

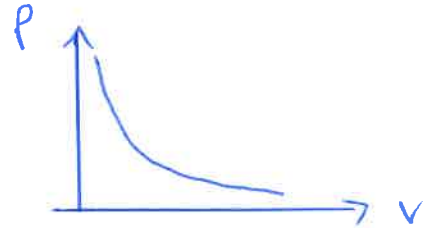
UNDERPINNING GAS LAWS:

BOYLE'S LAW

"For a fixed mass of gas at constant temperature the product of pressure and volume is constant",

$$PV = \text{constant}$$

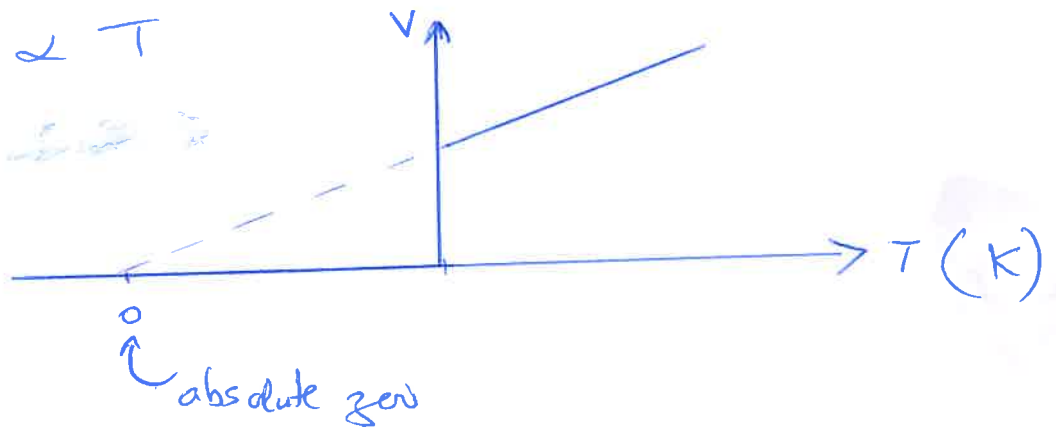
$$P = \frac{\text{constant}}{V}$$



CHARLES' Law

"For fixed mass of gas at constant pressure, the volume is directly proportional to the temperature measured in kelvins."

$$V \propto T$$



Celsius / kelvin

$$0^{\circ}\text{C} = 273.15\text{ K}$$

Ideal / Perfect gas

— a gas that obeys these laws exactly.

Reasonable approximation at low pressures, & temperatures well above liquefaction.

$$pV = nRT$$

where

p N m^{-2} (Pa)

V m^3

T kelvin

R molar gas constant $8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

n number of moles present.

N.B. moles

1 mole of a substance is when there is

$N_A = 6.02 \times 10^{23}$ atoms/molecules present (Avogadro's Number)

e.g. mass of 1 mole of ^{12}C is 12g
 mass of 1 mole of ^{16}O is 16g
 mass of 1 mole of O_2 is 32g.

see www.bipm.org

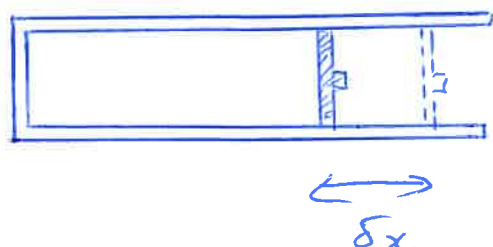
Aside:

Sometimes you'll see Specific Volume mentioned in texts. This is volume per unit mass

$$\text{Specific Volume} = \frac{1}{\rho}, \quad \rho \text{ density}$$

Work Done by an Expanding Gas

Consider a gas enclosed in a cylinder, with a frictionless piston of area A . The system is in equilibrium because a force F is applied to piston



If the pressure of gas is P , then the force on piston is pA

If gas expands to push piston out by a distance δx then

Work Done by gas $\delta W = pA \delta x$

$$\delta W = P \delta V$$

If the volume changes from V_1 to V_2

then work done by gas $W = \int_{V_1}^{V_2} P dV$

Assumptions:

↳ Reversible process

e.g. frictionless piston - no heat lost

Note: Compressing gas means we do work ON gas
i.e. we give it energy.

FIRST LAW OF THERMODYNAMICS

Thermodynamics — relationship between heat energy and other forms of energy

Let's apply Conservation of Energy to a gas system:

Internal Energy of gas, u , is kinetic energy of atoms/molecules due to its temperature.

