

قسم الفيزياء
اسم المادة:- الترموداينمك
المرحلة/ الثانية(صباحي ومسائي)
الكورس / الاول

اسماء اساتذة المادة/ د.مهدي حسن ، د.بشرى عباس، د.محمد رضا

What is thermodynamics?

Thermodynamics is the study of interaction between matter and energy. Today thermodynamics is a very broad field with applications in every area of science from biology to physics. Thermodynamics did not emerge as a science until the late 1600.

The name comes from the Greek words Therme (heat) & dynamis(dynamite/power), and was first used by Lord Kelvin . From a practical engineering point of view, thermodynamics is the study of the transformation process of converting work into heat and heat back into work, and the efficiency with which these two processes can occur.



There are two basic areas of thermodynamics: microscopic and macroscopic.

• **Microscopic study:** This area focuses on microscopic issues. Its main focus is the structure of matter and the interaction of molecules in collisions. It is known as statistical physics, or statistical thermodynamics. Topics studied in this discipline include: lasers, plasmas, high-speed gases, rarified gases (such as in the outer atmosphere), turbulence in fluids.

• **Macroscopic study:** This area focuses on macroscopic (bulk) energy flow. It is typically referred to as Classical Thermodynamics, or Engineering Thermodynamics.

This field focuses on

- the transfer of energy
- the transformation of energy
- the storage of energy

Energy comes in many forms. Here are a few common forms of energy:

- kinetic energy [energy due to motion]
- potential energy [energy due to position, or the configuration of a system]
- internal energy [energy stored in the molecules {both potential and kinetic {associated with temperature}]
- chemical energy [energy due to chemical composition (i.e., energy due to the arrangement of molecules with respect to other molecules in the system)]
- nuclear energy [subatomic energy (i.e, energy stored in the nucleus of an atom)]

In order for energy to change from one form to another it must go through some sort of transition. The transition process is a mechanism for converting one form of energy to another. Here are two conversion mechanisms:

- work [mechanical energy in transit]
- heat [molecular energy in transit]

Definition:

*For a given quantity of matter, a phase is a state where all of the matter has the same chemical composition throughout. Matter that is in the same phase is homogeneous.

* A thermodynamic system is defined as a quantity of matter or a region in space chosen for study. For brevity, we will use the verbiage system in place of thermodynamic system from here forward.

* Everything external to the system is defined to be the system's surroundings.

* The area separating the system from its surrounding is the boundary of the system. The boundary may be at rest or in motion. The boundary is the collection of points that is in contact with both the system and its surroundings. It is a surface, and since a surface is a two-dimensional object, it has zero volume.

*A closed system is a definite quantity of matter contained within some closed surface. A closed system is sometimes referred to as a control mass because the matter composing the system is assumed known for all time. Thus, a closed system consists of a fixed amount of mass. That is, no mass can ever enter or leave the system. This means no mass can ever cross the boundary of a closed system.

A closed system is appropriate for systems in some sort of enclosure, such as a gas being pressed by a piston in a closed cylinder. If we choose the gas as our system, then the gas cannot escape, although energy could escape through the piston walls. Although mass cannot leave a closed system, energy can escape in the form of heat or work. A special type of a closed system that does not allow the escape of energy is known as an isolated system. An isolated system is necessarily a closed system (since mass is energy, and if energy cannot cross the boundary, then neither can mass), but a closed system need not be isolated since energy can be transferred across a boundary in the form of heat without any mass transfer.

*A system is said to be isolated if no energy is transferred across the boundaries.

* An open system is a definite fixed location in space. The system is called open because mass may flow in or out of the system. An open system is sometimes referred to as a control volume because the location composing the system is assumed known for all time. The surface surrounding the control volume is sometimes known as a control surface. The control surface can be along a real surface of the system or it can be an imaginary surface chosen for convenience. Choosing a system boundary in practice is somewhat of an art. In general, choosing a system's boundary depends on two factors: the objective of the analysis, and what is known about the system at various locations, such as at an intake valve where we would have explicit information about heat flow at the boundaries.

Extensive and intensive properties- الخواص الشاملة والمركزة

Thermodynamic properties can be placed into two general classes: extensive and intensive.

* A property of a system is called extensive if its value for the overall system

is the sum of the values of the parts to which the system has been divided into. Some examples of extensive properties are: mass, volume, and energy. Extensive properties, as the name suggests, depend on the extent (size) of the system.

* A property of a system is called intensive if its value is independent of the extent (size) of the system, and may vary from place to place and from moment to moment. Some examples of intensive properties are: density, specific volume, pressure, and temperature. An easy test for whether a property is extensive or intensive is to imagine a fixed amount of matter and ask if you cut the matter into two pieces would the property in question remain unchanged.

*The density ρ of a homogeneous substance is defined as its mass m divided by its volume

*The specific volume v of a homogeneous substance is defined as its volume V divided by its mass m .

Conversion formulas

Between relative temperature scales:

- $T_F = 9/5T_C + 32$ (Convert from degrees Fahrenheit to degrees Celsius)
- $T_C = 5/9(T_F - 32)$ (Convert from degrees Fahrenheit to degrees Celsius)

Between absolute temperature scales:

- $T_K = T_C + 273.15$ (Convert from degrees Celsius to Kelvin)
- $T_R = T_F + 459.67$ (Convert from degrees Fahrenheit to degrees Rankine)

State Variables

When a gas is in a given state, it has definite values of: Pressure, Volume, Temperature and Number of molecules... These are called state variables.

The Ideal Gas Law is an example of an equation of state that relates the state variables to one another $PV = NkT$

Work and heat are not state variables. It is not correct to say that a system in a given state has a definite amount of work or a definite amount of heat.

Introduction to the 4 laws of thermodynamics

1-The zeroth law is defined in terms of the transitive property. Recall from algebra class: The Transitive property: If $a = b$ and $b = c$, then $a = c$.

The zeroth law of thermodynamics: If two systems A and C are each in thermodynamic equilibrium with a third system B, then A and C are in thermodynamic equilibrium with each other.

2-First Law of Thermodynamics

The heat, Q , transferred to a system increases the thermal (internal) energy, U , of the system and/or is used by the system to do work, W .

$dQ = dW + dU$; This is really just conservation of energy.

we consider Q and W to be *positive* if energy flows *into* the system.

3-The second law has been stated in several ways.

(i) *The principle of Thomson (Lord Kelvin) states:*

'It is impossible by a cyclic process to take heat from a reservoir and to convert it into work without simultaneously transferring heat from a hot to a cold reservoir.'

This statement of the second law is related to equilibrium, i.e. work can be obtained from a system only when the system is not already at equilibrium. If a system is at equilibrium, no spontaneous process occurs and no work is produced. Evidently, Kelvin's principle indicates that the spontaneous process is the heat flow from a higher to a lower temperature, and that only from such a spontaneous process can work be obtained.

(ii) *The principle of Clausius states:*

'It is impossible to devise an engine which, working in a cycle, shall produce no effect other than the transfer of heat from a colder to a hotter body.'

A good example of this principle is the operation of a refrigerator.

(iii) *The principle of Planck states:*

'It is impossible to construct an engine which, working in a complete cycle, will produce no effect other than raising of a weight and the cooling of a heat reservoir.'

(iv) *The Kelvin-Planck principle*

may be obtained by combining the principles of Kelvin and of Planck into one equivalent statement as the Kelvin-Planck statement of the second law.

It states: *'No process is possible whose sole result is the absorption of heat from a reservoir and the conversion of this heat into work.'*

Thermodynamics

Thermodynamics:

→ Describes macroscopic properties of equilibrium systems

→ Entirely Empirical

→ Built on 4 Laws and "simple" mathematics

0th Law ⇒ Defines Temperature (T)

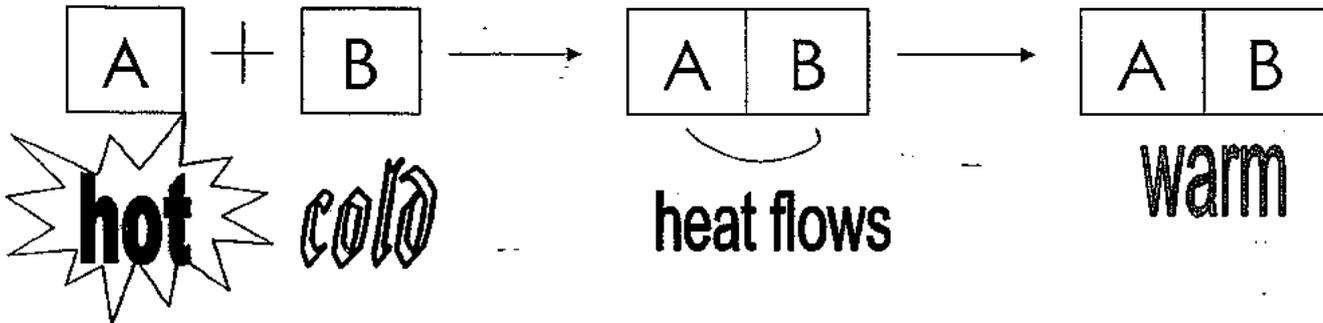
1st Law ⇒ Defines Energy (U)

2nd Law ⇒ Defines Entropy (S)

3rd Law ⇒ Gives Numerical Value to Entropy

These laws are UNIVERSALLY VALID, they cannot be circumvented.

Thermal Equilibrium (heat stops flowing)



When a hot object is placed in thermal contact with a cold object, heat flows from the warmer to the cooler object. This continues until they are in thermal equilibrium (the heat flow stops). At this point, both bodies are said to have the same "temperature".

This intuitively straightforward idea is formalized in the 0th Law of thermodynamics and is made practical through the development of thermometers and temperature scales.

==== ZERO'th LAW of Thermodynamics =====

If \boxed{A} and \boxed{B} are in thermal equilibrium and
 \boxed{B} and \boxed{C} are in thermal equilibrium,
 then \boxed{A} and \boxed{C} are in thermal equilibrium.

Consequence of the zero'th law:

\boxed{B} acts like a thermometer, and \boxed{A} , \boxed{B} , and \boxed{C} are all
 at the same "temperature".

Definitions:

- *System*: The part of the Universe that we choose to study
- *Surroundings*: The rest of the Universe
- *Boundary*: The surface dividing the System from the Surroundings



Systems can be:

- *Open*: Mass and Energy can transfer between the System and the Surroundings
- *Closed*: Energy can transfer between the System and the Surroundings, but NOT mass
- *Isolated*: Neither Mass nor Energy can transfer between the System and the Surroundings

Describing systems requires:

- A few macroscopic properties: p , T , V , n , m , ...
- Knowledge if System is Homogeneous or Heterogeneous
- Knowledge if System is in Equilibrium State
- Knowledge of the number of components

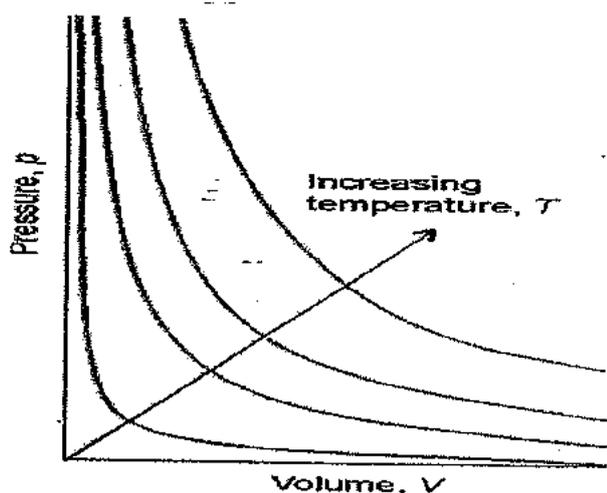
Boyle's Law

In 1661, he showed that to a very good approximation that for a constant amount of gas at a fixed temperature:

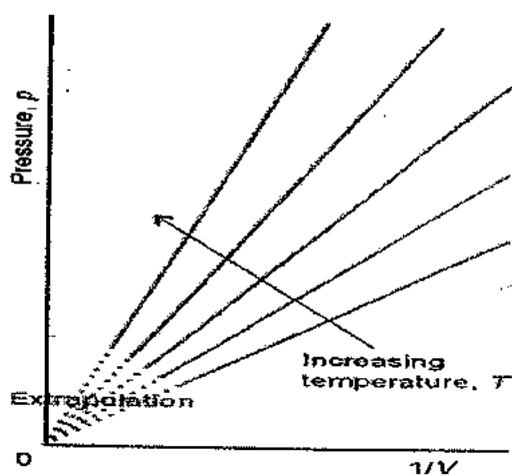
→ The pressure of a sample is inversely proportional to its volume, and the volume of a sample is inversely proportional to pressure.

