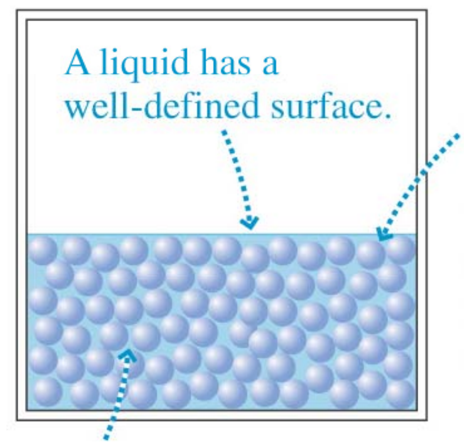
A Macroscopic Description of Matter

Readings: Chapter 16

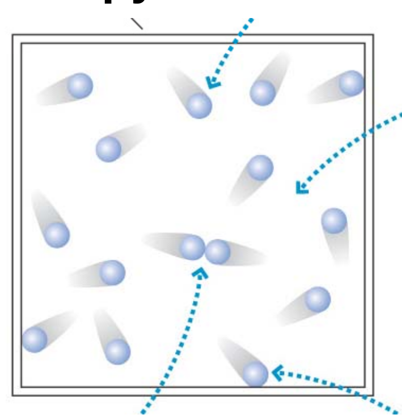
Solid, Liquid, Gas

-Solid has well-defined shape and well-defined surface. Solid is (nearly) incompressible.

-Liquid has well-defined surface (not shape), It is (nearly) incompressible.



- Gases are compressible. They occupy all volume.



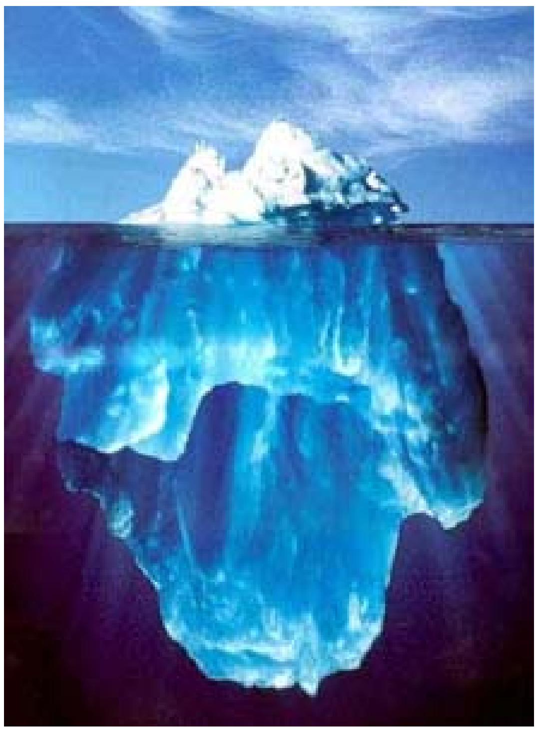
Solid, Liquid, Gas: Density

-Density is defined as a ratio of the mass of the object and occupied volume

$$\rho = \frac{m}{V}$$

The mass of unit volume (1m x 1m x 1m)

Units: kg/m^3



$$\rho_{gas} << \rho_{liquid} \sim \rho_{solid}$$

$$\rho_{ice} < \rho_{water}$$

The density of the ice is slightly less than water, causing them to float. Roughly 9/10 of the iceberg is below water.

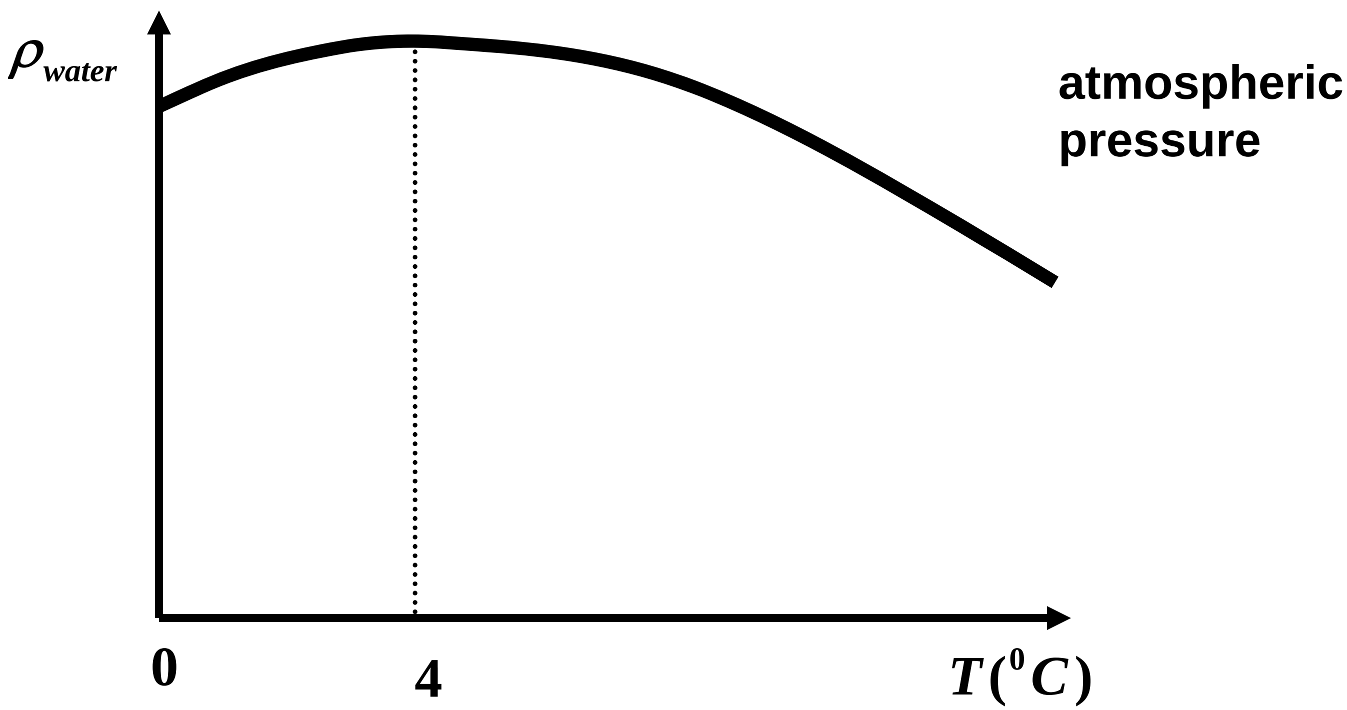
Solid, Liquid, Gas: Density

Material	Density (gm/cm^3)
Liquids	
Water at 4 C	1.0000
Water at 20 C	0.998
Gasoline	0.70
Mercury	13.6
Milk	1.03
Material	Density (gm/cm^3)