Suppose we supply a small amount of heat energy ΔQ to a gas. Some of this energy will increase its internal energy (because it gets hotter) and some of this heat energy might expand the gas, causing the gas to do some work ΔW on its surroundings.

$$\Delta Q = \Delta u + \Delta W$$

$\uparrow$
 heat energy in

$\uparrow$
 increase
 in internal
 energy

$\uparrow$
 energy (work done)
 by gas in expanding.

(5)

Molar Heat Capacities } of gas
Specific Heat Capacities }

Unlike solids, liquids, gases can expand when heated.

c_p specific heat capacity @ constant pressure
= heat required to raise unit mass of gas
by 1 degree.

c_v specific heat capacity @ constant volume
= heat required to raise unit mass of gas
by 1 degree

c_p is bigger than c_v because some heat
supplied is used in expansion of gas

When considering moles rather than mass
we use molar heat capacity not specific heat capacity

and use capital letters C_p , C_v .

It can be shown that

$$C_p - C_v = R$$

Also we denote $\frac{C_p}{C_v}$ by γ

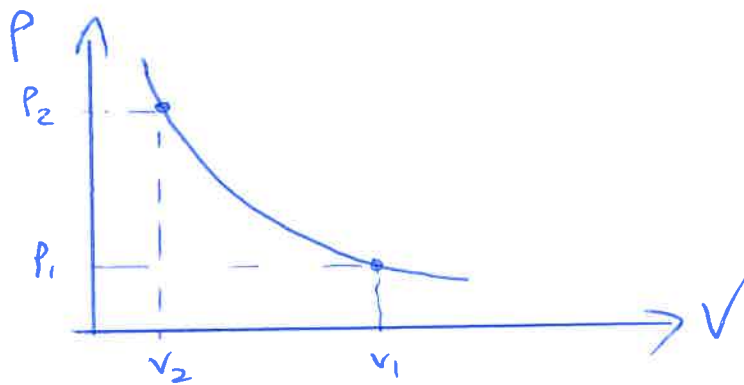
ISOTHERMAL PROCESS

(6)

Change of State @ constant temperature

From ideal gas equation, an isothermal process is where a gas expands/contracts so that

$$pV = \text{constant}$$



$$P_1 V_1 = P_2 V_2$$

Typically : slow process, plus good conduction through gas wall.

From 1st law of thermodynamics $\Delta Q = \Delta U + \Delta W$

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

$$\therefore \Delta Q = \Delta W$$

ADIABATIC PROCESS

(7)

Change of state of gas when no heat energy enters or leaves during the process

i.e. $\Delta Q = 0$ in 1st law

$$\therefore \Delta U = -\Delta W$$

i.e. if gas expands then temperature falls

or, an adiabatic compression causes temperature to rise
(compression $\Rightarrow \Delta V < 0$ i.e. $\Delta W < 0$)
 $\therefore \Delta U$ is positive above

When an ideal gas undergoes a reversible adiabatic change:

$$p V^\gamma = \text{constant}$$

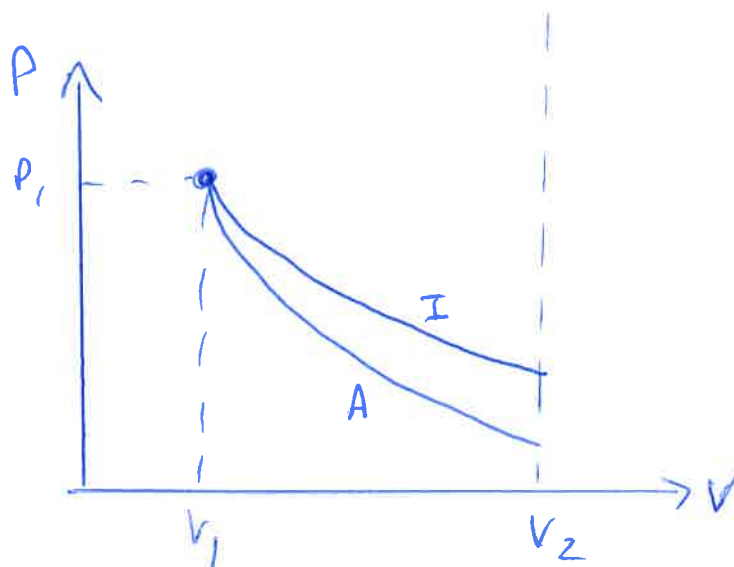
* Remember that ideal gas equation $pV = nRT$ still holds.

Comparing isothermal & adiabatic changes:

⑧

Example 1)

gas starts at state (P_1, V_1) and expands to volume V_2 :



Adiabatic has steeper curve & achieves lower pressure at V_2 since temperature is lower (heat lost due to expansion)

Example 2

Gas starts at state (P_2, V_2) and is compressed to volume V_1

