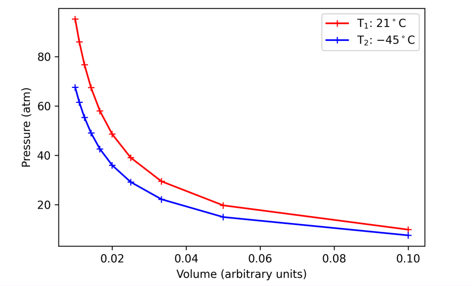
Isothermal (fixed temperature):

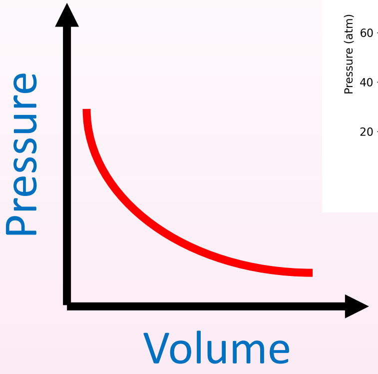
$$\boxed{0 = Q_{in} + W_{\text{on}}}$$

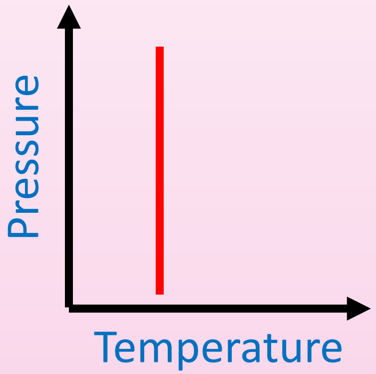
No change in temperature so no change in internal energy

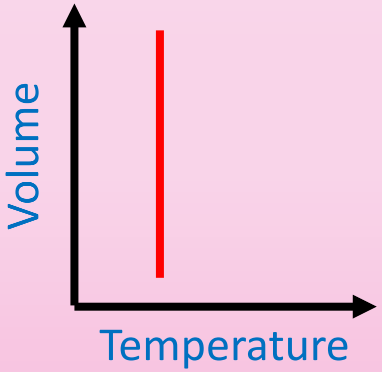
$\Delta T = \Delta U = 0$

In PV plane, $PV =$ constant









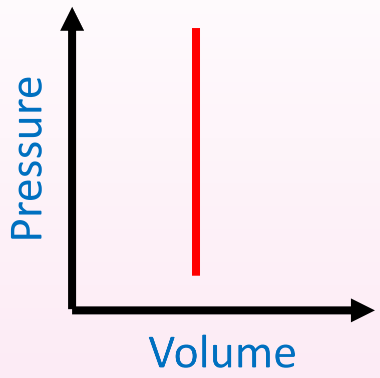
Thermodynamic transitions

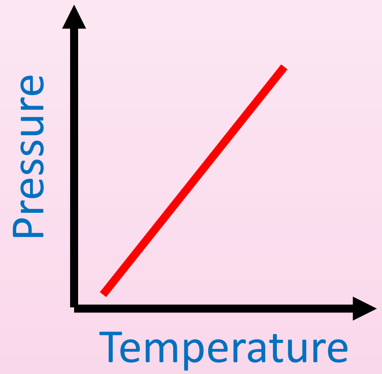
Isochoric (fixed volume):

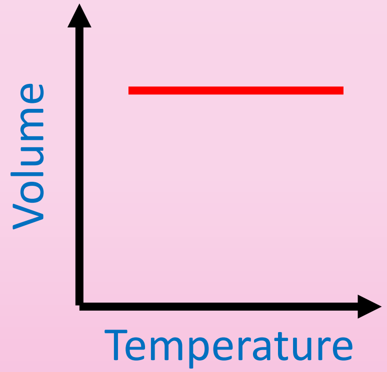
$$\boxed{\Delta U = Q_{in}}$$

As $W_{\text{on}} = (-)\int P\,\mathrm{d}V$ and $\mathrm{d}V = 0$,

$$W_{\text{on}} = 0$$







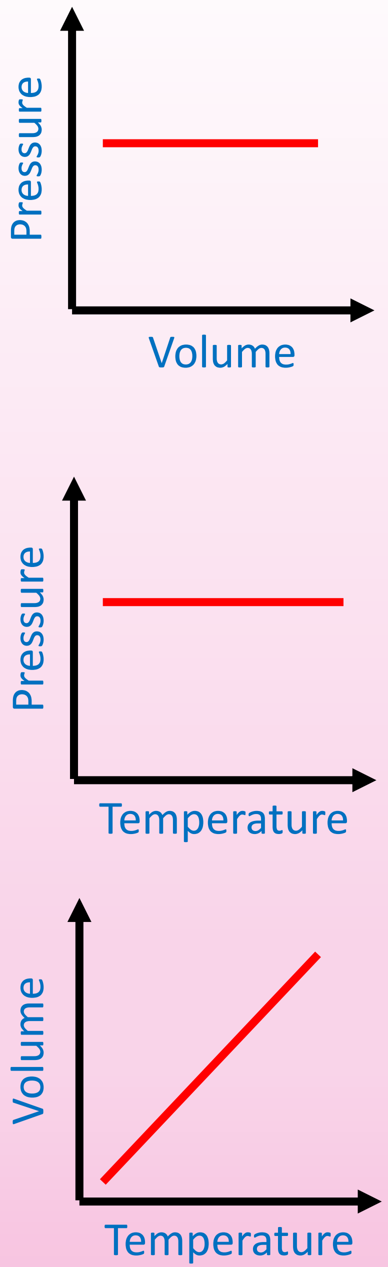
Thermodynamic transitions

Isobaric (fixed pressure):

$$\boxed{\Delta U = Q_{in} + P\,\Delta V}$$

No non-zero terms here, but…

$$W_{\text{on}} = (-)\int P\,\mathrm{d}V = (-)P\,\Delta V$$



Thermodynamic transitions

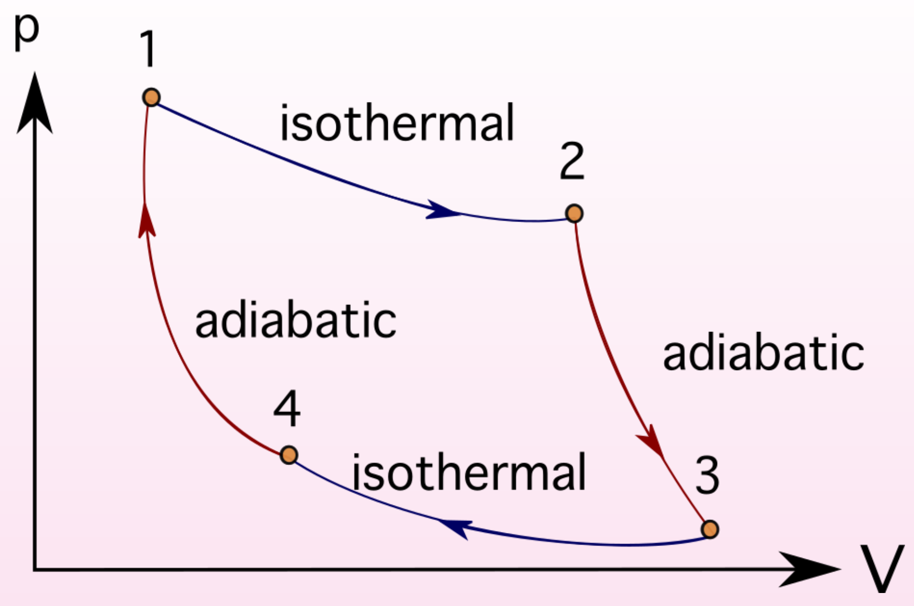
Adiabatic (no heat transfer):