Solids	
Magnesium	1.7
Aluminum	2.7
Copper	8.3-9.0
Gold	19.3
Iron	7.8
Lead	11.3
Platinum	21.4
Uranium	18.7
Osmium	22.5
Ice at 0 C	0.92

Gases at STP	
Air	0.001293
Carbon dioxide	.001977
Carbon monoxide	0.00125
Hydrogen	0.00009
Helium	0.000178
Nitrogen	0.001251

At 4°C water expands on heating or cooling. This density maximum together with the low ice density results in (i) the necessity that all of a body of fresh water (not just its surface) is close to 4°C before any freezing can occur, (ii) the freezing of rivers, lakes and oceans is from the top down, so permitting survival of the bottom ecology.



Solid, Liquid, Gas: Mole

1 mole (1 mol) of substance is an amount which contains 6.02×10^{23} basic particles (atoms or molecules)

Avogadro's number is the number of basic particles in 1 mole:

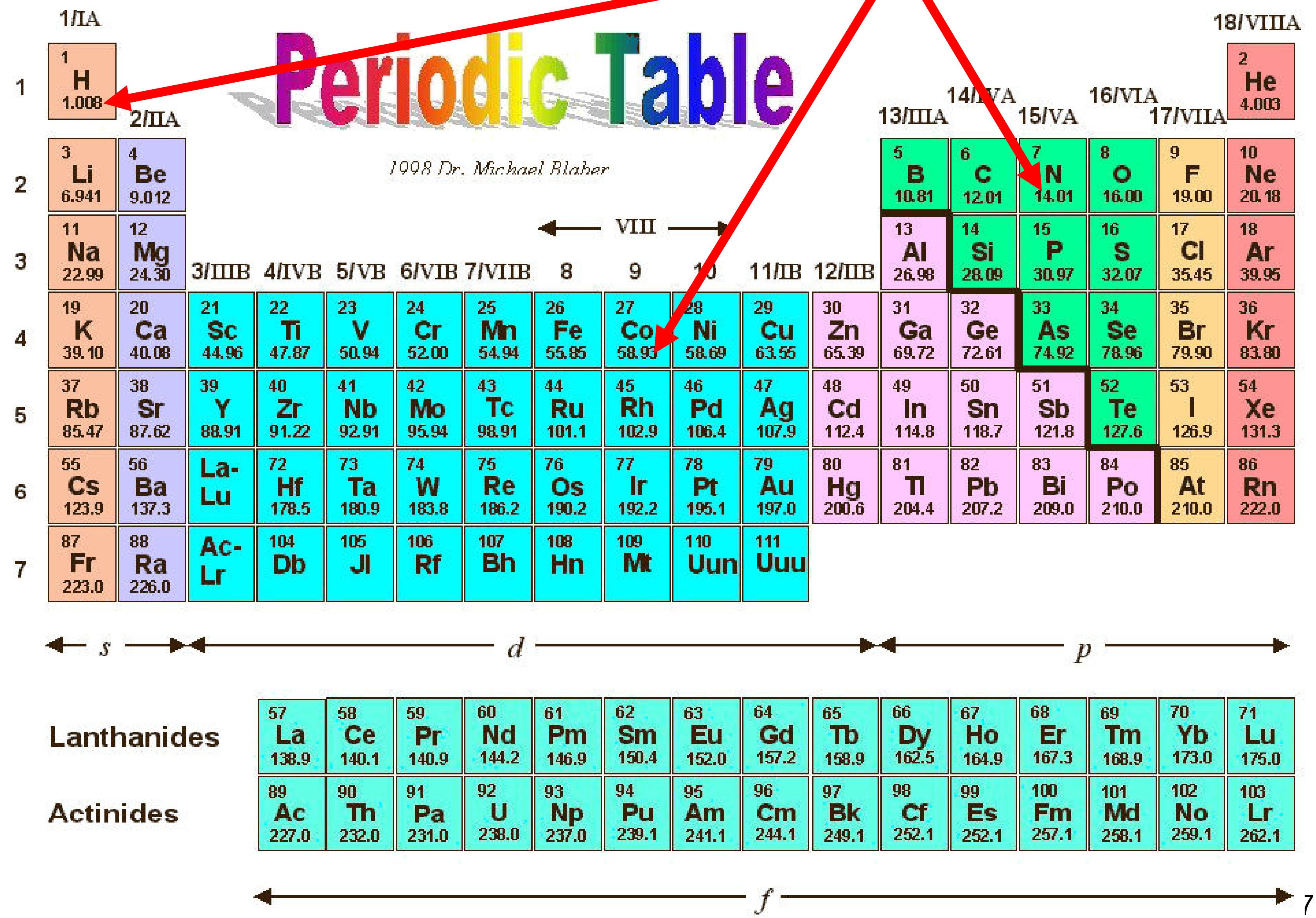
$$N_A = 6.02\times10^{23} mol^{-1}$$

If we know the number *n* of protons and neutrons in basic particles then we can find the mass of 1 mole:

$$m_{mole} = nm_{proton}N_A = n\cdot 1.661\times10^{-27}\cdot 6.02\times10^{23}\frac{kg}{mol} = 0.001n\frac{kg}{mol} = n\frac{g}{mol}$$

So, *n* is the molar mass (the mass of 1 mole in grams)

The number of protons and neutrons in atom



Temperature

Temperature is the measure of internal thermal energy

Different scale:

- Fahrenheit, *F*

- Celsius, *C*

- Kelvin, *K* **- SI scale of temperature**

$$T_F = \frac{9}{5} T_C + 32^0$$

$$T_K = T_C + 273$$

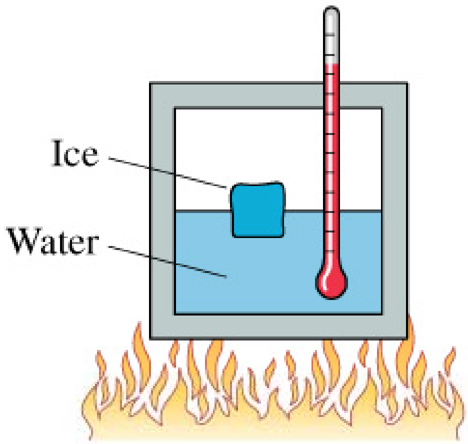
Example: $0^0 C = 273 K$

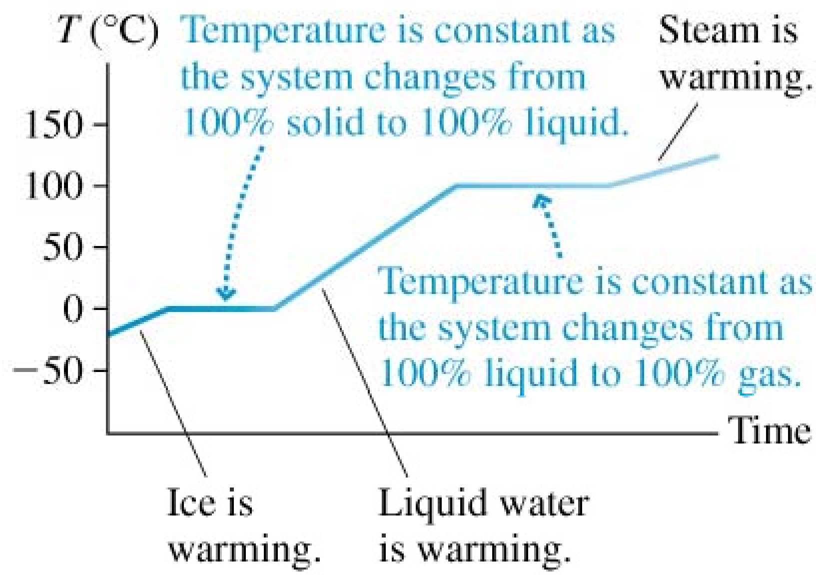
Absolute zero:

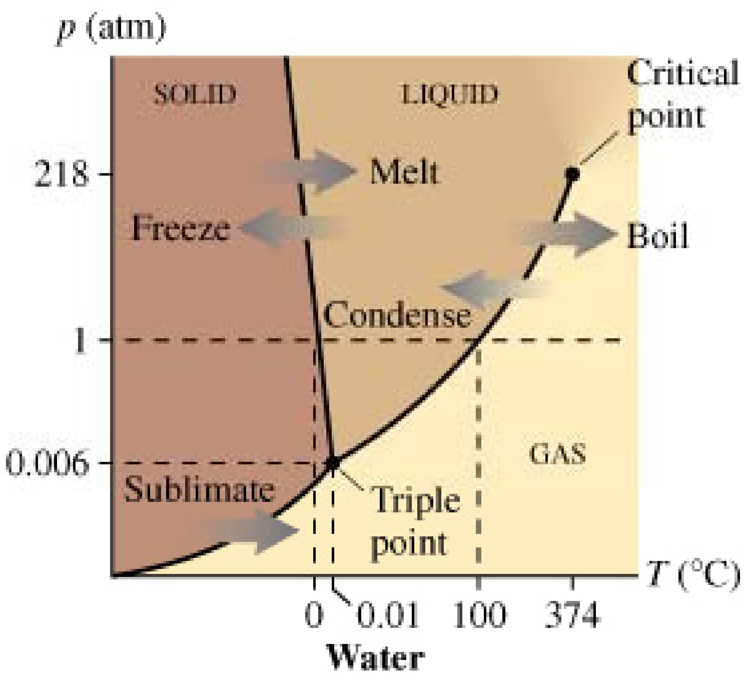
$$0K = -273^0 C$$

The temperature (in K) can be only positive

Solid, Liquid, Gas: Phase Changes







Heat: Specific Heat

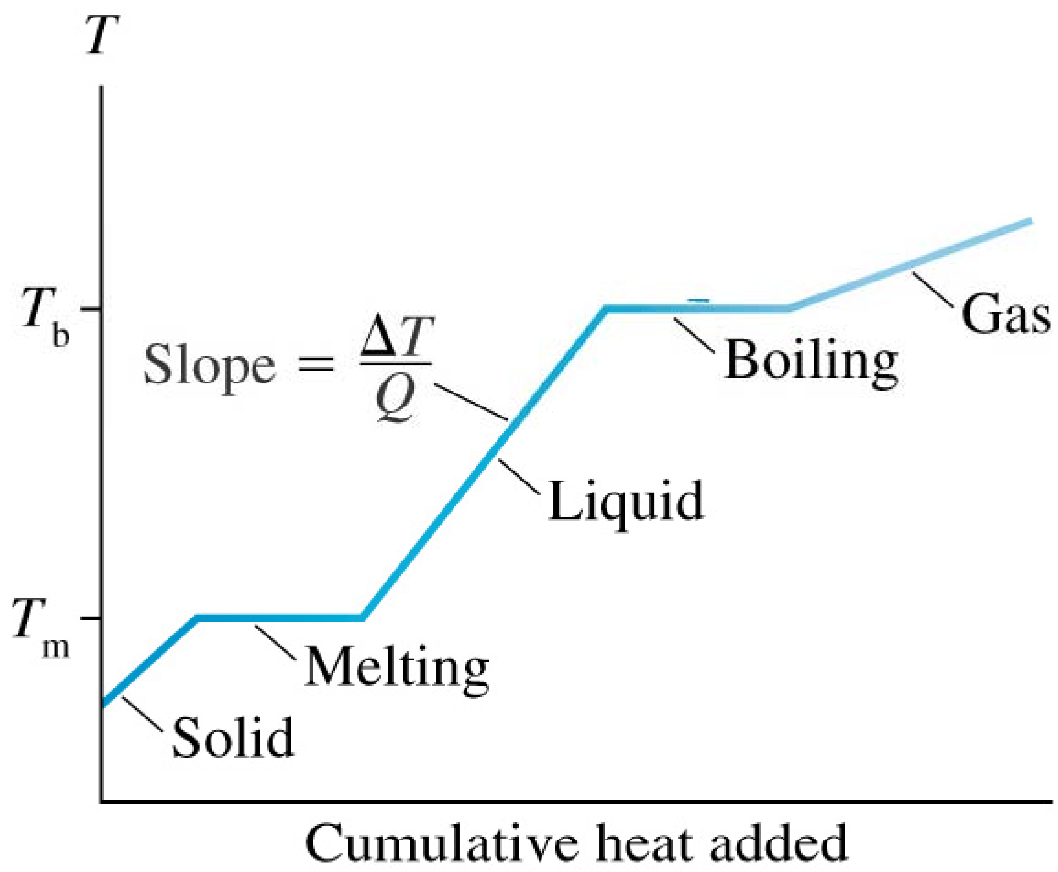
Specific heat of a substance is related to its thermal energy.
Specific heat is defined as:

The amount of energy that raises the temperature of 1 kg of a substance by 1 K is called specific heat, c.

$$Q = Mc\Delta T$$

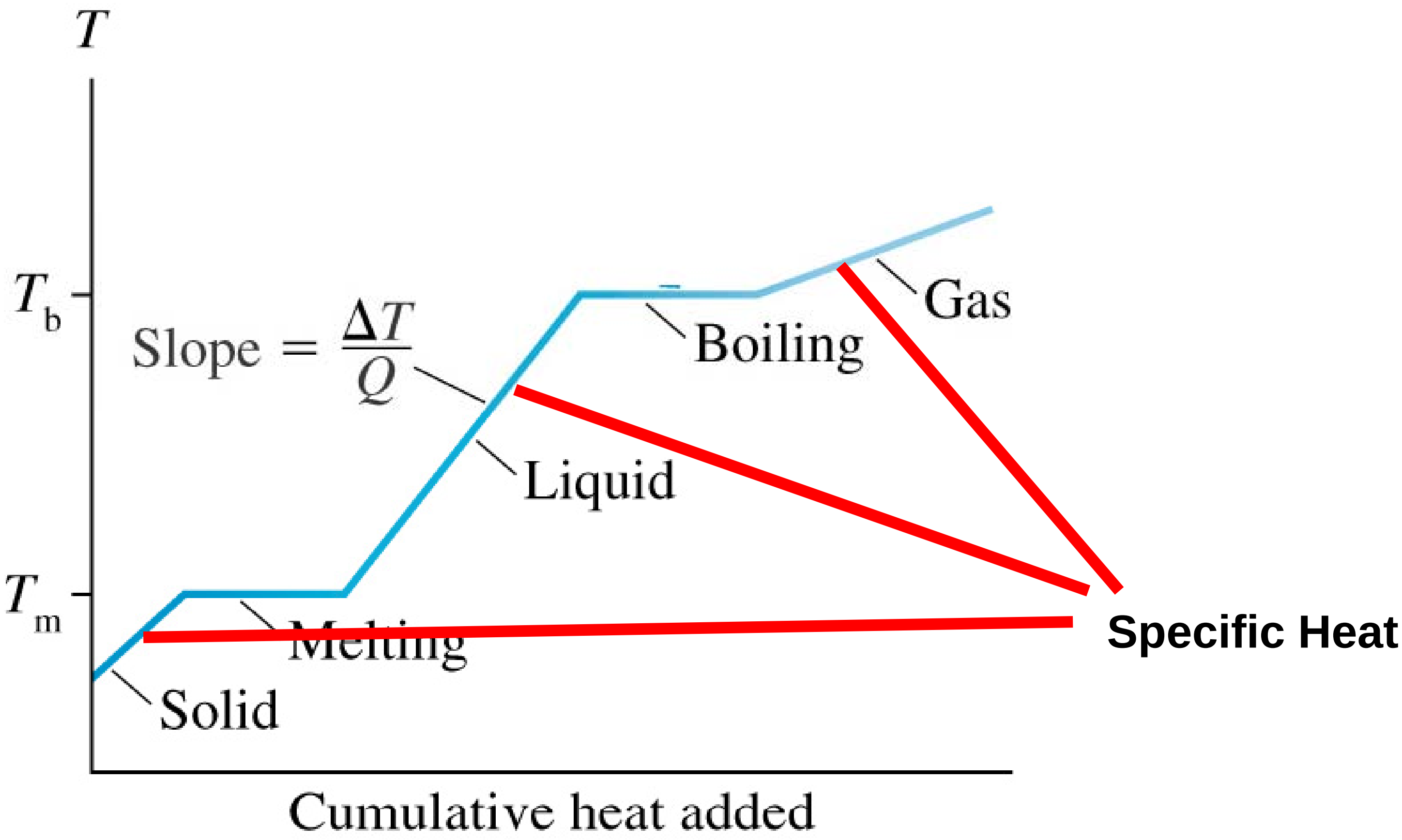
Phase Change: Solid, Liquid, and Gas

Phase change: change of thermal energy without a change in temperature



Phase Change: Solid, Liquid, and Gas

Phase change: change of thermal energy without a change in temperature

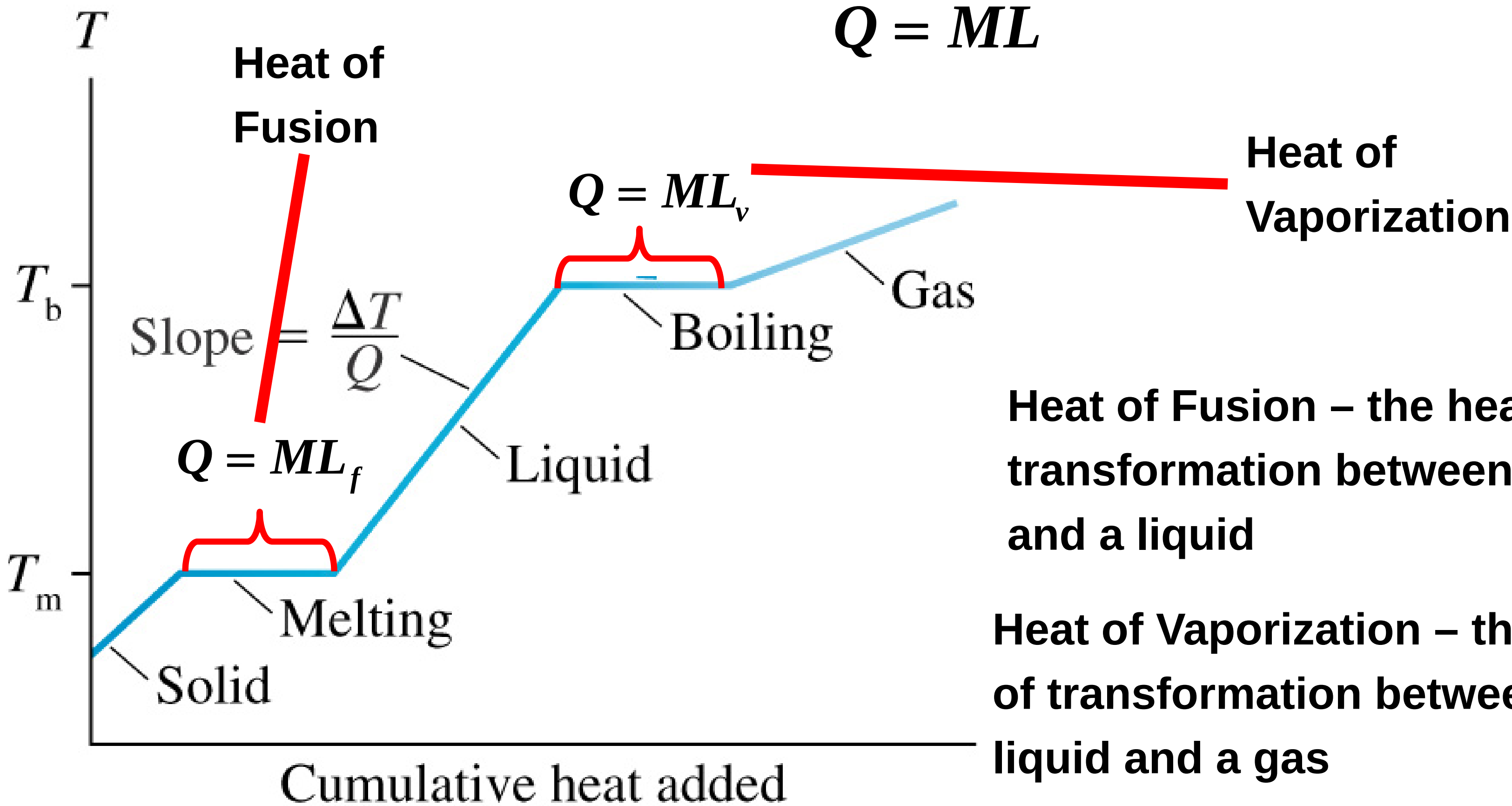


Phase Change: Solid, Liquid, and Gas

Phase change: change of thermal energy without a change in temperature

Heat of transformation (L) : the amount of heat energy that causes 1 kg of a substance to undergo a phase change.

$$Q = ML$$



Heat of Fusion – the heat of transformation between a solid and a liquid

Heat of Vaporization – the heat of transformation between a liquid and a gas