$$PV = \text{constant} \quad , P \propto 1/V \quad , V \propto 1/P$$

For plots of p vs. V , the isotherms are **hyperbolas** (i.e., plot of y as function of x when $xy = \text{constant}$)



For plots of p vs. $1/V$, the isotherms are **linear**



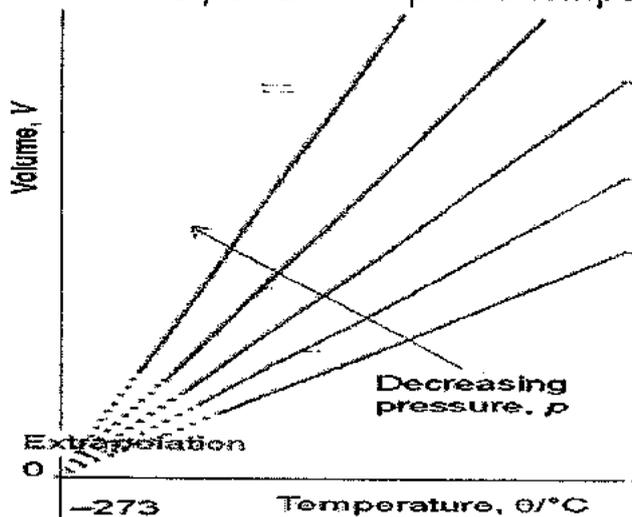
Charles Law

which states that the volume of a fixed quantity of gas at constant pressure is proportional to its temperature. Hence all gases, at the same pressure, expand equally for the same rise in temperature.

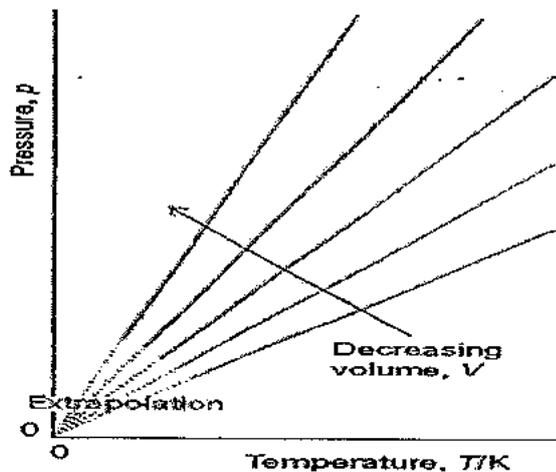
on the **thermodynamic temperature scale** devised by Kelvin

$$V = \text{constant} \times T, \quad p = \text{constant} \times T$$

Lines of constant pressure are known as **isobars**; notice how an infinitely small V implies a temperature near -273°C .



Lines of constant volume are known as **isochors**; Pressure falls to zero as T approaches absolute zero (i.e., no molecular motion).



Rationalizing Charles' Law: As the temperature is increased, the average speed of the molecules increases, thereby increasing the number and force of the collisions that the molecules have with the container's walls (again, this only really applies at **low pressures**)

In order to build up to the ideal gas law, we need to consider the relationship between volume and the number of molecules. The **molar volume** is the volume per mole of molecules:

$$V_m = V/n$$

For any gas, the molar volume is the same, regardless of the type of gas. So, **Avogadro's principle** says that the volume of any gas is directly proportional to the number of molecules *at constant temperature and pressure*:

$$V = \text{constant} \times n$$

Combining the Gas Laws

Boyle's Law: $pV = \text{constant}$, when n and T are constant

Charles' Law: $p \propto T$, $V \propto T$, if n & either V or p are held constant

Avogadro's Principle: $V \propto n$, at constant T and p

Single expression: $pV = \text{constant} \times nT = nRT$. This is the **perfect gas equation**, which becomes very accurate as the pressure decreases. A **real gas** behaves like a **perfect gas** in the low pressure limit: at this point, the gas constant, R , can be determined very accurately.

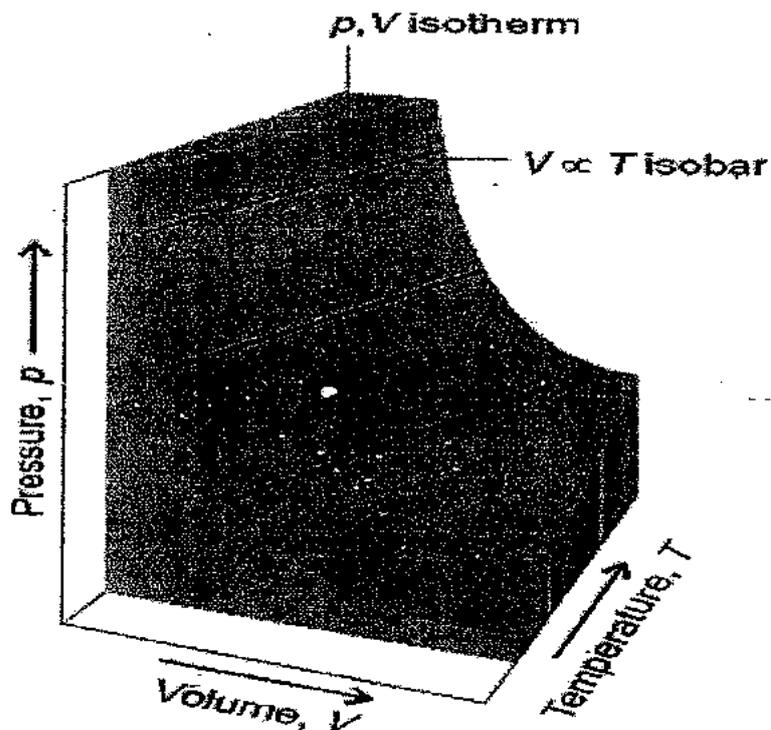
standard temperature and pressure (STP)

$T = 0^\circ\text{C}$, $p = 1 \text{ atm}$, molar volume of gas $V_m = 22.414 \text{ L mol}^{-1}$.

R is related to the Boltzmann constant, k : $R = k \times N_A = 8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$; Where, $k = 1.3806 \times 10^{-23} \text{ J K}^{-1}$, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$.

Surface of States

The perfect gas equation: $pV = nRT$ can be represented as a **three dimensional surface of possible states**, meaning that the gas cannot exist in states not on the surface.



Mixtures of Gases

When we have a mixture of two or more gases, what contribution do each of the member gases make to the overall pressure of the system?

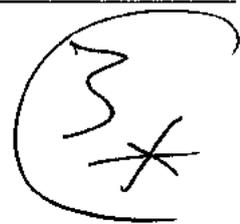
Dalton's Law: The total pressure exerted by a homogeneous mixture of gases is equal to the sum of the partial pressures of the individual gases.

The **partial pressure** of a gas is the pressure it would exert if all the other gases in the mixture were absent.

If the partial pressure of gas A is p_A , and the partial pressure of gas B is p_B , etc. then the total pressures for gases in the same vessel is: $p_{TOT} = p_A + p_B + \dots$ So, for each gas p_i : $p_i = n_i RT/V$.

where p is total pressure. It follows that for both real and perfect gases: $p_A + p_B + \dots = (x_A + x_B + \dots)p = p$. where x is the mole fraction, is the amount of each component of a gaseous mixture expressed as a fraction of the total number of molecules:

changing the state of a system with heat and work



① with heat

الطاقة الحرارية، الطاقة، انتقال الحرارة، النظام، الوسط

between a system and its surroundings

انتقال الحرارة، الوسط، النظام، انتقال الحرارة، النظام، الوسط

② with work

أيضا، انتقال الطاقة للنظام، العمل

من خلال نقل دفع أو سحب مثل كبح السيارة، عمل نقل

نقل من النظام أو كبح السيارة، عمل نقل

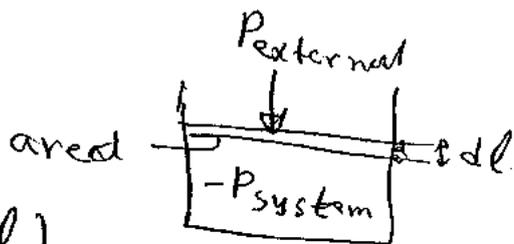
نقل كبح السيارة، عمل نقل، النظام، الوسط

+ve work → system does work on the surroundings (energy leaves the system)

-ve work : done on the system (energy added to the system)

$$dw = \text{Force} \cdot \text{distance}$$

$$= \frac{\text{Force}}{\text{area}} \cdot (\text{area} \cdot dl)$$



$$= \text{pressure} \cdot d \text{ volume} = P_{\text{ext}} \cdot dV$$

$$W = \int_{V_1}^{V_2} P \, dV$$

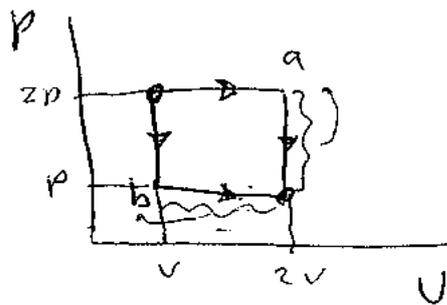


إذا هبب النظام لفتح ~~ص~~ القوة
 : النقل انجز بواسطة النظام

إذا هبب النظام نقلت ~~ص~~ القوة
 : النقل انجز بواسطة النظام

$P_{ext} = 0 \Rightarrow$ no work is done by the system

Work is a path dependent process



$$W_{\text{path a}} = 2P(2V - V) = 2PV$$

$$W_{\text{path b}} = P(2V - V) = PV$$

$$PV = nRT \Rightarrow P = \frac{nRT}{V}$$

$$\therefore W = \int P dV = \int_{V_1}^{V_2} \frac{nRT}{V} dV \quad \boxed{W = nRT \ln \frac{V_2}{V_1}}$$

at $T = \text{const}$ $P_1 V_1 = P_2 V_2 \Rightarrow \frac{P_1}{P_2} = \frac{V_2}{V_1}$

$$\therefore \boxed{W = nRT \ln \frac{P_1}{P_2}}$$

Ex Gas contained in volume 10 m^3 at $P (1.013 \times 10^5 \text{ N}\cdot\text{m}^{-2})$ and
 temp - 30 K . Find the no. of molecules. where Avogadro's
 no. is $6.022 \times 10^{23} \frac{\text{molecules}}{\text{mole}}$, $R = 8.314 \text{ J/mole}\cdot\text{K}$

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{1.013 \times 10^5 \text{ N}\cdot\text{m}^{-2} \times 10 \text{ m}^3}{8.314 \text{ J/mole}\cdot\text{K} \times 30 \text{ K}}$$

$$n = 4.05 \times 10^{-4} \text{ moles}$$

$$N = n * NA \quad \longrightarrow \text{No. of molecules}$$

$$= 4.05 \times 10^{-4} \times 6.022 \times 10^{23}$$

$$= 24.4 \times 10^{27} \text{ molecules}$$

Number of molecules = Avogadro's no. \times no. of moles

1 H.W Ball of radius ($r = 5 \text{ cm}$) contained 4 moles of gas
 expanded by heat (50° F). Find the pressure done
 by the gas.

$$PV = nRT, \quad C = \frac{5}{9}(F - 32) = 10^\circ, \quad K = 273 + 10 = 283 \text{ K}$$

$$V = \frac{4}{3} \pi r^3, \quad V = \frac{4}{3} \pi (5)^3 = 523.3 \text{ cm}^3$$

$$PV = nRT, \quad \frac{4 \times 8.314 \times 283}{523.3} \approx 18 \text{ atm.}$$