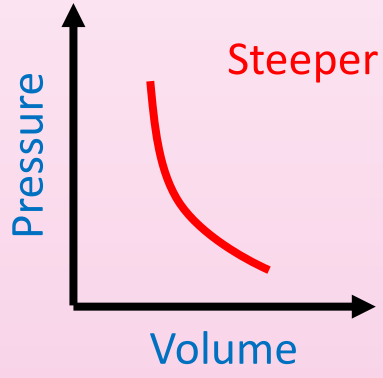
$$\Delta U = W_{\text{on}}$$

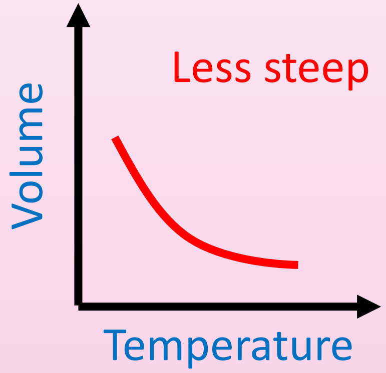
No heat transfer, so $Q_{in} = 0$

In PV plane, adiabatic processes are described by $PV^{\gamma} =$ constant

In VT plane, adiabatic processes are described by $TV^{\gamma-1} =$ constant

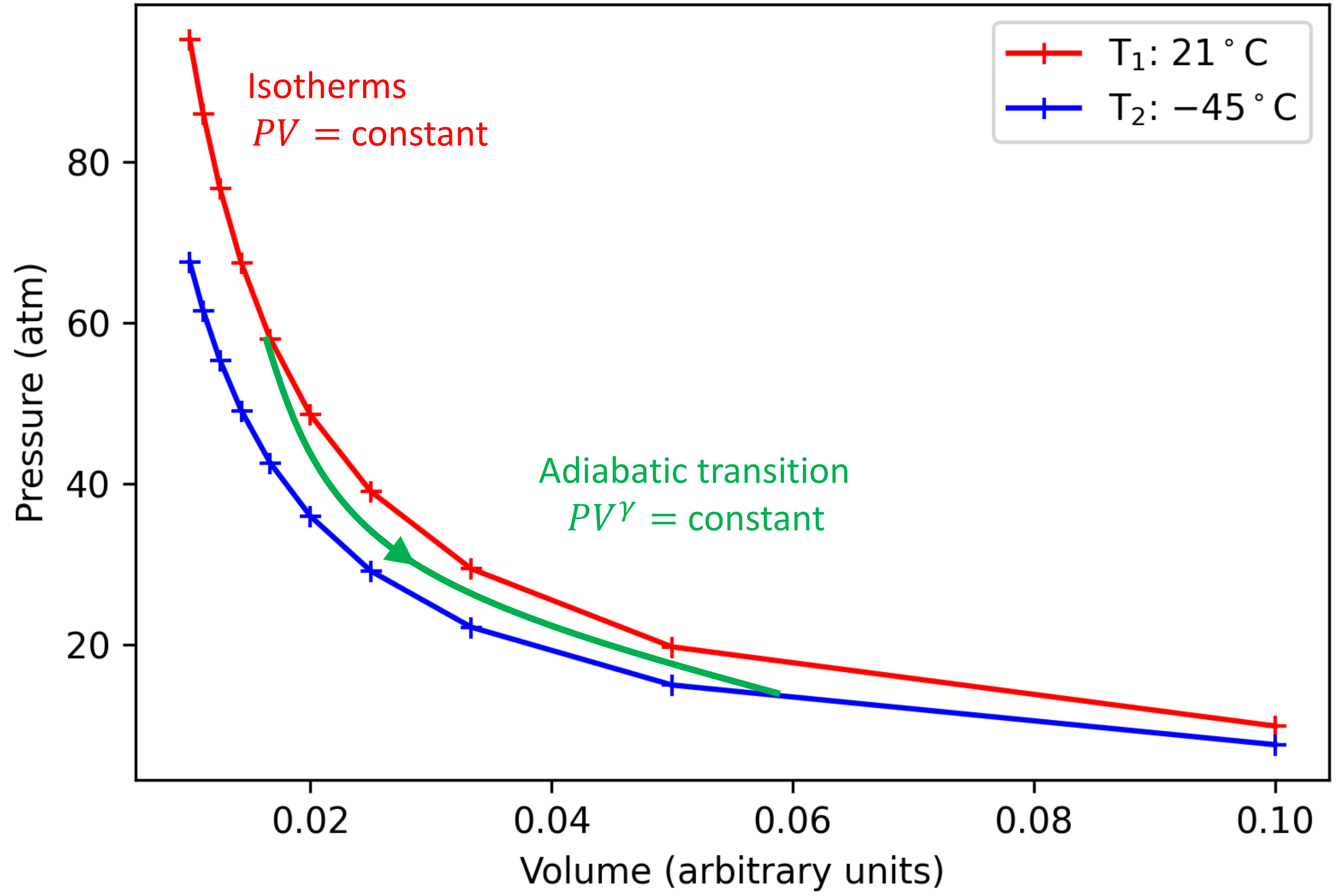






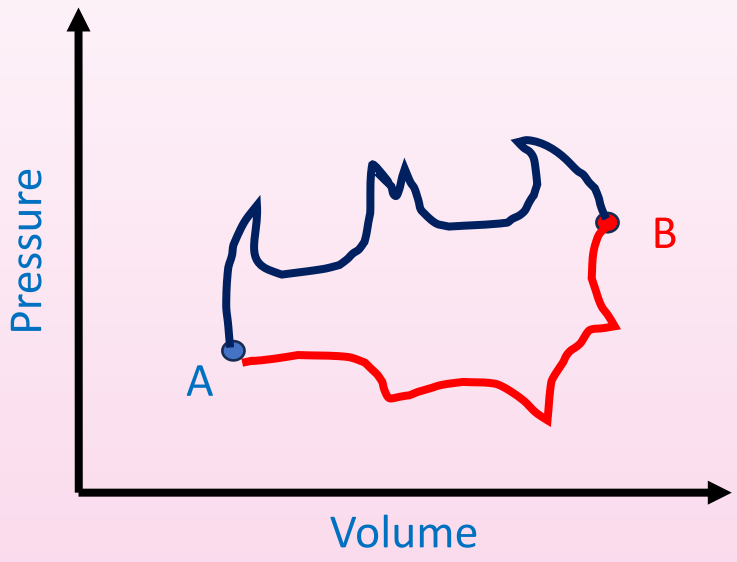
In the PV plane, adiabatic processes appear steeper than isothermal processes

Adiabatic processes are steeper in the PV plane than in the VT plane



As the pressure decreases and volume increases, the temperature of the gas decreases also

PV diagrams



We can move through the PV plane through processes, which usually involve some heat transfer and work (like in the case on the left)

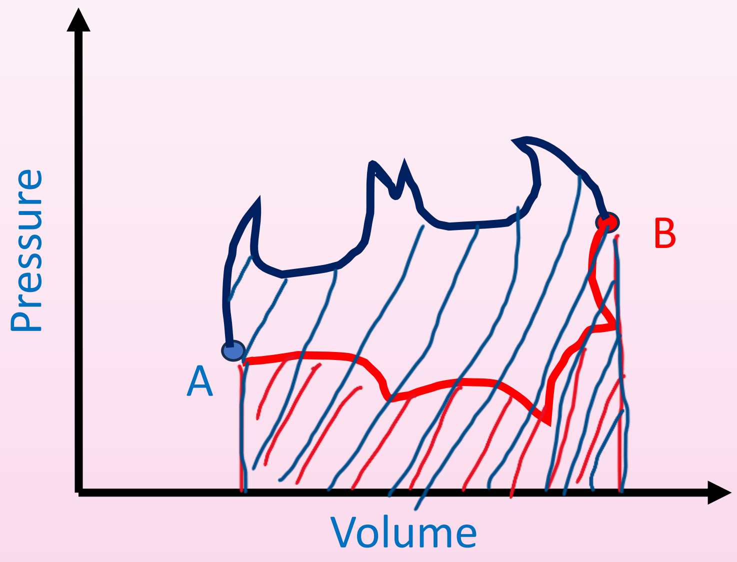
If we go along the blue path, is the change in internal energy U_{AB}

1) Larger than if we went via the red path?
2) smaller than if we went via the red path?
3) The same as if we went via the red path?