Ideal Gas

Ideal Gas:

Ideal gas:

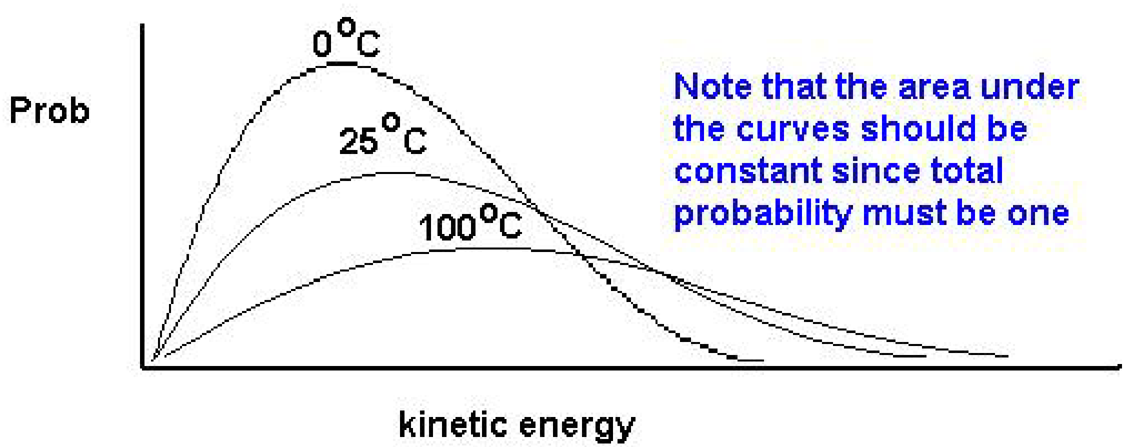
-no interactions between the atoms, (without interactions no phase transition to liquid phase)

-atom as a hard-sphere

-temperature will determine the average speed of atoms.

$$\frac{1}{2}m_{atom}v^2 = \frac{3}{2}k_B T$$

$$k_B = 1.38\times10^{-23}\,\frac{J}{K}$$ **Boltzmann's constant**



Ideal-Gas Law

$$pV = nRT$$

p – gas pressure

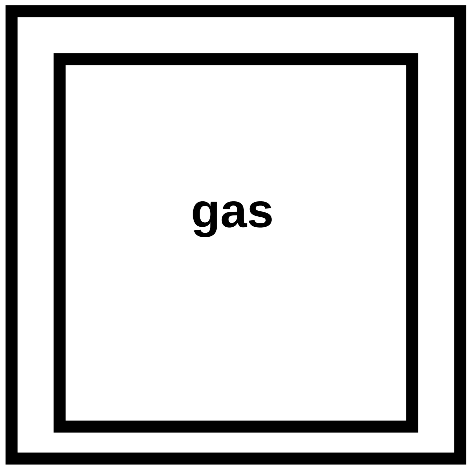
V – gas volume (container volume)

T – gas temperature (in Kelvin!!)

n – the number of moles – this can be found as $n = \frac{M}{M_{mol}}$ where M is the mass of the gas and M_{mol} is the mole mass

R=8.31 J/mol K - universal gas constant

$$R = k_B N_A$$



Ideal-Gas Processes

$$pV = nRT$$

The state of the gas is determined by two parameters:

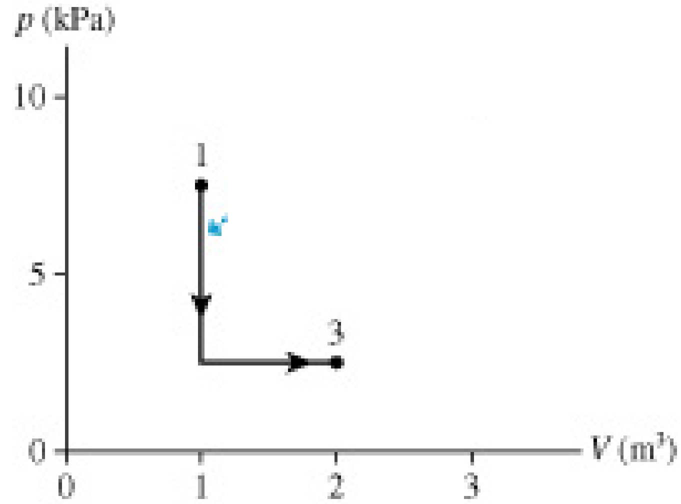
P and V or

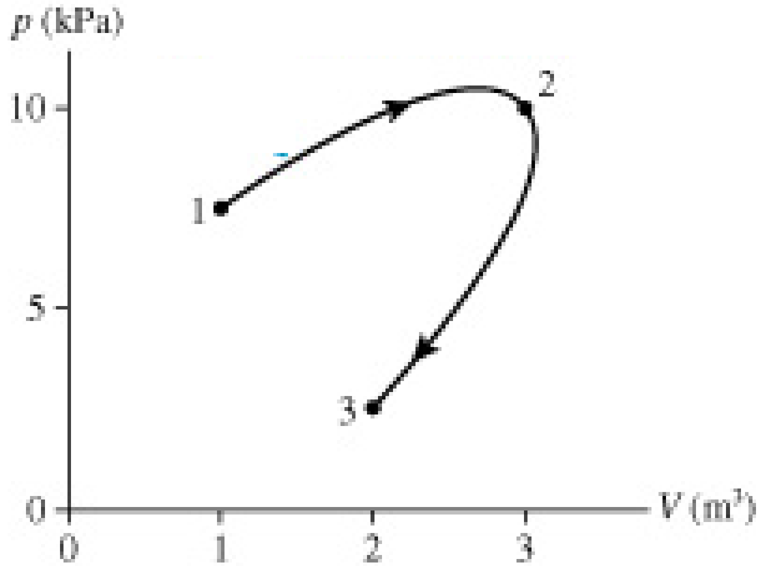
P and T or

V and T

If we know P and V then we can find T :