2 H.W

Final conditions are

(A)

$$P_f = ? \quad T_f = 298 \text{ K} \quad V_f = 80 \text{ liter}$$

$$P_f = \left(\frac{T_f}{V_f} \right) \left(\frac{P_i V_i}{T_i} \right) = \left(\frac{298}{80} \right) \left(\frac{15 \times 100}{293} \right)$$

$$= 19 \text{ atm}$$

$$T_f = 25 + 273 = 298 \text{ K}$$

$$T_i = 20 + 273 = 293 \text{ K}$$

$$F = \frac{9}{5} C + 32$$

F = Fahrenheit

(I)

$$C = \frac{5}{9} (F - 32)$$

$$K = C + 273$$

$$C = K - 273$$

Ex An object has a temperature of (50 F), what is the temp. in degree Celsius and in Kelvin.

$$C = \frac{5}{9} (F - 32)$$

$$C = \frac{5}{9} (50 - 32)$$

$$C = 10^\circ$$

$$K = 273^\circ, \text{ so in } K = 273 + 10 = 283 \text{ K}$$

Ex An ideal gas in constant pressure with (3 m³) volume and initial temperature 50°C, the gas expanded to (60 m³). What is the final temperature will be.

$$P = \text{constant}, V_1 = 3 \text{ m}^3, V_2 = 60 \text{ m}^3, T_1 = 50^\circ$$

$$\frac{P V_1}{T_1} = \frac{P V_2}{T_2}$$

$$\left(\frac{3}{50 + 273} \right) = \frac{60}{T_2}$$

$$T_2 = 6480 \text{ K}$$

Ex Gas under heat at 35°C and volume 5 l. What is the pressure of the gas if 2 moles of the gas.

$$P V = n R T, T = 35 + 273 = 308 \text{ K}$$

$$R = 0.08205 \frac{\text{atm}}{\text{mole}}$$

$$P = \frac{2 \times 0.08205 \times 308}{5}$$

2. Temperature scale

The thermometer is an instrument to measure temperature. according with changing one of physical properties of matter

Thermometer	Matter	Property
Liquid thermometer	Mercury and alcohol	Change in Length
Gas "	Hydrogen	" " pressure
Resistance "	Platinum	" " resistance
Radiation "	Pyrometer	" " radiation colour

You can design many types of thermometers according with changing of physical properties

Celsius scale

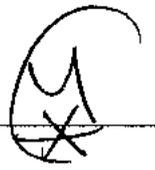
This thermometer depend on freezing and boiling points of water (ice point and steam point)

Fahrenheit scale

The corresponding values on the Fahrenheit scale are 32 and 212°F.

$$\frac{C - 0}{100 - 0} = \frac{F - 32}{212 - 32}$$

Kelvin scale (Absolute scale)



independent of the properties of substance.

$$K = 273.15 + C$$

The triple point of water

The state at which all three phases of water co exist in equilibrium, which is assigned the value 273.16 K.

The Temperature that we want to measure

$$T_x = 273.15 \frac{x}{x_3}$$

~~temperature~~
thermometer property

(Length, resistance etc)

If the length of mercury in thermometer is 6 cm at the triple point of water. calculate the length when it's record 150 K

$$T_x = 273.15 \frac{x}{x_3} \Rightarrow 150 = 273.15 \frac{x}{6}$$

$$x = \frac{150 \times 6}{273.15} = 3.3 \text{ cm}$$

(B)

الرمز	الرمز (X)	Th. meter
P	P	V center
R	R	R
Σ	e.m.f	Th. couple
P	P	Helium (نيت)
R (B)	Radiation	Color of lamp filament
		السطح المضيء

المختار (المختار) الخواص (X) - (X) - (X) - (X)

~~$\Theta(x)$~~

$\Theta(x) = ax$

$\Theta(x_1) = ax_1$ _____

حرارة اول

$\Theta(x_2) = ax_2$ _____

حرارة ثانيا

$\frac{\Theta(x_1)}{\Theta(x_2)} = \frac{x_1}{x_2}$ ①

اختبرت هذه الطريقة جيداً عام ١٩٥٤ م

- 1- توضع الحمله ودهن دريه الخواص التي تترجم بها الحمله المنقاه
مترجمه توازن مع اى الخواص بالهدار نسبة انقاس يورد
- 2- توضع الحمله ودهن دريه الخواص التي تترجم بها اى المنقاه

نقطة التجمد 273.16 ، ودرجة الحرارة
 النقطة الثلاثية Triple point
 نقطة انصهار الجليد ودرجة انصهارها (T_p) ودرجة انصهارها

مثال
 بين درجة حرارة $0 - 600$ تغير مقاومة الجهد
 في سلك من مادة النحاس مع زيادة درجة الحرارة

$$\bar{R} = R_0 (1 + At + Bt^2)$$

إذا كانت $R = 10 \Omega$ في $t = 0$ بقدر الكيل

$R = 13.94 \Omega$ في $t = 100$ درجة مئوية

$R = 24.817 \Omega$ في $t = 444.6$ درجة مئوية

المعطيات: $R_0 = 10 \Omega$ ، $R_1 = 13.94 \Omega$ ، $R_2 = 24.817 \Omega$
 $t_1 = 100$ ، $t_2 = 444.6$
 المطلوب: إيجاد A و B

$R = R_0 = 10 \Omega$ عند $t = 0$

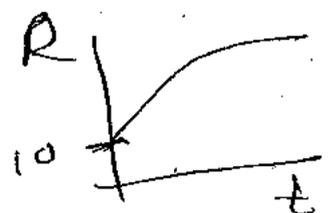
$R = 10 (1 + At + Bt^2)$

$13.94 = 10 (1 + A \times 100 + B (100)^2)$

$24.817 = 10 (1 + A \times 444.6 + B (444.6)^2)$

$$R = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$A = 4.076 \times 10^{-5}$
 $B = 1.366 \times 10^{-5}$



(B) انقل سوائل الحمار بالدرجة الاولى للحمار الغازي ذات

الحجم المناسبة وذلك

- ١- الغازات تتأخر عن السوائل بشدة مما يجعلها لا تكفي لدرجة لانها تنهدد اعمق مما تنهدد السوائل.
- ٢- الانارة المذرة عتوم الغاز لا يتطلب الا تسخينها قليلا
- ٣- التغير في كثرة الغاز يكون منتظما
- ٤- ضمن الحدود مع غازات يتعد نصفه
- ٥- تحتفظ على شكل الغازي ولحمها راسع زديت الكراهة

Ideal gas Temp

دستيم غاز الصليوم بكثرة وذلك بسبب

١- غاز الصليوم لا يتغير في ذلك الحارر الخاصة بياسه
دستيم الحرارة اللاتيم

٢- غاز الصليوم يتحول الى الحالة السائلة في درجات

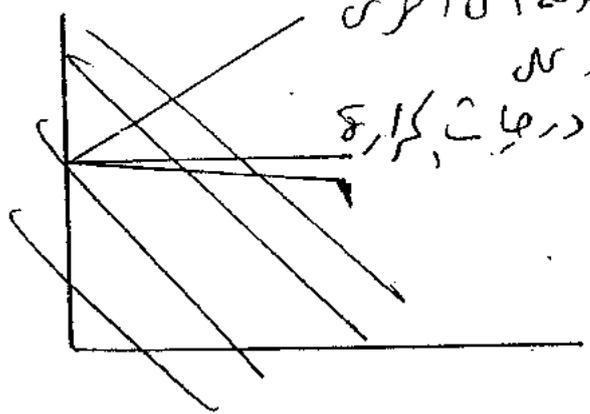
الحرارة الواطئة - مكارنتا بيحنة - الغازات

٣- دستيم قوي بياس درجات الحرارة الواطئة له

وتغير كانه غاز مثالي

(*) يختلف شكل الحمار من دولة الى اخرى
وقته في كل ارض ويعتمد على

(1) طبيعة الغاز (2) عدد درجات الحرارة
التي تستخدم لها



④ تغير المقاومة الكهربائية - يتكون من المقاومة (المادة المكونة) وتكون عبارة عن سلك معدني دقيق أو مقاومة كاربونيه

صلاً هذا المبدأ ،
 ويمكن إيجاد تغير المقاومة في درجات الحرارة
 $-25 \rightarrow 1200^\circ\text{C}$

$$R = R_0 (1 + At + Bt^2)$$

↓
 مقاومة سلك البلاستيك
 عند اهتزازها
 الشفط، التبريد

↓
 التوازي

④ المزدوج الكابلي :-

$$\Sigma = a + bt + ct^2 + dt^3$$

(S) (B)

Ex The mercury length is 6 cm in mercury thermometer at the triple point of water. Find the mercury length when the thermometer reach 150 K

$$\theta_x = 273.16 \frac{x}{x_3} \rightarrow 150 K = 273.16 \frac{x}{6}$$

$$x = 3.3 \text{ cm}$$

Ex A particular liquid inside a pressurized container under a pressure of 3.00 atm. The bulb of a constant-V gas thermometer is placed in the liquid where the gas pressure is measured to be 175 mmHg. The thermometer bulb is then placed in a water bath which is maintained at the triple point. The thermometer gas pressure in this bath is 225 mmHg. What is the indicated temperature of the high-pressure bath?

$$\theta_p = 273 \frac{P_p}{P_3}$$

$$\theta_p = 273 \frac{175}{225} = 212 \text{ K}$$

(B)

Ex A resistance thermometer is a thermometer in which the thermometric property is electrical resistance. A certain resistance thermometer is found to have a resistance R of 90.35 ohms when its bulb is placed in a water at the triple-point temp. What temp. is indicated by the thermometer if the bulb is placed in an environment such that its resistance is 96.28 ohms

$$\begin{aligned} \theta_R &= 273.16 \frac{R}{R_3} \\ &= 273.16 \frac{96.28 \text{ ohms}}{90.35 \text{ ohms}} = 291.1 \text{ K} \end{aligned}$$

Ex - H.W

The P_{tr} the pressure in the bulb of constant-volume gas thermometer when the bulb is at the t.p.w and the P the pressure when the bulb is at room temp. Given three constant-volume gas thermometers, for No. 1 the gas is O_2 and $P_{tr} = 20 \text{ cmHg}$, for No. 2 the gas also O_2 but $P_{tr} = 30 \text{ cmHg}$. the temp. values of P for the 3 thermometers are P_1, P_2, P_3 . find (a) An approximate value of the room temp (T) can be obtained with each of the thermometers using.

$$\theta_1 = 273.16 \frac{P_1}{P_3} = 273.16 \frac{P}{20 \text{ cmHg}} \quad \text{Mark (D or F)}$$

$$\theta_2 = 273.16 \frac{P_2}{30 \text{ cmHg}}$$

$$\theta_3 = 273.16 \frac{P_3}{30 \text{ cmHg}}$$

Ex The amplification or (gain) of transistor amplifier may depend on the temp. The gain for certain amplifier at room temp (20°C) is 30.0, whereas at 55°C it is 35.2. What would the gain be at 30°C if the gain depends linearly on temp. ~~etc~~

<u>T_c</u>	<u>Gain</u>
55	35.2
30	x

$$x = \frac{35.2 \times 30}{55} = 19.2$$

H.W

- 1) How would you suggest measuring the temp of
 - a) The sun
 - b) The earth's upper atmosphere
 - c) The moon
 - d) The ocean floor and
 - e) liquid helium.
- 2) Can you explain why the column of mercury first descends and then rises when a mercury in glass thermometer is put in a flame?