As internal energy is a function of state it does not matter which path we take…

U depends on solely on T, which itself depends on P and V (for same P and V, same T and hence same U)

PV diagrams



$$W_{\mathrm{blue}} > W_{\mathrm{red}}$$

We can move through the PV plane through processes, which usually involve some heat transfer and work (like in the case on the left)

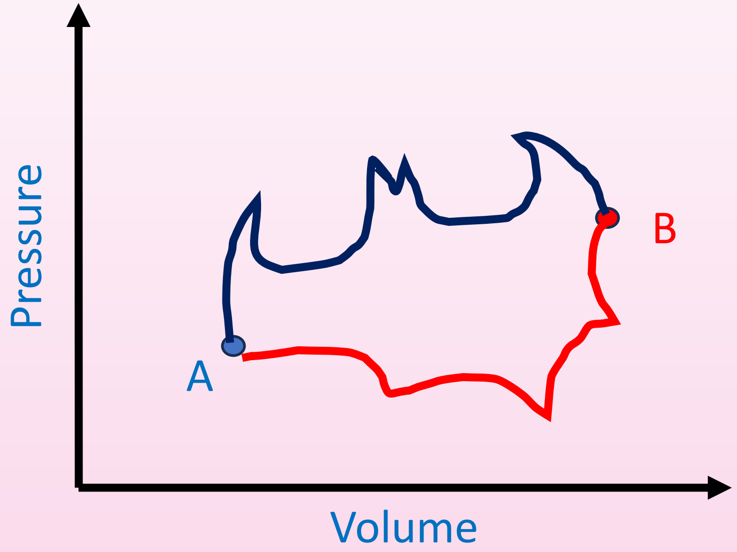
Is the work done by the gas, W_{by},

1) Greater for the red path?
2) Greater for the blue path?
3) The same for both paths?

$$W_{\mathrm{by}} = \int P \, \mathrm{d}V$$

Work is given by area under curve!

PV diagrams



We can move through the PV plane through processes, which usually involve some heat transfer and work (like in the case on the left)

Is the heat input to the gas, Q_{in},

1) Greater for the red path?

2) Greater for the blue path?

3) The same for both paths?

$$\Delta U = Q_{\text{blue}} - W_{\text{blue}}$$

$$\Delta U = Q_{\text{red}} - W_{\text{red}}$$

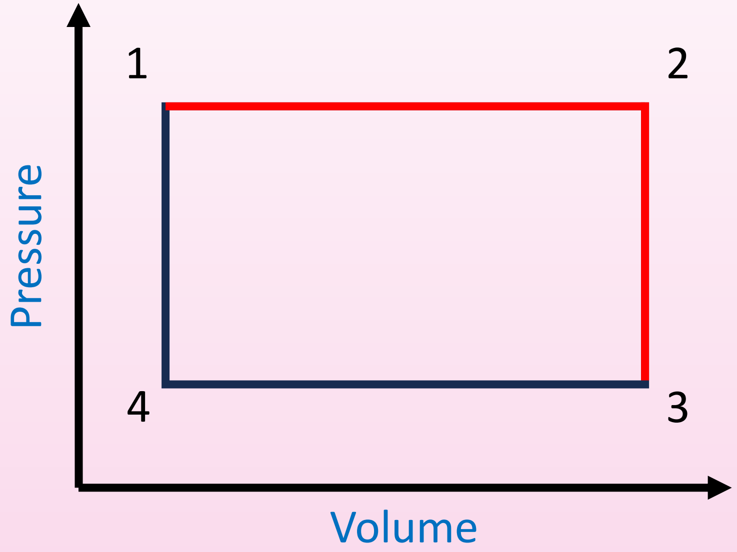
$$0 = Q_{\text{blue}} - W_{\text{blue}} - Q_{\text{red}} + W_{\text{red}}$$

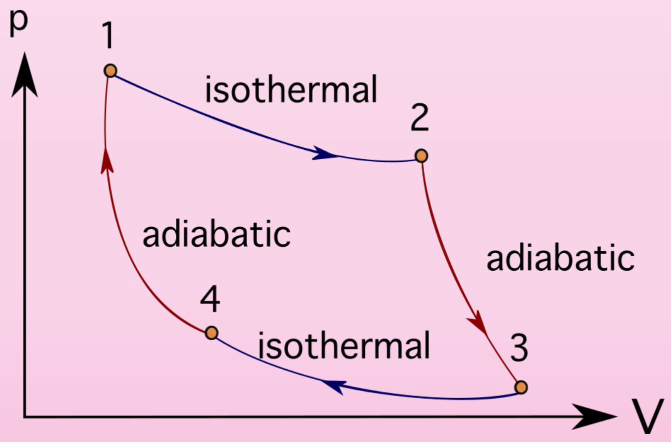
$$\Delta U = Q_{in} + W_{\text{on}} = Q_{in} - W_{\text{by}}$$

$$W_{\text{blue}} > W_{\text{red}}$$

$$Q_{\text{blue}} > Q_{\text{red}}$$

PV cycles





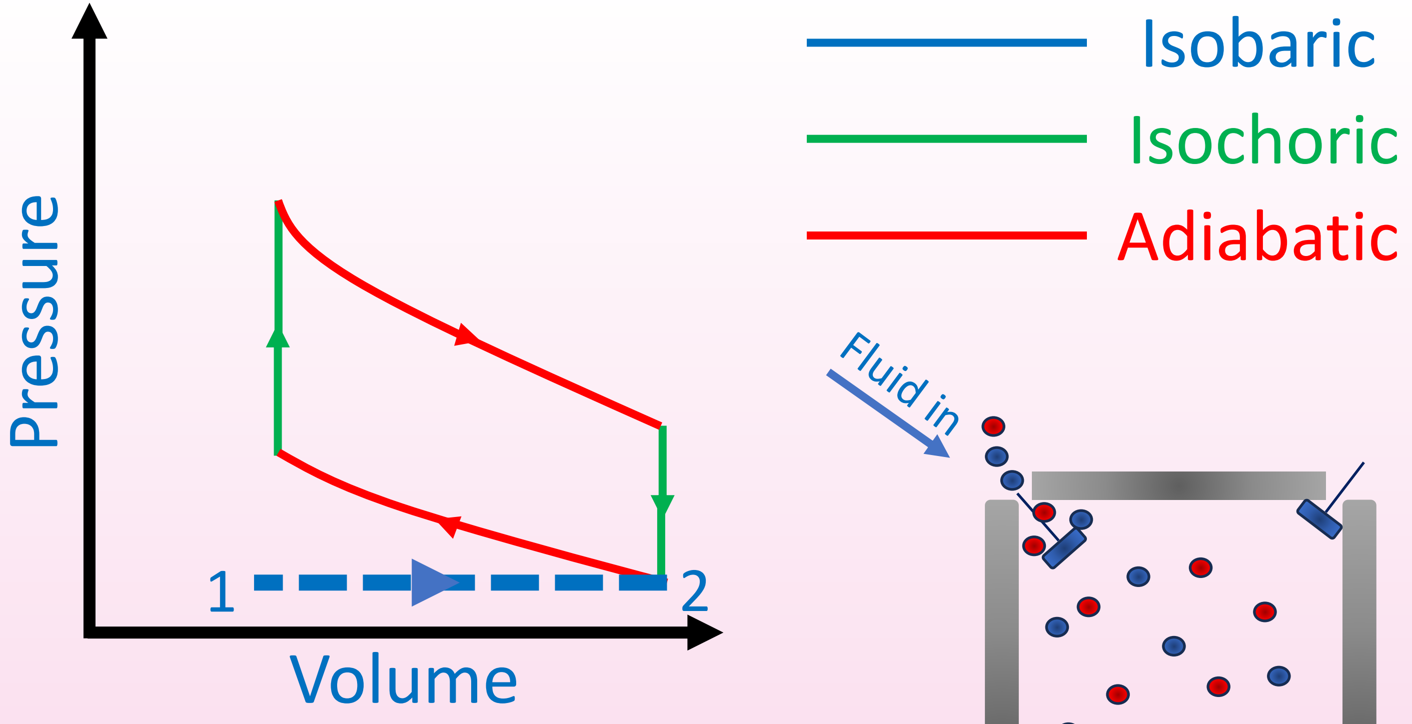
Rules for cycles:

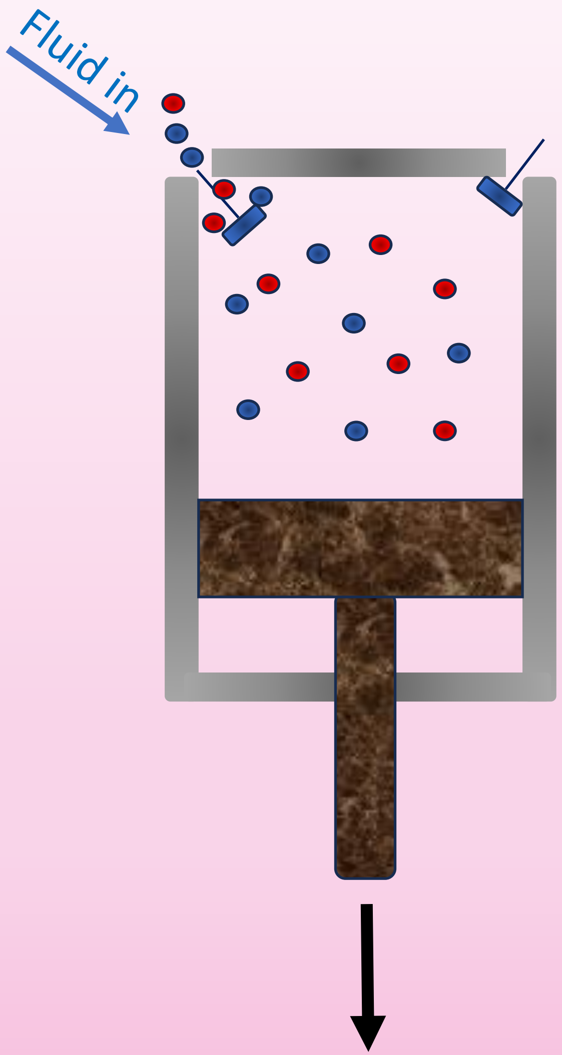
1) $\Delta U = 0$ for a full cycle ALWAYS
2) Work done given by area inside loop
3) Clockwise for positive work, anticlockwise for negative work
4) Q_{in} and W_{on} must sum to zero (as $\Delta U = 0$)

Otto cycle

Petrol internal combustion engine

1→2: Intake stroke (mass of air and fuel enters piston at a constant pressure)