pV diagram



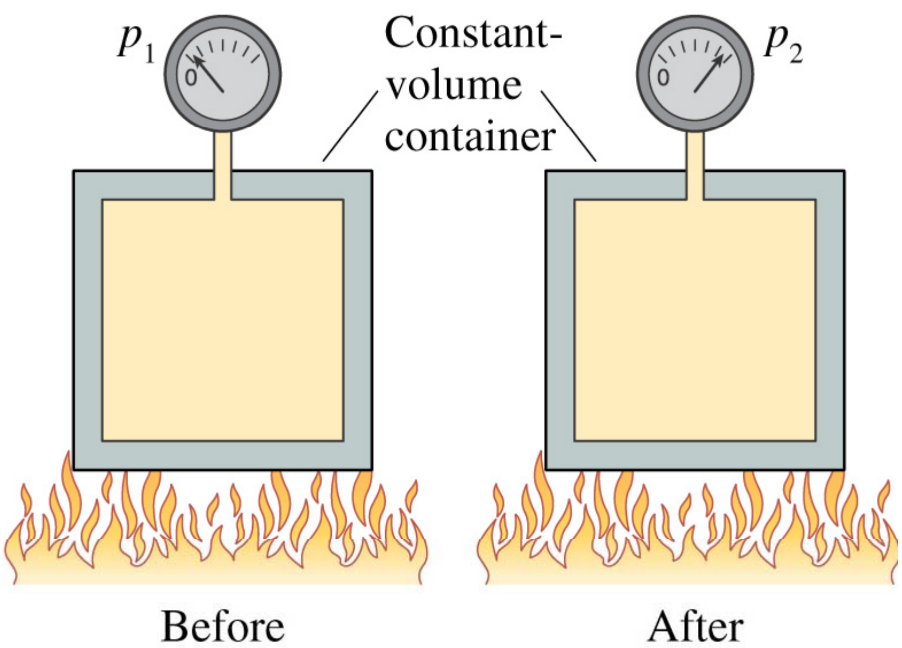


Ideal-Gas Processes: Constant Volume Process

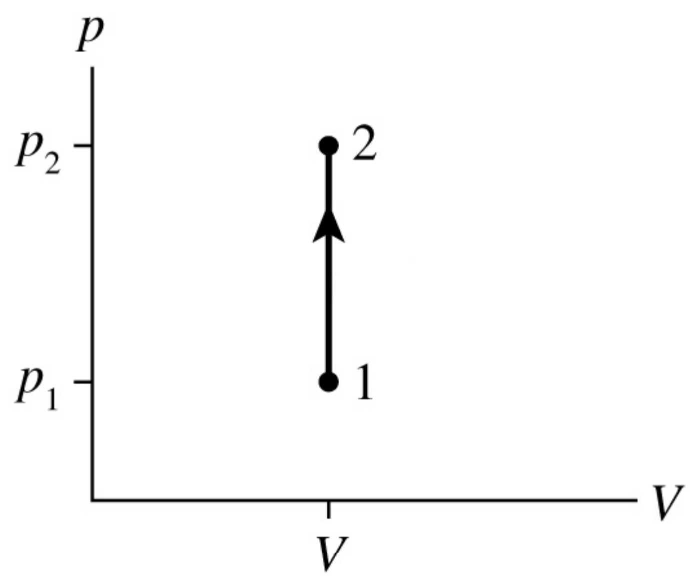
$$pV = nRT$$

V = constant

$$p = \frac{nR}{V}T$$



Isochoric process

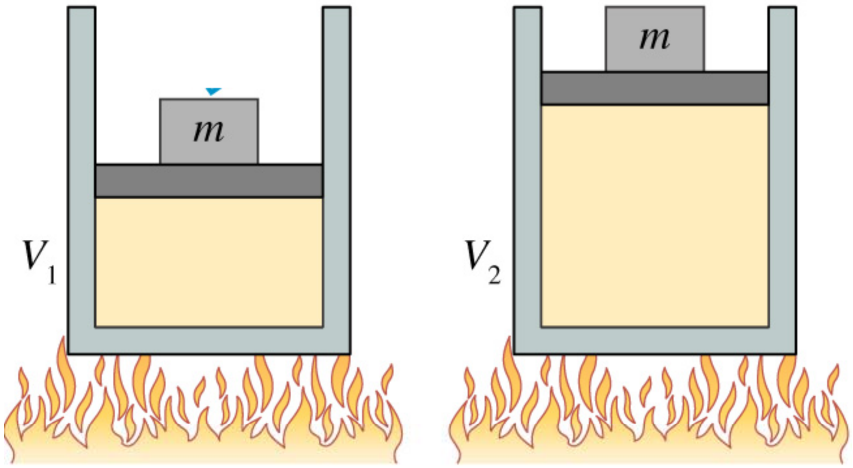


Ideal-Gas Processes: Constant Pressure Process

$$pV = nRT$$

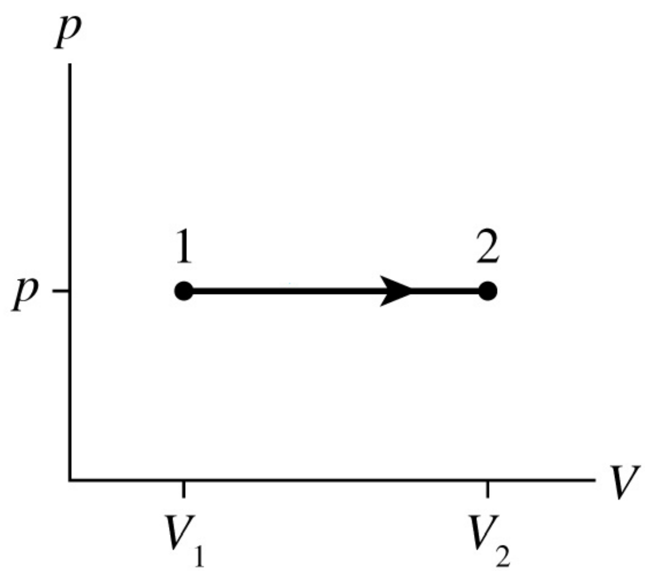
p = constant

$$V = \frac{nR}{p}T$$



Before After

Isobaric process

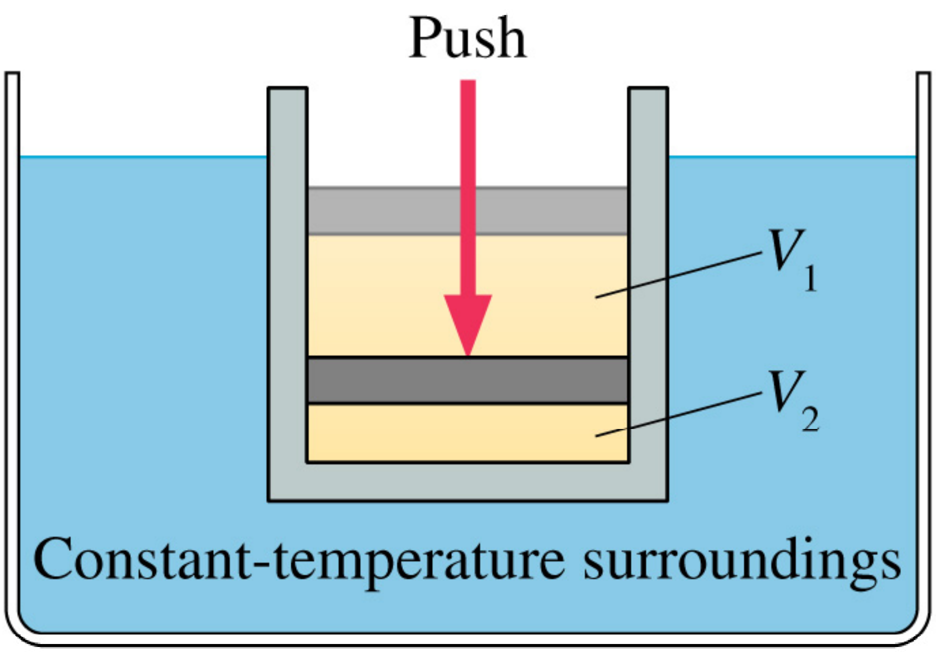


Ideal-Gas Processes: Constant Temperature Process

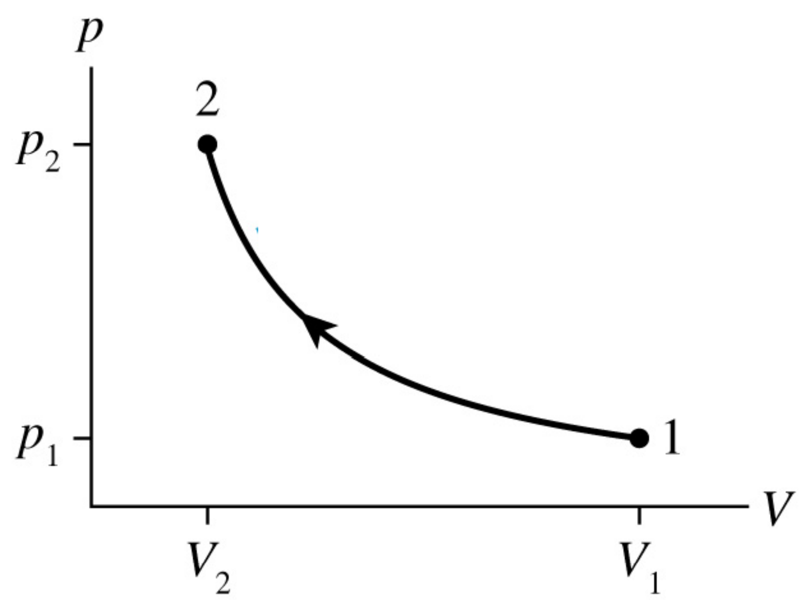
T = constant

$$pV = nRT$$

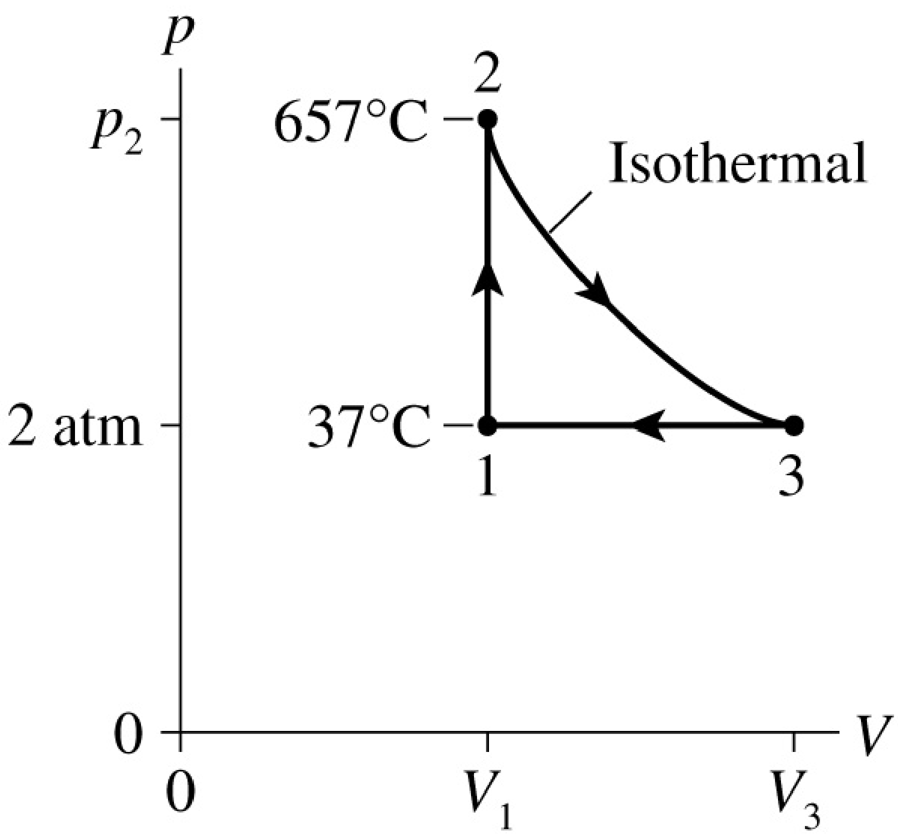