انتقال الحرارة

صالح ثروت طرف للانتقال الحرارة

١- التوصيل :- هي انتقال الطاقة من ذرة الى ذرة اخرى بالاصطدام
 فتركة الجسيمات تكون تيباً بعيدة المدى

٢- الحمل :- تنقل الطاقة ذلك من اجزاء الى اجزاء وسط الجزيئات ذات
 الطاقة تناسب كثافتها تيار وتعمل الطاقة الحركية به معها وتنقل
 الى مسافات بعيدة

٣- الاشعاع :- هي انتقال الحرارة عن طريق الفوتون [الانبعاث المستر للطاقة
 من كل سطح الاجسام والتمسك بالانواع الكهرومغناطيسية]

التوصيل

⊕ كمية الحرارة في التوصيل تتناسب مع مساحة المقطع في زمن معين

$$\Phi \propto A t$$

⊗ كمية الحرارة بالسيح الى مساحة المقطع في زمن معين تتناسب مع البعد في كمية الحرارة

$$\frac{\Phi}{A t} \propto \frac{\Delta \theta}{\Delta x}$$

$$\frac{\Phi}{A t} = k \frac{\Delta \theta}{\Delta x}$$

↓ معامل التوصيل

$$\left(\frac{d\theta}{dt} \right) = \Phi = -k A \left(\frac{d\theta}{dx} \right)$$

القدره الحرارية
 الاشارة الحركية
 الاشارة الحركية
 الاشارة الحركية

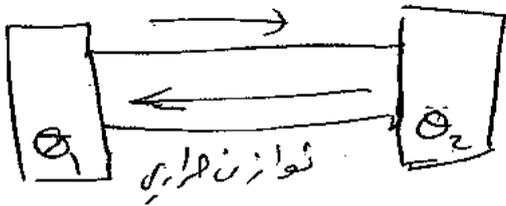
الاشارة الحركية

k - thermal conductive
 دائماً موجب

- ① Type of materials ② Temperature ③ internal structure of metals ④ impurity

در (K) ولتاژ و یاباد تهره (K) ولتاژ و یاباد تهره

Linear transformation - انتقال، کما، و، نقطه - انتقال، کما، و، نقطه

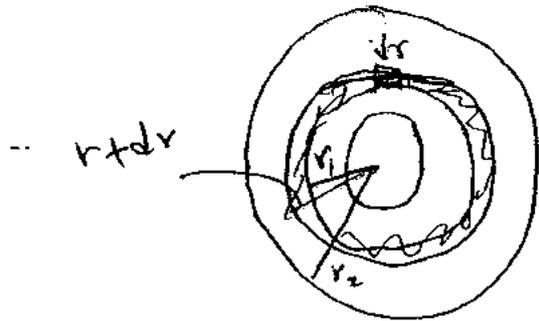


$$\dot{\Phi} = KA \frac{\theta_1 - \theta_2}{x}$$

③ کرینین همدمه بلر کر

رادیوسه و اوله رادیوسه رقیق قطر \$\theta_1\$

\$r_2\$ = رادیوسه و اوله رادیوسه رقیق قطر \$\theta_2\$



$$V = \frac{4}{3} \pi r^3 \rightarrow A = 4\pi r^2$$

$$\dot{\Phi} = -k 4\pi r^2 \frac{d\theta}{dr}$$

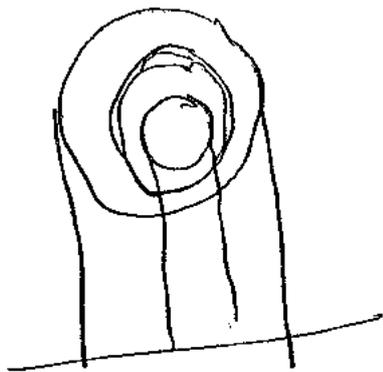
$$k = \frac{\Phi}{4\pi(\theta_1 - \theta_2) \left[\frac{1}{r_1} - \frac{1}{r_2} \right]}$$

$$(\theta_1 - \theta_2) = \frac{\Phi}{4\pi k} \left[\frac{1}{r_1} - \frac{1}{r_2} \right]$$

④ استوانه همدمه بلر کر

رادیوسه و اوله رادیوسه رقیق قطر \$\theta_1\$

\$r_2\$ = رادیوسه و اوله رادیوسه رقیق قطر \$\theta_2\$



$$A = 2\pi r L$$

$$\dot{\Phi} = \frac{2\pi L k (\theta_1 - \theta_2)}{\ln r_2 / r_1}$$

$$(\theta_1 - \theta_2) = \frac{\dot{\Phi}}{2\pi L k} \ln \frac{r_2}{r_1}$$

انتقال الحرارة

صالح ثروت طرف للانتقال الحرارة

١- التوصيل :- هي انتقال الطاقة من ذرة الى ذرة الاخرى بالتصادم
 فتركة الجسيمات تكون تيباً بعيدة المدى

٢- الحمل :- تنقل الطاقة دلك من ساج الى مادة وسط . الجزيئات ذات
 الطاقة تناسب كتلهم تيار وتعمل الطاقة الحركية به معها وتنقل
 الى مسافات بعيدة

٣- الاشعاع :- هي انتقال الحرارة طول الفراغ [الانبعاث ، الامتصاص للطاقة
 من كل سطح الاشياء المنصه بالانواع الكروية وفضائية]

التوصيل

⊛ كمية الحرارة التي تتوصل تناسب مع مساحة المقطع في زمن معين

$$Q \propto At$$

⊛ كمية الحرارة بالتناسب مع مساحة المقطع في زمن معين متناسب مع البنية في كمية الحرارة

$$\frac{Q}{At} \propto \frac{\Delta\theta}{\Delta x}$$

$$\frac{Q}{At} = k \frac{\Delta\theta}{\Delta x}$$

↓
 معامل التوصيل

$$\frac{d\theta}{dt} = \dot{Q} = -kA \left(\frac{d\theta}{dx} \right)$$

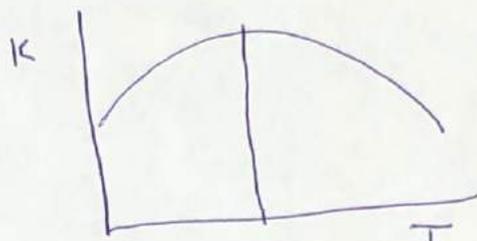
↓
 المقدار الحركية
 التباين الحركية

↓
 الحرارة تنقل بالاتجاه الموجب
 (سبب ان منه التباين الحركية ⊕)
 الاتجاه الحركية ⊖

k - thermal conductive
 دائماً موجب

- * تكون معامل التوصيل الكهربي k عاكس للمعادن
- * عند k منخفضة عند طول المادة في حجمها الكلي
- * k تزداد مع ارتفاع درجة الحرارة.
- * تلك الامهات، الصلبة الغير معدنية تكون k أقل منها
- دسبه التوصيل في درجه الحرارة، لا يتبادر به

للتماثل، ولان k في الذهب
والفضة فان k ذهب اكبر منه
وعند k منخفضة وقد يصل الى الصفر



- معامل التوصيل الكهربي k
= اللدائري σ
هذا رأيان

* تغيران - - - السه بين $k = \frac{1}{\sigma}$

⊗ لورنتز $\frac{1}{\sigma} = \text{const} = 2.23 \times 10^{-8}$

$$\sigma = \frac{1}{\rho \text{ (resistivity)}}$$

المقاوميه

$$R = \frac{\rho L}{A}$$

الطول - المقاومة

الحمل - انتقال الحرارة في مكانين أي أكثر بمرحلة واحدة والوسط الموجود، ويريد سببه اختلاف في، المساحة.

→ surface area

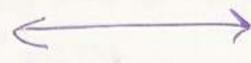
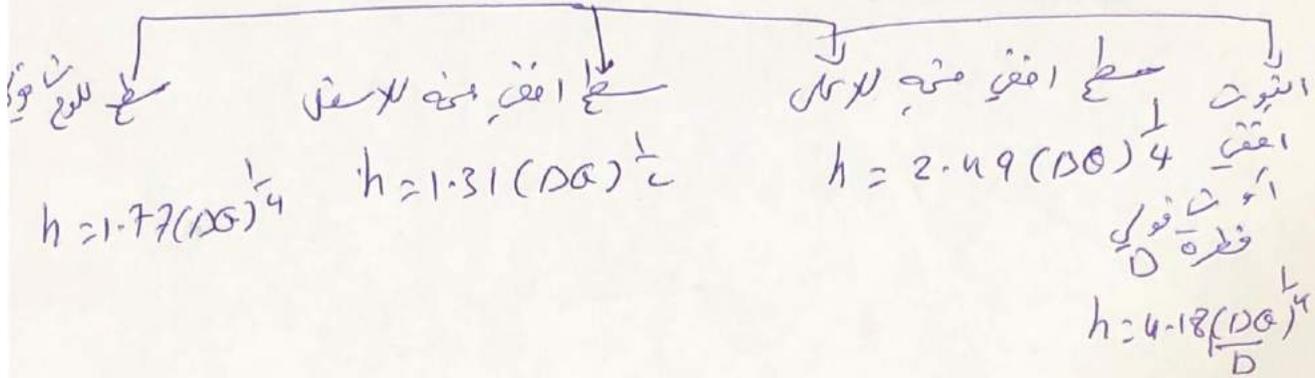
$$\dot{Q} = h A \Delta T$$

↳ temperature difference between surface and coolant

heat transfer coefficient

معامل الحمل

القيمة h - كل الفرق في درجة الحرارة، وكل نوع السطح

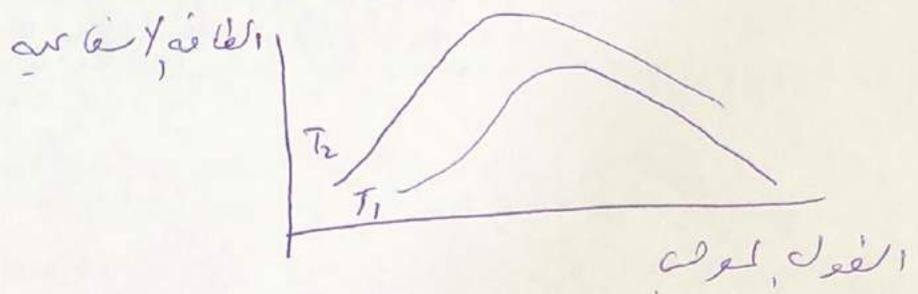


* ويمكن ان يتولد من تغير اللو. مثل boiling, condensation *
*

⊗ ان كراهه الاستقامية المنتهية من صبي ما تقمده
 ① ماضية (توعيه فادته) (دريم حرارته)

⊗ اكبر الاسوداء وهو كيمي الذي له اكثر قدره
~~استقامية~~ استقامية فيها صبي لا تقم الكلد وعقنا هنت الاستقامية
 وباننا كي لا يكون هنتالك هنتود فتكسي منه تندر بسطوع
 كذب لوتته له قدره كالبه الامضاها وايضا له قدره
 عاليه الاستقام

ويمكن عقده بحجم فقلق اهيون ذي سطح داخل طولي
 باللون الاسود وفيه ثقب هنتود ان الاستقامية لنا قدته
 من هنتود الثقب لنا سطح لا يخرج من ثقبه لانكسارات
 المتناهيه



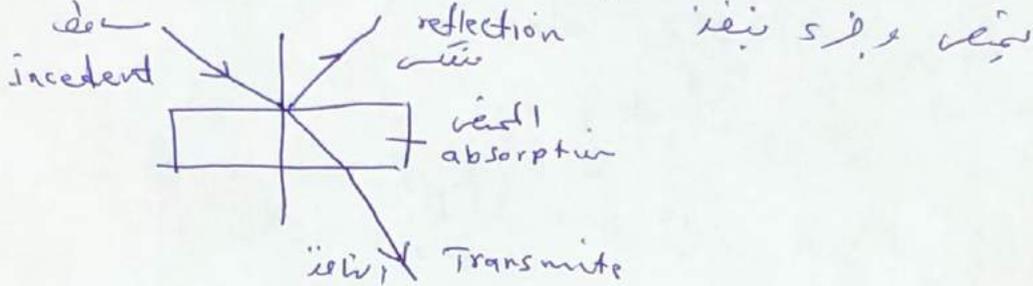
- * حيث كذا الاستقامية ولا تكبر بفضة النظر عن الطول الموجي
- * له قدره عاليه كذا الاستقامية بالمقارنة بالاصحاب الاقوي
- * فمن الطائفة الاستقامية المنتهية من كيم الاسود لا تقمده من طبيعه فادته وكذا كذا دريم حرارته
- ⊗ المتغيرات عند دريم كراهه المتكسرة تقع فاما ميد افلا المتغيرات ذات درجات كراهه العاليه
- * عند دريم حراره آ تان الطاقة الاستقامية المنتهية تزداد كلما زاد الطول الموجي المتصل الي القيمة العظمى تبدأ بعد ما بالاتفاق تزداد

٢) الاستقار... وتغيره

١) عند قابلية الامتصاص للمادة... الجسم المختلف... يكون في

٢) المواد التي لها قابلية تطبيق على نفس خواصها الاستقار... بها
المواد الكافية لا تصنف على هذه الخواص