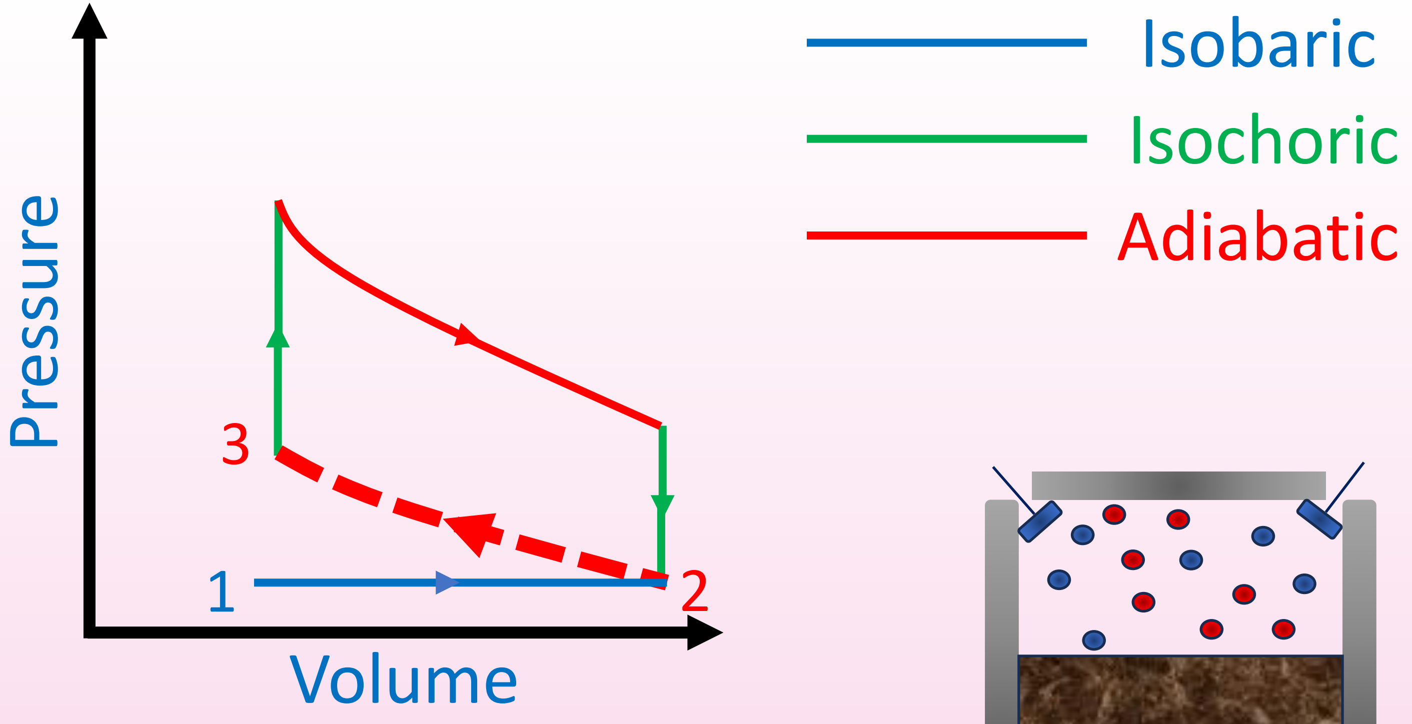


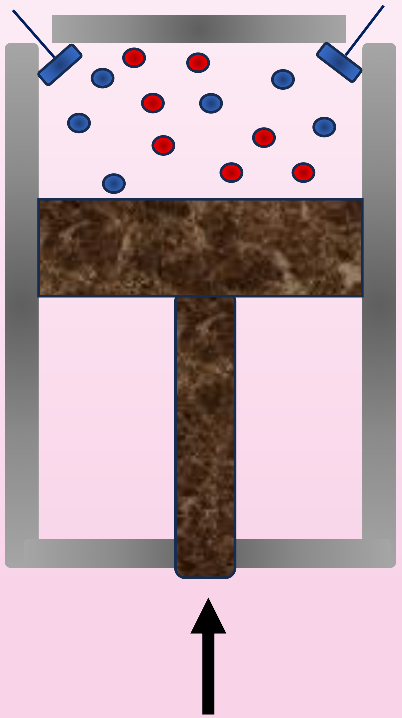


Otto cycle

Petrol internal combustion engine

2→3: Adiabatic compression of the fluid as the piston compresses it

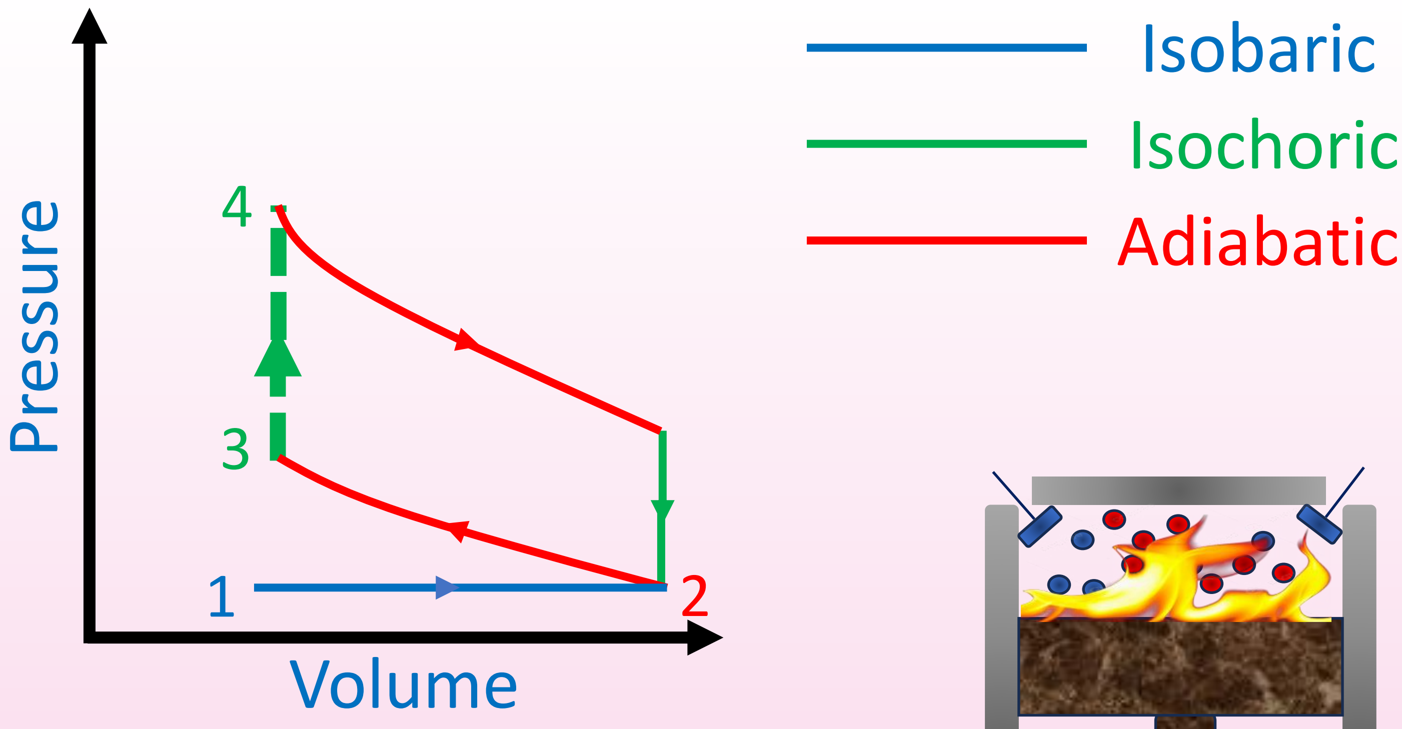


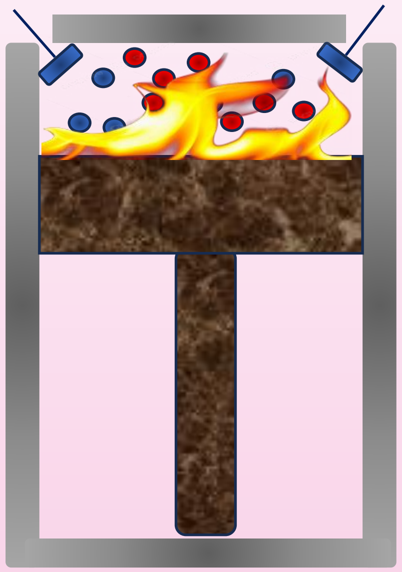


Otto cycle

Petrol internal combustion engine

3→4: Constant volume heat transfer (ignition of the fluid mixture)

