Equation of State of an Ideal Gas

$$pV = nRT$$

$R = 8.314\ J\ mol^{-1}\ K^{-1}$

n = # moles

T = Temp in K

V = Volume in m^3

P = Pressure in N/m^2 = Pa

1 atm = 1.013×10^5 Pa

1 bar = 10^5 Pa

Weather: Millibars = $\frac{1}{1000}$ bar

1 atm = 1,013 millibars

1 atm = 760 mm Mercury in a manometer

760 mm Hg

1 TORR = 1 mm Hg

Vacuum or Low pressure.

Universal Gas Constant.

$R = .08207 \frac{\text{liters} \cdot \text{atm}}{\text{mol}\ K}$

Ideal Gas is a gas is one where $pV = nRT$

Volume of 1 mole of gas:

$V = \frac{nRT}{P}$ at $T = 0°C = 273\ K$

and $P = 1\ atm = 1.01 \times 10^5$ Pa

$$V = \frac{(1\ mol)(8.314\ J\ mol^{-1}\ K^{-1})(273\ K)}{1.01 \times 10^5\ Pa}$$

$= 0.0224\ m^3 = 22{,}400\ cm^3 = 22.4\ l$

$\frac{PV}{T} = nR$ for fixed mass = fixed moles

$\frac{PV}{T} = \text{Const.} \Rightarrow \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

If Temp is Constant:

$P_1 V_1 = P_2 V_2$ = Boyle's Law for Ideal Gas

Helium storage Tank

Capacity $.05\,m^3$ Press = 100 atm

T = 27°C How many moles?

$PV = nRT \Rightarrow$

$n = PV/RT$

P = 100 atm = $100\,atm\left(\frac{1.013 \times 10^5\,Pa}{1\,atm}\right)$

$= 1.013 \times 10^7\,Pa$

$V = 0.05\,m^3$

$T = 27°C = (27 + 273)\,K = 300\,K$

$n = \frac{PV}{RT} = \frac{(1.013 \times 10^7\,Pa)(0.005\,m^3)}{(8.314\,J\,mol^{-1}K^{-1})(300\,K)}$

= 203 moles of He

Mass of He? $m = nM$

Helium M = 4 g/mol

$m = (203)(4\,g/mol) = 812\,g$

= 0.812 kg

Heat

2 Bodies (A and B) in contact approach thermal equil.

Temp (A) > Temp (B)

Temp(A) drops, Temp(B) rises } Heat transfer

= energy transfer.

If by temp. diff. only

= Heat Flow

Equivalent of Work

Units of heat transfer

1 Calorie = heat req'd to change temp of 1 g of water from 14.5°C to 15.5°C.

(Advertiser's Calorie = Kcal = 1000 cal)

British Thermal Unit = BTU = energy to raise 1 pound of water from 63°F to 64°F

1 BTU = 252 cal = .252 Kcal

1 Cal = 4.186 Joules.

Heat Capacity

Relation b/w heat flow and temp change

small Qty of Heat = ΔQ

Small temp change = ΔT

Specific heat capacity of a mass m

or $c = \frac{\Delta Q}{m \Delta T}$

Specific Heat Capacity of water $C = 1 \, cal \, g^{-1} (^\circ C)^{-1}$
$= 4.19 \, J \, g^{-1} (^\circ C)^{-1}$

Use mole to decsribe amount of stuff.
$n = m / M$ ← molecular mass

Molar Heat Capacity
$M_c = \frac{\Delta Q}{n \Delta T} = C$ = Molar Heat Capacity

Molar Heat Capacity of water is $75.3 \, J \, mol^{-1} (^\circ C)^{-1}$
$= 18 \, cal \, (mol)^{-1} (^\circ C)^{-1}$

Total Qty of heat Q to change temp $T_1 \to T_2$
$Q = mC (T_2 - T_1)$

Molar heat capacity heat transfer in metals depends on one electron per atom ⇒ #electrons = Heat Capacity

Most metals: $C = 25 \frac{J}{mol \, ^\circ C}$
Dulong + Petit.

In many cases Heat Capacity depends on how heat transfer is done, i.e. under constant Pressure (C_p) or Constant Volume (C_V)

Transfer heat → change in Phase ⇒ takes more energy than temp change

Heat req'd to change Liquid to gas = Heat of Vaporization = Heat of Condensation

Liquid to Solid: Heat of fusion, Heat of melting

2 phases in equilibrium

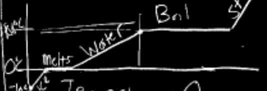
If q'ty's don't change and no heat in or out temp remains constant

Heat per unit mass required to change Phase = Latent Heat = L

$$Q = mL$$

Ice to steam, apply heat at constant rate

g ice at $-10°C$ to steam at $100°C$:



Temp change $Q = mc\Delta T$

Phase change $Q = mL$

$C_{ice} = 2.30\ J\ g^{-1}(°C)^{-1}$

$L_{ice \to water} = 335\ J\ g^{-1}$

$C_{water} = 4.19\ J\ g^{-1}(°C)^{-1}$

$L_{water-steam} = 2256 J g^{-1}$

$Q = (1g)(2.30 J g^{-1} (°C)^{-1})(0°C - (-10°C))$

- heat ice to 0°C

$+ (1g)(335 J/g)$ - melt ice

$+ (1g)(4.19 J g^{-1} (°C)^{-1})(100°C - 0°C)$

Heat water to 100°C

$+ (1g)(2256 J g^{-1})$ - Boil water to steam

$= 23 J + 335 J + 419 J + 2256 J = 3033 J$

Latent Heat of Vaporization

Perspiration: mass of water req'd to cool 80kg human 1°C

$C_{body} = C_{water} = 1 cal g^{-1} (°C)^{-1}$

$L_{vapor} (at 37°C) = 577 cal g^{-1}$

$Q = mc\Delta T = (80 \times 10^3 g)(1 cal g^{-1} (°C)^{-1})(-1°C)$

$= -80 \times 10^3 cal$ = heat needed to remove

with $Q = mL$, $L = 577 cal/g$ at $T = 37°C$

$m(577 cal g^{-1}) = -80 \times 10^3 cal$

$m = 139 g$