٣) إذا سقط شعاع على جسم فان جزء منه ينعكس وجزء



$$T + A + R = 1$$

خواصها الاستقار... الاستقار

١- قانون بلانك: $E = nhf = nh\omega$

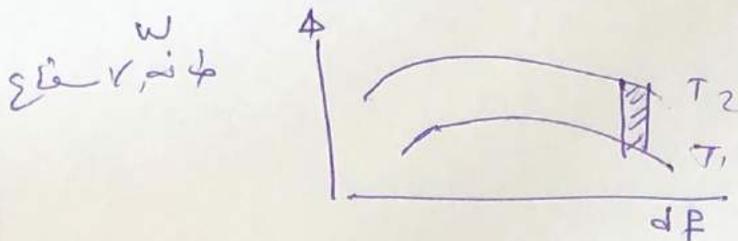
where $h \rightarrow \frac{h}{2\pi}$

$$\omega = 2\pi f$$

$w_f = \frac{dw_{bb}}{df}$ - for black body
angular frequency

طاقة الاستقار في وحدة التردد ودرجة الحرارة

$$w(\lambda) = \frac{8\pi hc}{\lambda^5} \left(\frac{1}{e^{\frac{hc}{\lambda kT}} - 1} \right)$$



④ قانون فين للإشعاع

العلاقة بين الإشعاع العظمي للقول الموجي λ_{max} ودرجة الحرارة هي علاقة عكسية
 $\lambda_{max} T = \text{const.}$

أو ان تردد الإشعاع الضيف متناسب طردياً مع درجة الحرارة
التي لا سود
 $f = 16.4 \times 10^{10} T$

وهذا يعني ان الإشعاع العظمي يتزاح مع بلانك تناقص لقول
الموجي وهذا يتفق مع الحقيقتة انه اذا ارتفعت درجة
الحرارة الكمية الموجي يصبح أكثر طعناً وأكثر بيضاء
قانون ريليه حينئذ :-

الإشعاع الموجي الطويل
عند الترددات المنخفضة
للحافة الاسفامية

$$u(\lambda) = \frac{T}{\lambda^4}$$

⑤ قانون فين

عند الترددات المرتفعة فان الحافة الاسفامية

$$u(\lambda) \propto \lambda^{-5} e^{-b/\lambda T} \quad b = \text{constant} = \frac{hc}{k}$$

⑥ - sheets of brass and steel, each of thickness l , are placed in contact. The outer surface of the brass is kept at 100°C and the outer surface of the steel kept at what is the temperature of the common interface. Thermal conductivities of brass and steel are in the ratio of 2:1

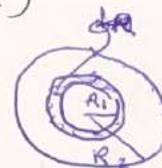
$$H = K_1 A \left(\frac{100-t}{l} \right) = K_2 A \frac{t-0}{l} \Rightarrow \frac{K_1}{K_2} = \frac{t}{100-t}$$

$$200t - 2t = t \rightarrow t = \frac{200^\circ\text{C}}{3} = 66.2^\circ\text{C}$$

⑦

A wire 0.5 mm in diameter is stretched along the axis of a cylinder 5 cm in diameter and 25 cm in length. The wire is maintained at a temp = 750°K by passing a current through it, the cylinder is kept at $T = 250^\circ\text{K}$ and the gas in it has a thermal conductivity of 6×10^{-5} cal/cm-deg-sec. Find the rates at which the heat is dissipated both by conduction through the gas and by radiation. If the wire is perfectly black.

$$H = \frac{2\pi K L (t_2 - t_1)}{\ln\left(\frac{R_2}{R_1}\right)} = \frac{2 \times 3.14 \times 6 \times 10^{-5} \times 25 (750 - 250)}{\ln\left(\frac{2.5}{0.025}\right)} = 1.02 \text{ cal/sec}$$



$$R = e \sigma (T^4 - T_0^4)$$

$$H' = RA = e \sigma A (T^4 - T_0^4) =$$

$$= 1 \times \sigma \times (2\pi R_1 L) (T^4 - T_0^4)$$

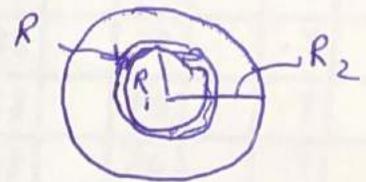
$$= 1 \times 5.67 \times 10^{-12} \times 2\pi \times 0.025 \times 25 [(750)^4 - (250)^4]$$

$$= 1.67 \text{ cal/sec}$$

Q1

Insulation material having a cylinder shape at outer diameter R_2 , surrounded by a glass tube at R_1 . The inner temperature θ_1 and outer temperature θ_2 . Find the distance R at the temperature of the glass tube at equilibrium state when the vapour pass through it.

$$k = \frac{Q}{2\pi l(\theta_1 - \theta_2)} \ln \frac{r_2}{r_1}$$



$$\frac{2\pi l k (\theta_1 - \frac{\theta_1 + \theta_2}{2})}{\ln \frac{R_2}{R}} = \frac{2\pi l k (\frac{\theta_1 + \theta_2}{2} - \theta_2)}{\ln \frac{R}{R_1}}$$

$$\ln \frac{R_2}{R} = \ln \frac{R_2}{R_1}$$

$$\frac{R_2}{R} = \frac{R_2}{R_1} \Rightarrow R = \sqrt{R_1 R_2}$$

لو 2 طول 10 cm مربع الة، طرفه من دره دره 300 K،
 الطرف الاخر من دره دره 20°C، طرفه الاخر،
 الحيزه لولده الة. كذا، ان $\sigma = 5.67 \times 10^{-8} \frac{\text{watt}}{\text{m}^2 \cdot \text{K}^4}$

$$K = 6.62 \times 10^{-34}$$

$$\begin{aligned} \frac{Q}{A} &= \sigma (T^4 - T_s^4) \\ &= 5.67 \times 10^{-8} [300 + 273]^2 - (20 + 273)^2] \\ &= 1.588 \times 10^{-5} \frac{\text{watt}}{\text{m}^2} \end{aligned}$$

② حل

one mole of a monoatomic perfect gas initially at temperature T_0 expands from volume V_0 to $2V_0$ (a)

constant temperature. (b) at constant pressure.

calculate the work of expansion and the heat absorbed by the gas in each case.

(a) At constant temperature. $w = \int_{V_0}^{2V_0} p dv = \int_{V_0}^{2V_0} \frac{nRT}{V} dV$

$$W = RT_0 \ln \frac{2V_0}{V_0} = RT_0 \ln 2$$

$$du = 0 \Rightarrow Q = w = RT_0 \ln 2$$

(b) At constant pressure.

$$w = \int_{V_0}^{2V_0} p dv = p(2V_0 - V_0) = pV_0 = RT_0$$

$$du = C_v dT = \frac{3}{2} nR dT = \frac{3}{2} p dV = \frac{3}{2} p V_0 = \frac{3}{2} RT_0$$

$$Q = du + w = \frac{5}{2} RT_0$$

①

The thermometer take out from ^{tank} water that contains boiling water. after 30 sec the temperature of thermometer come down from 95 to 80°C. The room temperature was 20°C. The process subject to Newton's Law of cooling. calculate the time needed for the thermometer to reach ~~to 65°C~~ a temperature of 65°C.

$$\theta_0 = 95^\circ\text{C} \quad \text{initial temp}$$

$$\theta = 80^\circ\text{C} \quad \text{at } t = 30 \text{ sec}$$

$$\therefore \theta_s = 20^\circ\text{C}$$

المعدل

$$\theta = \theta_s + (\theta_0 - \theta_s) e^{-kt}$$

$$80 = 20 + (95 - 20) e^{-30k}$$

$$e^{-30k} = \frac{60}{75} \Rightarrow k = 7.44 \times 10^{-3}$$

تطبيق القانون لدرجة الحرارة

$$65 = 20 + (80 - 20) e^{-7.44 \times 10^{-3} t}$$

$$\frac{45}{60} = e^{-7.44 \times 10^{-3} t}$$

$$t = 39 \text{ sec}$$

Q

A solid sphere of copper of radius (R) and a hollow sphere of the same material of inner radius (r) and outer radius (R) are heated to the same temperature and allowed to cool in the same environment. Which of them starts cooling faster.

∴ The rate of heat radiation by both spheres.

∴ The net rate of heat radiation by both spheres.

$$\frac{dQ}{dt} = e\sigma V (T^4 - T_0^4)$$

rate of heat radiation = rate of heat loss due to decrease in temperature

$$\frac{dQ}{dt} = mc \Delta t$$

$$\text{The rate of cooling} \rightarrow \Delta t = \frac{\frac{dQ}{dt}}{mc} = \frac{e\sigma V (T^4 - T_0^4)}{mc}$$

∴ The rate of cooling of the hollow sphere is more than that of the solid sphere.

∴ The rate of cooling of the hollow sphere is more than that of the solid sphere.

H.W A

The temperature of a body falls from 90°C to 70°C in 5 minutes when placed in a surrounding of constant temperature 20°C . Find the time taken for the body to become 50°C .

Q1 The density of air at 101.325 kPa and 298.15 K is 1.159 g/m^3 . Assuming that air behaves as an ideal gas, calculate its molar mass

$$PV = nRT \Rightarrow PV = \frac{m}{M} RT \Rightarrow M = \frac{m}{V} \cdot \frac{RT}{P}$$

$$P = \frac{\rho RT}{M} \Rightarrow M = \rho \frac{RT}{P}$$

$$= \frac{1.159 \times 10^{-3} \times 8.31 \times 298.15}{101.325 \times 10^3} = 28.36$$

Q2 With the temperature maintained at 0°C , 2 mole of an ideal gas are allowed to expand against a piston that supports 2 bar pressure. The initial pressure of the gas is 10 bar and the final pressure 2 bar. (a) How much energy is transferred to the surroundings during the expansion (b) What is the change in the internal energy of the gas. (c) How much heat has been absorbed by the gas

(a) $PV = nRT \rightarrow V_i = nRT / P_i = \frac{2 \times 8.31 \times 273}{10} = 2268 \text{ L}$

$$V_f = \frac{P_i V_i}{P_f} = \frac{2 \times 2268}{2} = 4536 \text{ L}$$

$$W = PdV = 2(4536 - 2268) = 4536 \text{ J}$$

(b) $\Delta U = 0$

(c) $dq = 4536 \text{ J}$

We have three types of gases

① Monoatomic gases \rightarrow He, Ne, Ar, Kr, Xe, Rn

④ $C_v \sim$ almost constant for along range of temperatures $\approx \frac{3}{2} R$