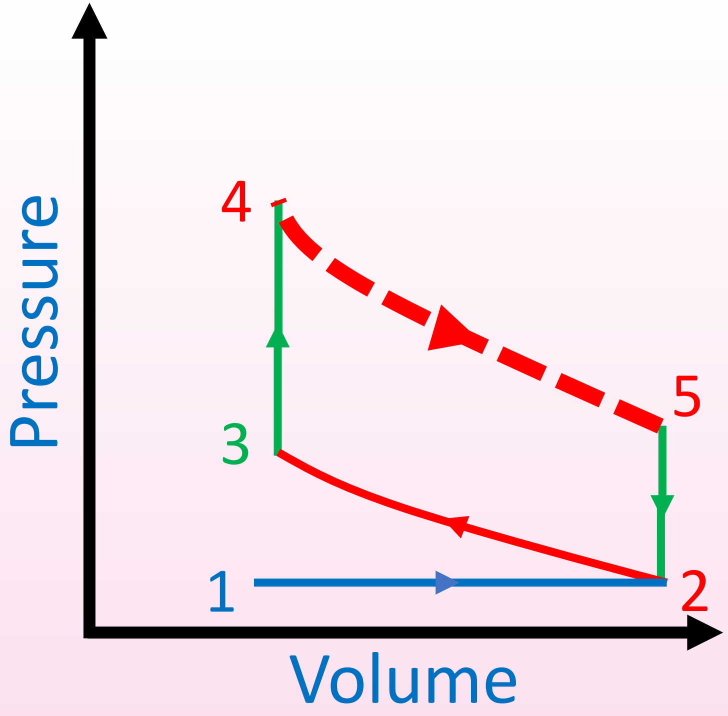


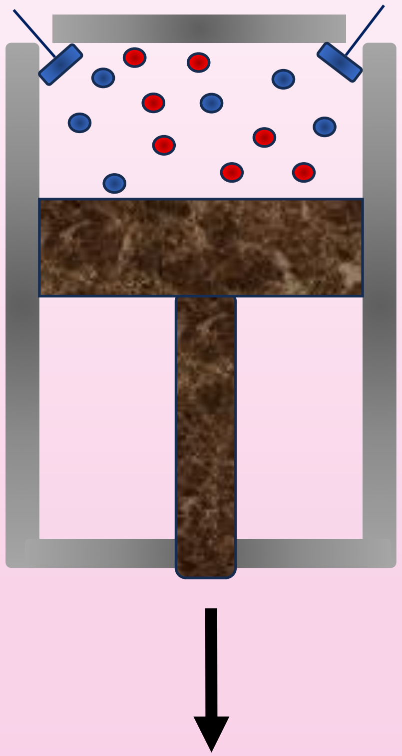


Otto cycle

Petrol internal combustion engine

4→5: Adiabatic expansion of the fluid as the gas pushes away the piston

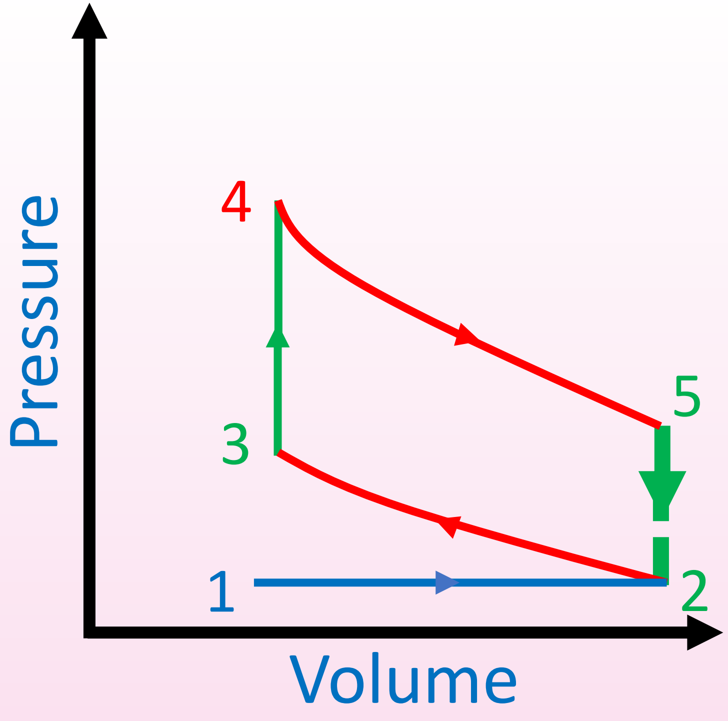


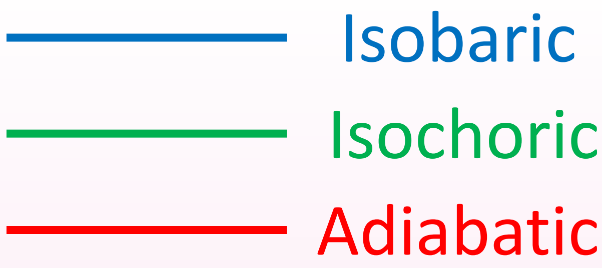


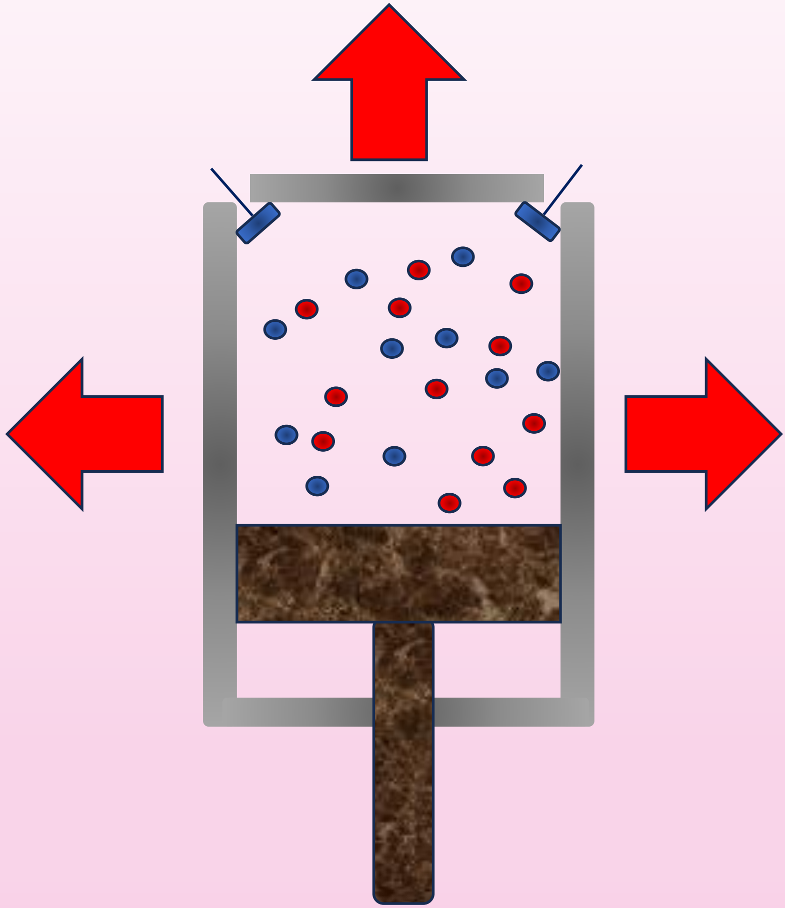