$$p = nRT\,\frac{1}{V}$$



Isothermal process



Example: Find p_2, V_1 and V_3 if n = 3 mol



$$p_1V_1 = nRT_1$$

$$p_1 = 2atm = 200000Pa$$

$$T_1 = 273 + 37 = 310K$$

$$V_1 = \frac{nRT_1}{p_1} = \frac{3 \cdot 8.3 \cdot 310}{200000} = 0.04m^3$$

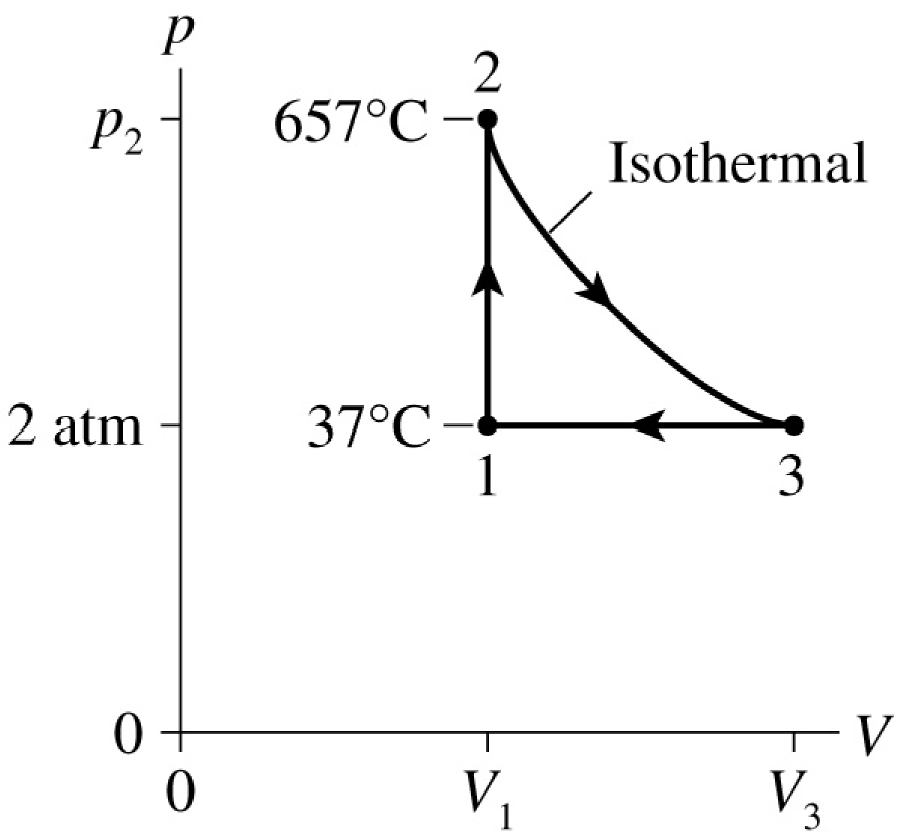
$$p_2V_2 = nRT_2$$

$$T_1 = 273 + 657 = 930K$$

$$V_2 = V_1 = 0.04m^3$$

$$p_2 = \frac{nRT_2}{V_2} = \frac{3 \cdot 8.3 \cdot 930}{0.04} = 5.8 \cdot 10^5 Pa = 5.8atm$$

Example: Find p_2 , V_1 and V_3 if n = 3 mol



$$p_3V_3 = nRT_3$$

$$p_3 = p_1 = 2atm = 200000Pa$$

$$T_3 = T_2 = 930K$$

$$V_3 = \frac{nRT_3}{p_3} = \frac{3 \cdot 8.3 \cdot 930}{200000} = 0.12m^3$$