~~② Diatomic gases \rightarrow O₂, N₂, H₂, CO, NO, HCl, HBr, HI, H₂O, NH₃, CH₄, C₂H₆, C₂H₄, C₂H₂, C₃H₈, C₃H₆, C₃H₄, C₄H₁₀, C₄H₈, C₄H₆, C₄H₂, C₅H₁₂, C₅H₁₀, C₅H₈, C₅H₆, C₅H₄, C₆H₁₄, C₆H₁₂, C₆H₁₀, C₆H₈, C₆H₆, C₆H₄, C₆H₂, C₇H₁₆, C₇H₁₄, C₇H₁₂, C₇H₁₀, C₇H₈, C₇H₆, C₇H₄, C₈H₁₈, C₈H₁₆, C₈H₁₄, C₈H₁₂, C₈H₁₀, C₈H₈, C₈H₆, C₈H₄, C₉H₂₀, C₉H₁₈, C₉H₁₆, C₉H₁₄, C₉H₁₂, C₉H₁₀, C₉H₈, C₉H₆, C₉H₄, C₁₀H₂₂, C₁₀H₂₀, C₁₀H₁₈, C₁₀H₁₆, C₁₀H₁₄, C₁₀H₁₂, C₁₀H₁₀, C₁₀H₈, C₁₀H₆, C₁₀H₄, C₁₁H₂₄, C₁₁H₂₂, C₁₁H₂₀, C₁₁H₁₈, C₁₁H₁₆, C₁₁H₁₄, C₁₁H₁₂, C₁₁H₁₀, C₁₁H₈, C₁₁H₆, C₁₁H₄, C₁₂H₂₆, C₁₂H₂₄, C₁₂H₂₂, C₁₂H₂₀, C₁₂H₁₈, C₁₂H₁₆, C₁₂H₁₄, C₁₂H₁₂, C₁₂H₁₀, C₁₂H₈, C₁₂H₆, C₁₂H₄, C₁₃H₂₈, C₁₃H₂₆, C₁₃H₂₄, C₁₃H₂₂, C₁₃H₂₀, C₁₃H₁₈, C₁₃H₁₆, C₁₃H₁₄, C₁₃H₁₂, C₁₃H₁₀, C₁₃H₈, C₁₃H₆, C₁₃H₄, C₁₄H₃₀, C₁₄H₂₈, C₁₄H₂₆, C₁₄H₂₄, C₁₄H₂₂, C₁₄H₂₀, C₁₄H₁₈, C₁₄H₁₆, C₁₄H₁₄, C₁₄H₁₂, C₁₄H₁₀, C₁₄H₈, C₁₄H₆, C₁₄H₄, C₁₅H₃₂, C₁₅H₃₀, C₁₅H₂₈, C₁₅H₂₆, C₁₅H₂₄, C₁₅H₂₂, C₁₅H₂₀, C₁₅H₁₈, C₁₅H₁₆, C₁₅H₁₄, C₁₅H₁₂, C₁₅H₁₀, C₁₅H₈, C₁₅H₆, C₁₅H₄, C₁₆H₃₄, C₁₆H₃₂, C₁₆H₃₀, C₁₆H₂₈, C₁₆H₂₆, C₁₆H₂₄, C₁₆H₂₂, C₁₆H₂₀, C₁₆H₁₈, C₁₆H₁₆, C₁₆H₁₄, C₁₆H₁₂, C₁₆H₁₀, C₁₆H₈, C₁₆H₆, C₁₆H₄, C₁₇H₃₆, C₁₇H₃₄, C₁₇H₃₂, C₁₇H₃₀, C₁₇H₂₈, C₁₇H₂₆, C₁₇H₂₄, C₁₇H₂₂, C₁₇H₂₀, C₁₇H₁₈, C₁₇H₁₆, C₁₇H₁₄, C₁₇H₁₂, C₁₇H₁₀, C₁₇H₈, C₁₇H₆, C₁₇H₄, C₁₈H₃₈, C₁₈H₃₆, C₁₈H₃₄, C₁₈H₃₂, C₁₈H₃₀, C₁₈H₂₈, C₁₈H₂₆, C₁₈H₂₄, C₁₈H₂₂, C₁₈H₂₀, C₁₈H₁₈, C₁₈H₁₆, C₁₈H₁₄, C₁₈H₁₂, C₁₈H₁₀, C₁₈H₈, C₁₈H₆, C₁₈H₄, C₁₉H₄₀, C₁₉H₃₈, C₁₉H₃₆, C₁₉H₃₄, C₁₉H₃₂, C₁₉H₃₀, C₁₉H₂₈, C₁₉H₂₆, C₁₉H₂₄, C₁₉H₂₂, C₁₉H₂₀, C₁₉H₁₈, C₁₉H₁₆, C₁₉H₁₄, C₁₉H₁₂, C₁₉H₁₀, C₁₉H₈, C₁₉H₆, C₁₉H₄, C₂₀H₄₂, C₂₀H₄₀, C₂₀H₃₈, C₂₀H₃₆, C₂₀H₃₄, C₂₀H₃₂, C₂₀H₃₀, C₂₀H₂₈, C₂₀H₂₆, C₂₀H₂₄, C₂₀H₂₂, C₂₀H₂₀, C₂₀H₁₈, C₂₀H₁₆, C₂₀H₁₄, C₂₀H₁₂, C₂₀H₁₀, C₂₀H₈, C₂₀H₆, C₂₀H₄, C₂₁H₄₄, C₂₁H₄₂, C₂₁H₄₀, C₂₁H₃₈, C₂₁H₃₆, C₂₁H₃₄, C₂₁H₃₂, C₂₁H₃₀, C₂₁H₂₈, C₂₁H₂₆, C₂₁H₂₄, C₂₁H₂₂, C₂₁H₂₀, C₂₁H₁₈, C₂₁H₁₆, C₂₁H₁₄, C₂₁H₁₂, C₂₁H₁₀, C₂₁H₈, C₂₁H₆, C₂₁H₄, C₂₂H₄₆, C₂₂H₄₄, C₂₂H₄₂, C₂₂H₄₀, C₂₂H₃₈, C₂₂H₃₆, C₂₂H₃₄, C₂₂H₃₂, C₂₂H₃₀, C₂₂H₂₈, C₂₂H₂₆, C₂₂H₂₄, C₂₂H₂₂, C₂₂H₂₀, C₂₂H₁₈, C₂₂H₁₆, C₂₂H₁₄, C₂₂H₁₂, C₂₂H₁₀, C₂₂H₈, C₂₂H₆, C₂₂H₄, C₂₃H₄₈, C₂₃H₄₆, C₂₃H₄₄, C₂₃H₄₂, C₂₃H₄₀, C₂₃H₃₈, C₂₃H₃₆, C₂₃H₃₄, C₂₃H₃₂, C₂₃H₃₀, C₂₃H₂₈, C₂₃H₂₆, C₂₃H₂₄, C₂₃H₂₂, C₂₃H₂₀, C₂₃H₁₈, C₂₃H₁₆, C₂₃H₁₄, C₂₃H₁₂, C₂₃H₁₀, C₂₃H₈, C₂₃H₆, C₂₃H₄, C₂₄H₅₀, C₂₄H₄₈, C₂₄H₄₆, C₂₄H₄₄, C₂₄H₄₂, C₂₄H₄₀, C₂₄H₃₈, C₂₄H₃₆, C₂₄H₃₄, C₂₄H₃₂, C₂₄H₃₀, C₂₄H₂₈, C₂₄H₂₆, C₂₄H₂₄, C₂₄H₂₂, C₂₄H₂₀, C₂₄H₁₈, C₂₄H₁₆, C₂₄H₁₄, C₂₄H₁₂, C₂₄H₁₀, C₂₄H₈, C₂₄H₆, C₂₄H₄, C₂₅H₅₂, C₂₅H₅₀, C₂₅H₄₈, C₂₅H₄₆, C₂₅H₄₄, C₂₅H₄₂, C₂₅H₄₀, C₂₅H₃₈, C₂₅H₃₆, C₂₅H₃₄, C₂₅H₃₂, C₂₅H₃₀, C₂₅H₂₈, C₂₅H₂₆, C₂₅H₂₄, C₂₅H₂₂, C₂₅H₂₀, C₂₅H₁₈, C₂₅H₁₆, C₂₅H₁₄, C₂₅H₁₂, C₂₅H₁₀, C₂₅H₈, C₂₅H₆, C₂₅H₄, C₂₆H₅₄, C₂₆H₅₂, C₂₆H₅₀, C₂₆H₄₈, C₂₆H₄₆, C₂₆H₄₄, C₂₆H₄₂, C₂₆H₄₀, C₂₆H₃₈, C₂₆H₃₆, C₂₆H₃₄, C₂₆H₃₂, C₂₆H₃₀, C₂₆H₂₈, C₂₆H₂₆, C₂₆H₂₄, C₂₆H₂₂, C₂₆H₂₀, C₂₆H₁₈, C₂₆H₁₆, C₂₆H₁₄, C₂₆H₁₂, C₂₆H₁₀, C₂₆H₈, C₂₆H₆, C₂₆H₄, C₂₇H₅₆, C₂₇H₅₄, C₂₇H₅₂, C₂₇H₅₀, C₂₇H₄₈, C₂₇H₄₆, C₂₇H₄₄, C₂₇H₄₂, C₂₇H₄₀, C₂₇H₃₈, C₂₇H₃₆, C₂₇H₃₄, C₂₇H₃₂, C₂₇H₃₀, C₂₇H₂₈, C₂₇H₂₆, C₂₇H₂₄, C₂₇H₂₂, C₂₇H₂₀, C₂₇H₁₈, C₂₇H₁₆, C₂₇H₁₄, C₂₇H₁₂, C₂₇H₁₀, C₂₇H₈, C₂₇H₆, C₂₇H₄, C₂₈H₅₈, C₂₈H₅₆, C₂₈H₅₄, C₂₈H₅₂, C₂₈H₅₀, C₂₈H₄₈, C₂₈H₄₆, C₂₈H₄₄, C₂₈H₄₂, C₂₈H₄₀, C₂₈H₃₈, C₂₈H₃₆, C₂₈H₃₄, C₂₈H₃₂, C₂₈H₃₀, C₂₈H₂₈, C₂₈H₂₆, C₂₈H₂₄, C₂₈H₂₂, C₂₈H₂₀, C₂₈H₁₈, C₂₈H₁₆, C₂₈H₁₄, C₂₈H₁₂, C₂₈H₁₀, C₂₈H₈, C₂₈H₆, C₂₈H₄, C₂₉H₆₀, C₂₉H₅₈, C₂₉H₅₆, C₂₉H₅₄, C₂₉H₅₂, C₂₉H₅₀, C₂₉H₄₈, C₂₉H₄₆, C₂₉H₄₄, C₂₉H₄₂, C₂₉H₄₀, C₂₉H₃₈, C₂₉H₃₆, C₂₉H₃₄, C₂₉H₃₂, C₂₉H₃₀, C₂₉H₂₈, C₂₉H₂₆, C₂₉H₂₄, C₂₉H₂₂, C₂₉H₂₀, C₂₉H₁₈, C₂₉H₁₆, C₂₉H₁₄, C₂₉H₁₂, C₂₉H₁₀, C₂₉H₈, C₂₉H₆, C₂₉H₄, C₃₀H₆₂, C₃₀H₆₀, C₃₀H₅₈, C₃₀H₅₆, C₃₀H₅₄, C₃₀H₅₂, C₃₀H₅₀, C₃₀H₄₈, C₃₀H₄₆, C₃₀H₄₄, C₃₀H₄₂, C₃₀H₄₀, C₃₀H₃₈, C₃₀H₃₆, C₃₀H₃₄, C₃₀H₃₂, C₃₀H₃₀, C₃₀H₂₈, C₃₀H₂₆, C₃₀H₂₄, C₃₀H₂₂, C₃₀H₂₀, C₃₀H₁₈, C₃₀H₁₆, C₃₀H₁₄, C₃₀H₁₂, C₃₀H₁₀, C₃₀H₈, C₃₀H₆, C₃₀H₄, C₃₁H₆₄, C₃₁H₆₂, C₃₁H₆₀, C₃₁H₅₈, C₃₁H₅₆, C₃₁H₅₄, C₃₁H₅₂, C₃₁H₅₀, C₃₁H₄₈, C₃₁H₄₆, C₃₁H₄₄, C₃₁H₄₂, C₃₁H₄₀, C₃₁H₃₈, C₃₁H₃₆, C₃₁H₃₄, C₃₁H₃₂, C₃₁H₃₀, C₃₁H₂₈, C₃₁H₂₆, C₃₁H₂₄, C₃₁H₂₂, C₃₁H₂₀, C₃₁H₁₈, C₃₁H₁₆, C₃₁H₁₄, C₃₁H₁₂, C₃₁H₁₀, C₃₁H₈, C₃₁H₆, C₃₁H₄, C₃₂H₆₆, C₃₂H₆₄, C₃₂H₆₂, C₃₂H₆₀, C₃₂H₅₈, C₃₂H₅₆, C₃₂H₅₄, C₃₂H₅₂, C₃₂H₅₀, C₃₂H₄₈, C₃₂H₄₆, C₃₂H₄₄, C₃₂H₄₂, C₃₂H₄₀, C₃₂H₃₈, C₃₂H₃₆, C₃₂H₃₄, C₃₂H₃₂, C₃₂H₃₀, C₃₂H₂₈, C₃₂H₂₆, C₃₂H₂₄, C₃₂H₂₂, C₃₂H₂₀, C₃₂H₁₈, C₃₂H₁₆, C₃₂H₁₄, C₃₂H₁₂, C₃₂H₁₀, C₃₂H₈, C₃₂H₆, C₃₂H₄, C₃₃H₆₈, C₃₃H₆₆, C₃₃H₆₄, C₃₃H₆₂, C₃₃H₆₀, C₃₃H₅₈, C₃₃H₅₆, C₃₃H₅₄, C₃₃H₅₂, C₃₃H₅₀, C₃₃H₄₈, C₃₃H₄₆, C₃₃H₄₄, C₃₃H₄₂, C₃₃H₄₀, C₃₃H₃₈, C₃₃H₃₆, C₃₃H₃₄, C₃₃H₃₂, C₃₃H₃₀, C₃₃H₂₈, C₃₃H₂₆, C₃₃H₂₄, C₃₃H₂₂, C₃₃H₂₀, C₃₃H₁₈, C₃₃H₁₆, C₃₃H₁₄, C₃₃H₁₂, C₃₃H₁₀, C₃₃H₈, C₃₃H₆, C₃₃H₄, C₃₄H₇₀, C₃₄H₆₈, C₃₄H₆₆, C₃₄H₆₄, C₃₄H₆₂, C₃₄H₆₀, C₃₄H₅₈, C₃₄H₅₆, C₃₄H₅₄, C₃₄H₅₂, C₃₄H₅₀, C₃₄H₄₈, C₃₄H₄₆, C₃₄H₄₄, C₃₄H₄₂, C₃₄H₄₀, C₃₄H₃₈, C₃₄H₃₆, C₃₄H₃₄, C₃₄H₃₂, C₃₄H₃₀, C₃₄H₂₈, C₃₄H₂₆, C₃₄H₂₄, C₃₄H₂₂, C₃₄H₂₀, C₃₄H₁₈, C₃₄H₁₆, C₃₄H₁₄, C₃₄H₁₂, C₃₄H₁₀, C₃₄H₈, C₃₄H₆, C₃₄H₄, C₃₅H₇₂, C₃₅H₇₀, C₃₅H₆₈, C₃₅H₆₆, C₃₅H₆₄, C₃₅H₆₂, C₃₅H₆₀, C₃₅H₅₈, C₃₅H₅₆, C₃₅H₅₄, C₃₅H₅₂, C₃₅H₅₀, C₃₅H₄₈, C₃₅H₄₆, C₃₅H₄₄, C₃₅H₄₂, C₃₅H₄₀, C₃₅H₃₈, C₃₅H₃₆, C₃₅H₃₄, C₃₅H₃₂, C₃₅H₃₀, C₃₅H₂₈, C₃₅H₂₆, C₃₅H₂₄, C₃₅H₂₂, C₃₅H₂₀, C₃₅H₁₈, C₃₅H₁₆, C₃₅H₁₄, C₃₅H₁₂, C₃₅H₁₀, C₃₅H₈, C₃₅H₆, C₃₅H₄, C₃₆H₇₄, C₃₆H₇₂, C₃₆H₇₀, C₃₆H₆₈, C₃₆H₆₆, C₃₆H₆₄, C₃₆H₆₂, C₃₆H₆₀, C₃₆H₅₈, C₃₆H₅₆, C₃₆H₅₄, C₃₆H₅₂, C₃₆H₅₀, C₃₆H₄₈, C₃₆H₄₆, C₃₆H₄₄, C₃₆H₄₂, C₃₆H₄₀, C₃₆H₃₈, C₃₆H₃₆, C₃₆H₃₄, C₃₆H₃₂, C₃₆H₃₀, C₃₆H₂₈, C₃₆H₂₆, C₃₆H₂₄, C₃₆H₂₂, C₃₆H₂₀, C₃₆H₁₈, C₃₆H₁₆, C₃₆H₁₄, C₃₆H₁₂, C₃₆H₁₀, C₃₆H₈, C₃₆H₆, C₃₆H₄, C₃₇H₇₆, C₃₇H₇₄, C₃₇H₇₂, C₃₇H₇₀, C₃₇H₆₈, C₃₇H₆₆, C₃₇H₆₄, C₃₇H₆₂, C₃₇H₆₀, C₃₇H₅₈, C₃₇H₅₆, C₃₇H₅₄, C₃₇H₅₂, C₃₇H₅₀, C₃₇H₄₈, C₃₇H₄₆, C₃₇H₄₄, C₃₇H₄₂, C₃₇H₄₀, C₃₇H₃₈, C₃₇H₃₆, C₃₇H₃₄, C₃₇H₃₂, C₃₇H₃₀, C₃₇H₂₈, C₃₇H₂₆, C₃₇H₂₄, C₃₇H₂₂, C₃₇H₂₀, C₃₇H₁₈, C₃₇H₁₆, C₃₇H₁₄, C₃₇H₁₂, C₃₇H₁₀, C₃₇H₈, C₃₇H₆, C₃₇H₄, C₃₈H₇₈, C₃₈H₇₆, C₃₈H₇₄, C₃₈H₇₂, C₃₈H₇₀, C₃₈H₆₈, C₃₈H₆₆, C₃₈H₆₄, C₃₈H₆₂, C₃₈H₆₀, C₃₈H₅₈, C₃₈H₅₆, C_{38</}~~