Otto cycle

Petrol internal combustion engine

5→2: Constant volume expulsion of heat from the system



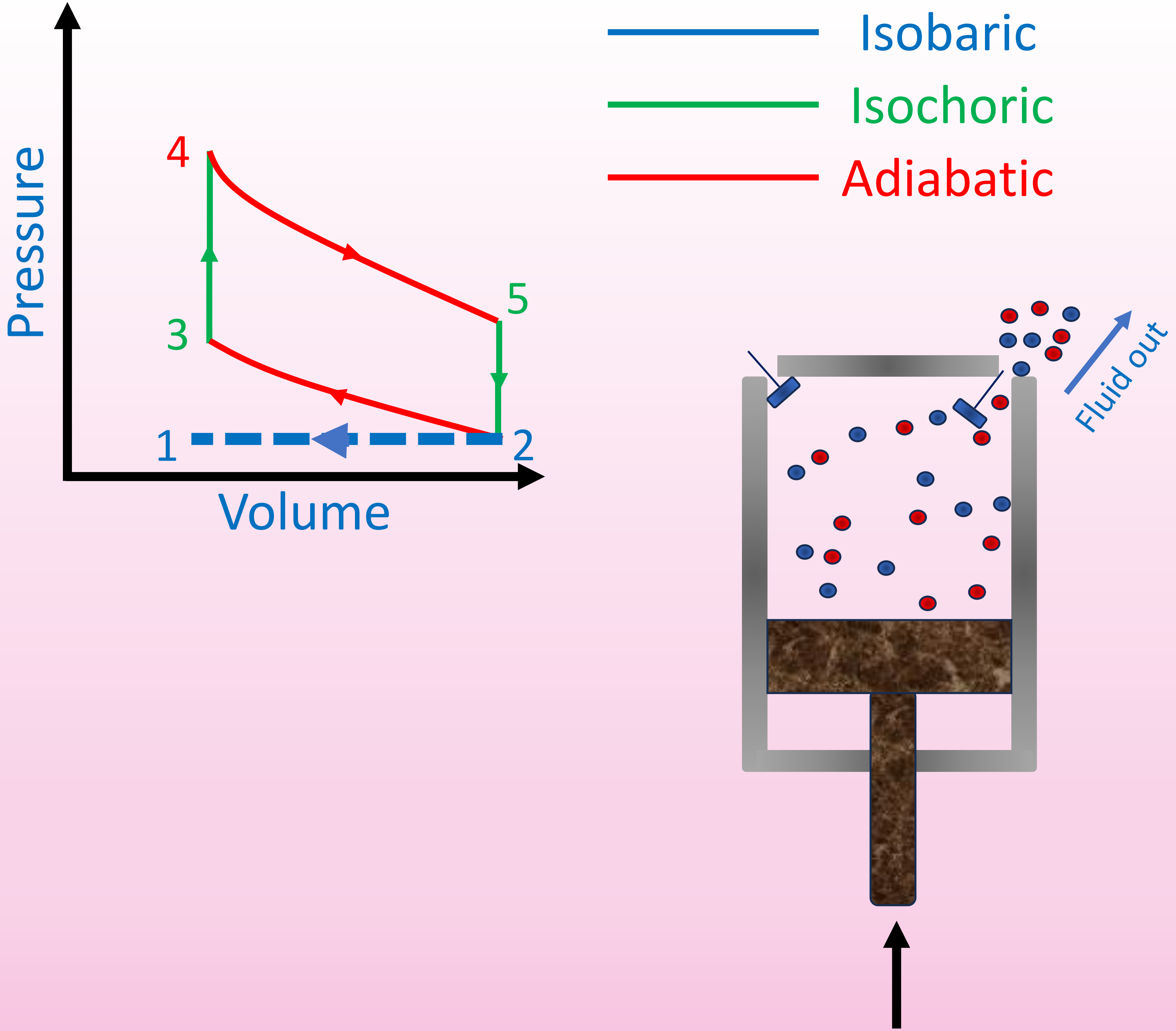




Otto cycle

Petrol internal combustion engine

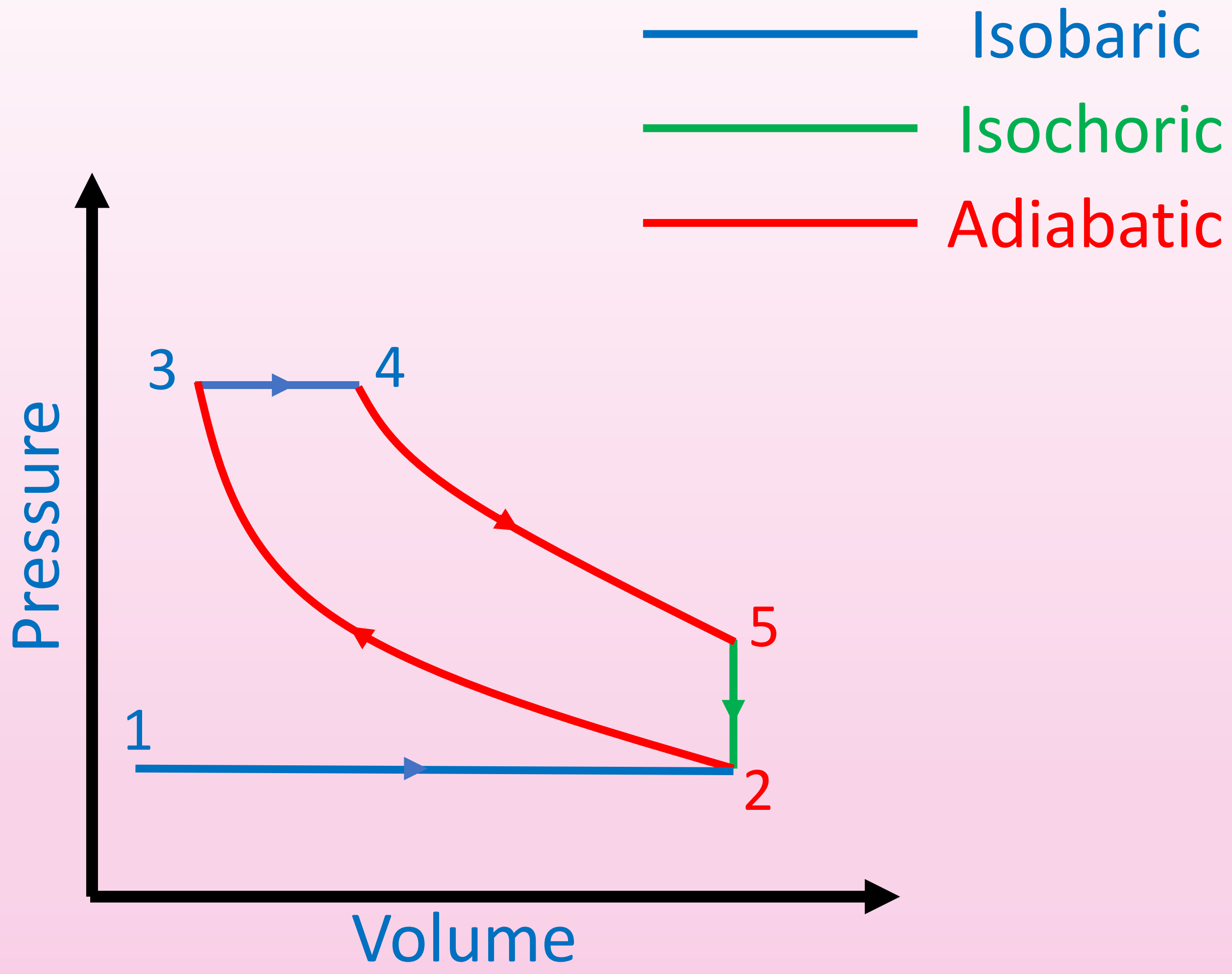
2→1: Mass of air released at a constant pressure (exhaust)