(b) For adiabatic process

$$pV^\gamma = \text{const}$$

$$\gamma p V^{\gamma-1} dV + V^\gamma dp = 0$$

$$\frac{dp}{dV} = - \frac{p \gamma V^{\gamma-1}}{V^\gamma} = - \gamma \frac{p}{V}$$

$$\therefore \beta_{\text{adiab}} = -V \left(- \frac{p \gamma}{V} \right) = \gamma p$$

comperation coefficient K $\left[\frac{1}{\beta} \right]$

قلوب صند، لبرته
الخصيب

$$K = \frac{1}{\beta} \rightarrow K_{\text{isoth}} = \frac{1}{p}, \quad K_{\text{adiab}} = \frac{1}{\gamma p}$$

The relation between temperature and atmospheric pressure above the earth surface

تكون طبقات الارض على نوعين $\left\{ \begin{array}{l} \text{طبقة صلبة فوق الارض} \\ \text{وعلى عدة مستويات اخرى} \end{array} \right.$

تغير الطبقات، التي تحتها الغلاف، لظروفها على سطح الارض، بالاضافة لظروف

- 1) تغير سرعة دورانها بين الاقطاب وقت الاستواء، كما ان
- 2) هناك طبقة صلبة، وطبقة هوائية فوقها، لظروفها على سطح الارض، بالاضافة لظروف
- 3) طبقة غازية، تحتها طبقة صلبة، كما ان

هناك نوعان من الطبقات، احدى طبقات

1) احدى طبقاتها Dry adiabatic، تميزها ان سرعة التغير في

2) الطبقة Wet، تكون الهواء رطب، يتبخر الماء في

3) سرعة التغير في، كما ان سرعة التغير في

$$dP = du + dw$$

$$0 = cv dT + P dV \rightarrow P dV = -cv dT \quad \text{--- (1)}$$

$$P V = nRT \Rightarrow P dV + V dP = R dT \quad \text{--- (2)}$$

$$dP = -\rho g dy \quad \text{--- (3)}$$

$$R = C_p - C_v$$

(4)

(3)

بعوضه 1, 3, 4 في 2

$$-C_v dT + v(-\rho g dy) = (C_p - C_v) dT$$

$$-C_v dT - v \rho g dy = C_p dT - C_v dT$$

$$-g dy = C_p dT$$

$$\Rightarrow \left[-\frac{dT}{dy} = \frac{g}{C_p} = \alpha_d \right]$$

Rate of cooling
معامل التبريد

$$\rho v = m = \rho g$$

في هذه الحالة، في ارتفاع معين، الضغط يقل، شدة الإشعاع في هذه الحالة، كما أن الكثافة تقل، وبالتالي تقل درجة الحرارة.

$$\alpha_w = \alpha_d - F$$

الانخفاض في الإشعاع عن كثرة الإشعاع، كما أن الكثافة تقل، وبالتالي تقل درجة الحرارة.

$$\alpha_w < \alpha_d$$

في هذه الحالة، في ارتفاع معين، الضغط يقل، شدة الإشعاع في هذه الحالة، كما أن الكثافة تقل، وبالتالي تقل درجة الحرارة.

في هذه الحالة، في ارتفاع معين، الضغط يقل، شدة الإشعاع في هذه الحالة، كما أن الكثافة تقل، وبالتالي تقل درجة الحرارة.

$$dp = -\rho g dy \Rightarrow -\frac{dp}{dy} = \rho g$$

$$pV = nRT = \frac{m}{M} RT \Rightarrow pM = \frac{m}{V} RT$$

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

$$p = \frac{\rho M}{RT} \Rightarrow \frac{dp}{dy} = \frac{\rho M}{RT} g$$

$$\int_{p_1}^{p_2} \frac{dp}{p} = -\frac{Mg}{RT} \int_{y_1}^{y_2} dy \Rightarrow \ln \frac{p_2}{p_1} = -\frac{Mg}{RT} (y_2 - y_1)$$

$$k = -\frac{1}{v} \frac{dv}{dp} \Rightarrow \frac{dv}{v} = -k dp$$

$$dw = p dv = -k p v dp$$

$$\therefore w = -k v \int_{p_1}^{p_2} p dp = -\frac{k v}{2} (p_2^2 - p_1^2) = -\frac{k m}{2 \rho} (p_2^2 - p_1^2)$$

(X8)

Example Cylender ~~with~~ filled with water at volume of $1m^3$ at pressure of 1 atmosphere and Temp. $300K$. Increase the pressure to 100 atmosphere at constant temp.

- calculate the work done on the system for
- (1) (a) ideal gas (b) Liquid with $K = 5 \times 10^{-12} / \text{ps}$.
- (2) calculate change in volume for each case.

(1) (a) $w_T = nRT \ln \frac{P_1}{P_2} = P_1 V_1 \ln \frac{P_1}{P_2}$
 $= 1 \times 10^5 \ln \frac{1}{100}$
 $= -4.65 \times 10^5 \text{ J}$

(b) $w = -\frac{KV}{2} (P_2^2 - P_1^2) = -\frac{5 \times 10^{-12} \times 1}{2} ((100)^2 - 1^2) (10^5)^2$
 $= -250 \text{ J}$

(2) (a) $P_1 V_1 = P_2 V_2 \Rightarrow 1 \times 1 = 100 \times V_2 \Rightarrow V_2 = 0.01$
 $\therefore \Delta V = 0.01 - 1 = -0.99 \text{ m}^3$

(b) $K = -\frac{1}{V} \frac{\Delta V}{\Delta P}$
 $5 \times 10^{-12} = -\frac{1}{1} \frac{V_2 - 1}{(100 - 1) \times 1.01 \times 10^5} \Rightarrow V_2 = 1.00005$

$\therefore \Delta V = 1.00005 - 1 = 0.00005 \text{ m}^3$

4

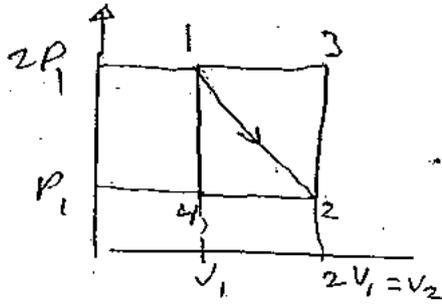
$$W = \int dw = P dv$$

$$= C \int \frac{dv}{v^\gamma} = C \left[\frac{v^{-\gamma+1}}{-\gamma+1} \right]_{v_1}^{v_2}$$

$$Pv^\gamma = C$$

$$P = \frac{C}{v^\gamma}$$

$$= \frac{C}{1-\gamma} \left[v_2^{-\gamma+1} - v_1^{-\gamma+1} \right] = \frac{P_2 v_2 - P_1 v_1}{1-\gamma}$$



work done
 ① J L

$$W_{1-3} = P(v_2 - v_1) = 2P_1 v_1$$

$$W_{1 \rightarrow 3 \rightarrow 2} = 2P_1 v_1 =$$

$$W_{2 \rightarrow 4 \rightarrow 1} = P_1 v_1$$

$$W_{1 \rightarrow 2} = \frac{3}{2} P_1 v_1$$

work done

② J L

Calculate the work for 1 mole of gas at isotherm process when the volume change from v_1 to v_2 the equation of state become

$$\left(P + \frac{a}{v^2} \right) (v - b) = RT$$

$$W = \int P dv = \int_{v_1}^{v_2} \left(\frac{RT}{v-b} - \frac{a}{v^2} \right) dv = RT \ln \frac{v_2-b}{v_1-b} + a \left(\frac{1}{v_1} - \frac{1}{v_2} \right)$$

a cylindrical / with water with volume 1 m^3 at 1 atm. and 300 K . The pressure increase to 100 atm. at constant temperature, calculate the work done on the system if

- (1) The fluid is ideal gas
- (2) The fluid is liquid and $K = 5 \times 10^{-12} / P$
- (3) The change in volume in the fluid