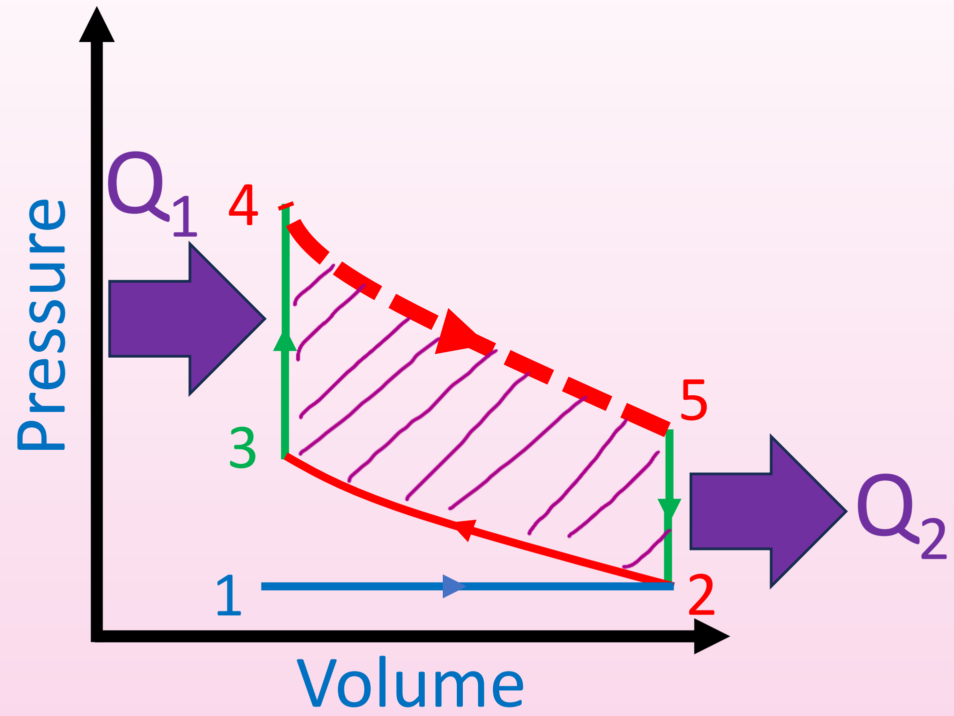


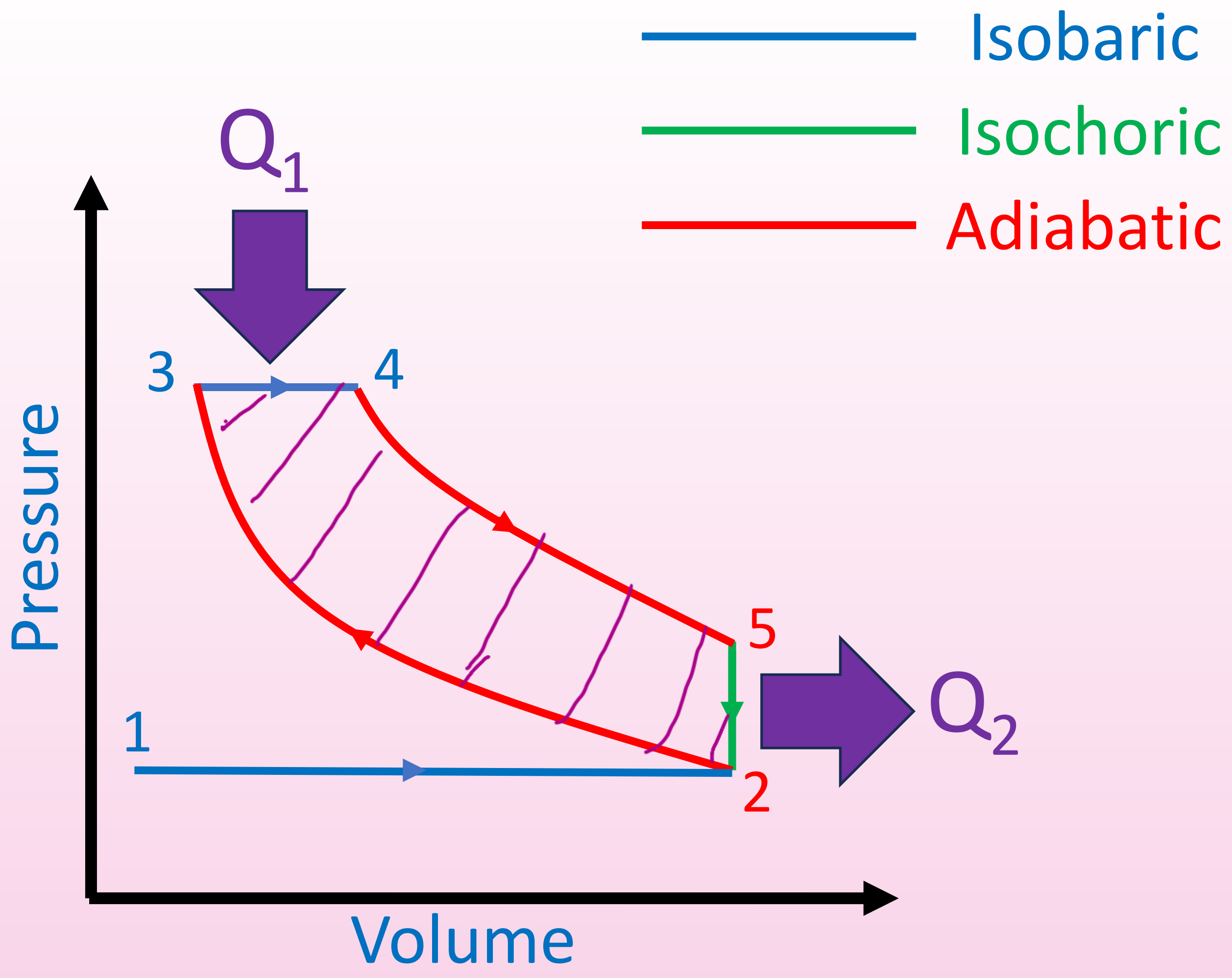
Diesel cycle

Diesel engine (named after Rudolf Diesel)

Here, the ignition/combustion process in 3→4 is performed at a constant pressure (so work is done by the gas)







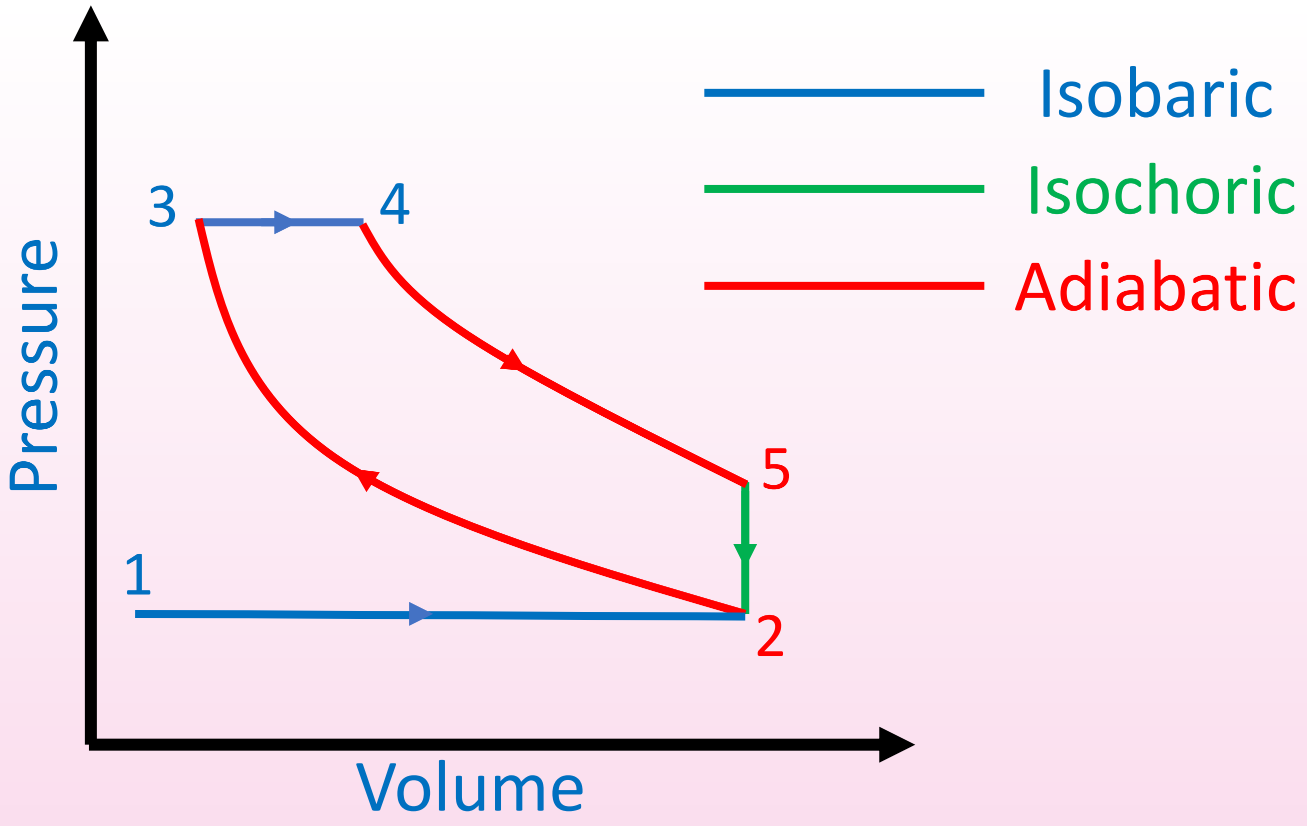
Useful work done = Q_1-Q_2 = area enclosed by cycle

Example question

Consider the adiabatic gas compression stroke in a diesel engine:

10^{-3} m^3 of nitrogen gas, initially at atmospheric pressure and 298 K, is compressed to 1/15 of its original volume.

You may assume the nitrogen gas is an ideal diatomic gas, with $\gamma = 1.4$ and $C_V = 20.85$ J K^{-1} mol^{-1}



Calculate: a) The final pressure

b) the final temperature

c) the number of moles of gas

d) the change in internal energy

e) the work done by the gas

Summary

Discussed PV diagrams generally and how they can be related to the first law of thermodynamics

Learnt about PV cycles generally, and the rules they follow. More specifically, a couple of useful ones – Otto and Diesel for petrol and diesel engines