(1)
$$W = nRT \ln \frac{P_1}{P_2} = P_1 V_1 \ln \frac{P_1}{P_2} = 1 \times 1.01 \times 10^5 \text{ m} \frac{1}{100}$$

$$= 4.65 \times 10^5 \text{ J}$$

(2)
$$W = \frac{KV}{2} (P_2^2 - P_1^2) = - \frac{5 \times 10^{-12} \times 1}{2} \left[(100 \times 10^5)^2 - (1 \times 10^5)^2 \right]$$

$$= -250 \text{ J}$$

(3) $P_1 V_1 = P_2 V_2$
 $1 \times 1 = 100 \times V_2 \rightarrow V_2 = 0.01$

$\Delta V = V_2 - V_1 = 0.01 - 1 = -0.99 \text{ m}^3$ For ideal gas

For liquid $K = - \frac{1}{V} \frac{dV}{dP}$

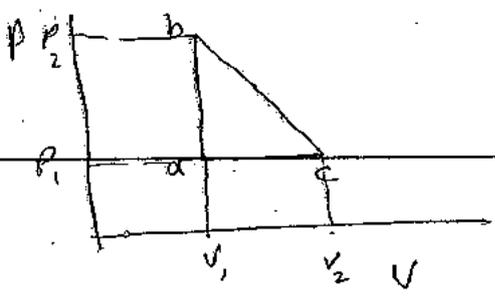
$5 \times 10^{-12} = \frac{1}{1} \left[\frac{V_2 - 1}{(100 - 1) \times 1.01 \times 10^5} \right] \rightarrow V_2 = 1.0005$

$\Delta V = 1.0005 - 1 = 0.0005 \text{ m}^3$

an ideal gas at pressure (P_1) and volume (V_1) heat it (4 J) at constant volume until the pressure become double ~~at constant temperature~~. expand and reach the original pressure at constant temperature. then compress at constant pressure until reach to the original volume. calculate the

- (1) draw the PV diagram
- (2) the total work if $n = 2 \text{ mol}$
 $P_1 = 2 \text{ atm}$, $V_1 = 4 \text{ m}^3$.

6



$$p_a = 2$$

$$V_a = 4$$

$$p_1 = p_a = p_c$$

$$V_1 = V_a = V_b, \quad T = T_b = T_c$$

$$T_a = \frac{p_a V_a}{nR} = 48.6 \text{ deg}, \quad \frac{p_a}{T_a} = \frac{p_b}{T_b} \Rightarrow T_b = 97.2 = T_c$$

$$w_{bc} = nR T_b \ln \frac{p_b}{p_c} = 11.2 \times 10^5 \text{ J}$$

$$w_{ab} = 0$$

$$w_{ca} = p \Delta V = 2 \times 10^5 \times (4 - 8) = -8 \times 10^5 \text{ J}$$

$$V_2 = V_c = \frac{nR T_c}{p_c} \approx 8 \text{ m}^3$$

$$w_{\text{total}} = w_{ab} + w_{bc} + w_{ca} = 0 + 11.2 \times 10^5 - 8 \times 10^5 = 3.2 \times 10^5 \text{ J}$$

The pressure increase from 0-3000 atom on the metal with mass = 100 gm at constant temperature 5 J Co
 calculate the work done of the metal. Assume the density = 10^4 , $\beta = 0.675 \times 10^{-6}$

$$W = - \frac{m k}{2 \rho} (p_2^2 - p_1^2)$$

$$= - \frac{100 \times 10^{-3} \times 0.675 \times 10^{-6}}{2 \times 10^4} \left((3000)^2 - (0)^2 \right)$$

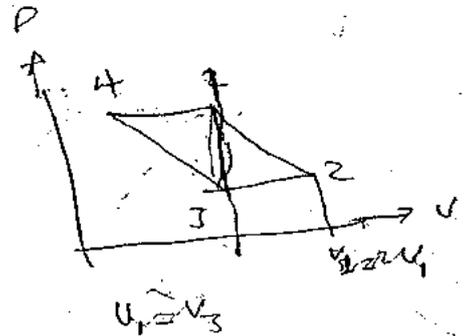
$$= -0.3375 \text{ J}$$

⑤ one liter of an ideal gas under a pressure of 1 atm is expanded isothermally until its volume is doubled. It is then compressed to its original volume at constant pressure and further compressed isothermally to its original pressure. Plot the process on P-V diagram and calculate (1) The total work done on the gas.

(2) If 50 J of heat were removed during the constant pressure process, what would be the total change in the internal energy, when 50 J of heat were removed

during the constant pressure process:

$$\begin{aligned} \text{From } 1 \rightarrow 2 \quad w &= - \int_{V_1}^{V_2} P \, dV = -nRT \int \frac{dV}{V} \\ &= -nRT \ln \frac{V_2}{V_1} = -P_1 V_1 \ln \frac{V_2}{V_1} \\ &= -P_1 V_1 \ln \frac{P_1}{P_2} \end{aligned}$$



$$w_{1-2} = -P_1 V_1 \ln \frac{V_2}{V_1} = -1 \times 1.01 \times 10^5 \times 1 \times \ln 2 = -0.7032 \text{ J}$$

2 → 3

$$P_1 V_1 = P_2 V_2 \rightarrow P_2 = P_1 \frac{V_1}{V_2} = \frac{1}{2} P_1$$

$$w_{2 \rightarrow 3} = -P_2 \int_{V_2}^{V_3} dV = -P_2 (V_3 - V_2) = -\frac{1}{2} P_1 (V_1 - 2V_1) \quad w_{2 \rightarrow 3}$$

$$= \frac{1}{2} P_1 V_1 = \frac{1}{2} \times 1 \times 1.01 \times 10^5 \times 1 = 0.5065 \text{ J}$$

$$w_{4 \rightarrow 3} = -P_3 V_3 \ln \frac{P_3}{P_4} = -\frac{1}{2} P_1 V_1 \ln \frac{P_2}{P_1} = \frac{1}{2} P_1 V_1 \ln \frac{1}{2}$$

$$= -0.3511$$

$$w_{\text{Total}} = w_{1-2} + w_{2-3} + w_{4-3} = -0.155 \text{ J}$$

② $U \rightarrow$ constant in $1 \rightarrow 2$ and $4 \rightarrow 1$ ($T = \text{const}$)

$$dU = dQ + dW = 50 - (-0.5065) = 49.5 \text{ J}$$

① The extremes of temp. in New York, over a period of 50 years differ by 116 Fahrenheit degrees, Express this range in Celsius degrees.

$$\Delta C = \frac{5}{9} \Delta F = \frac{5}{9} \times 116 = 64.5^\circ C$$

② Does an ideal gas get hotter or colder when it expands according to the law $PV^2 = \text{constant}$

Identifies $PV = nRT \rightarrow PV^2 = \text{const} \rightarrow (nRT)V = \text{const} \rightarrow nRTV = \text{const} \rightarrow V \propto \frac{1}{T}$

③ Air at pressure $1.47 \frac{N}{m^2}$ is pumped into a tank whose volume is $42.5 m^3$, what volume of air must be pumped in to make the gage read $55.3 \frac{N}{m^2}$ if the temperature is raised from 70 to 80 degree centigrade

$$P_2 = 14.7 + 55.3 = 70 \frac{N}{m^2}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

④ A 5 gm block of (Al) at 200 K is placed in contact with a 15 gm (Cu) block at 375 K, the equilibrium temp. of the system is 321 K, what is the change in entropy of the system when the two blocks of metal are placed in contact. C_V for Al = $0.91 \frac{J}{gm \cdot K}$

$$C_V \text{ for Cu} = 0.39 \frac{J}{gm \cdot K}$$

$$\Delta S = \int_{T_1}^{T_2} m c_V \frac{dT}{T} = m c_V \ln \frac{T_2}{T_1}$$

$$\Delta S = S_1 \text{ Al} + S_2 \text{ Cu} = 5 \times 0.91 \ln \frac{321}{250} + 15 \times 0.39 \ln \frac{321}{375}$$

$$= 1.14 - 0.91 = 0.23 \text{ J/K}$$

①

9

Prove that $R = C_p - C_v$

$$dQ = n c_p dT = c_p dT \quad \text{when } n=1$$

$$pV = nRT \Rightarrow p dV + V dp = nR dT$$

دقیقاً ~~نویس~~ ~~همه~~ ~~چیز~~ ~~ها~~

$$\therefore \boxed{p dV = R dT}$$

$$du = dQ - dw = dQ - p dV$$

$$n c_v dT = n c_p dT - n R dT$$

$$\therefore c_v = c_p - R \Rightarrow \boxed{R = c_p - c_v}$$

(1)

adiabatic processes P, V, T, γ relation

reversible ^{adiabatic} processes for ~~adiabatic~~ ideal gas

$$dQ = 0, \quad du = n c_v dT, \quad dw = PdV$$

$$dQ = du + dw \Rightarrow 0 = n c_v dT + PdV$$

$$n c_v dT = -PdV \quad \text{--- (1)}$$

$$PV = nRT \Rightarrow PdV + VdP = nRdT \quad \text{--- (2)}$$

$$\Rightarrow dT = -\frac{P}{n c_v} dV \quad \text{--- (3)}$$

$$R = c_p - c_v \quad \text{--- (4)}$$

put equation (4) in (2)

$$PdV + VdP = n(c_p - c_v) dT \quad \text{--- (5)}$$

put equation (3) in (5)

$$PdV + VdP = n(c_p - c_v) \left(-\frac{P}{n c_v}\right) dV$$

$$VdP = PdV \left[\frac{c_v - c_p}{c_v} - 1 \right] = -\frac{c_p}{c_v} PdV$$

PV is constant

$$\frac{dP}{P} + \gamma \frac{dV}{V} = 0 \Rightarrow \ln P + \gamma \ln V = \ln K$$

where $\gamma = \frac{c_p}{c_v}$

$$\therefore PV^\gamma = K$$

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$



(6)

(3)

$$P_1 V_1 = nRT_1$$

$$V_1 = \frac{nRT_1}{P_1}$$



$$P_2 V_2 = nRT_2 \Rightarrow V_2 = \frac{nRT_2}{P_2}$$

بفرض γ ثابت

$$\frac{nRT_1}{V_1} V_1^\gamma = \frac{nRT_2}{V_2} V_2^\gamma$$

$$T_1 \frac{V_1^\gamma}{V_1} = T_2 \frac{V_2^\gamma}{V_2}$$

$$\boxed{T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}} \quad \text{--- (7)}$$

$$V_1 = \frac{nRT_1}{P_1}$$

$$V_2 = \frac{nRT_2}{P_2}$$

بفرض γ ثابت

$$P_1 \left(\frac{nRT_1}{P_1} \right)^\gamma = P_2 \left(\frac{nRT_2}{P_2} \right)^\gamma$$

$$P_1 P_1^{-\gamma} T_1^\gamma = P_2 P_2^{-\gamma} T_2^\gamma$$

γ constant

$$P_1^{1-\gamma} T_1^\gamma = P_2^{1-\gamma} T_2^\gamma$$

$$\boxed{T_1 P_1^{\frac{1-\gamma}{\gamma}} = T_2 P_2^{\frac{1-\gamma}{\gamma}}} \quad \text{--- (8)}$$

① A sample of H_2 gas, which may be assumed to be ideal, is initially at 3 bar pressure and a temperature $25^\circ C$ and has a volume of $1.5 m^3$. It is expanded reversibly and adiabatically until the volume is $5 m^3$. The heat capacity C_p of H_2 is $28.8 J/K.mol$ and may be assumed to be independent of temperature
 (a) calculate the final pressure and temperature after the expansion, (b) calculate ΔU for the process

$$c) C_v = C_p - R = 28.8 - 8.31 = 20.48$$

$$\gamma = \frac{C_p}{C_v} = \frac{28.8}{20.48} = 1.4$$

$$P_f = P_i \left(\frac{V_i}{V_f} \right)^\gamma = 3 \times \left(\frac{1.5}{5} \right)^{1.4} = 0.552 \text{ bar}$$

$$T_f = T_i \left(\frac{V_i}{V_f} \right)^{\gamma-1} = (273+25) \left(\frac{1.5}{5} \right)^{1.4-1} = 183 K$$

$$b) \Delta u = C_v (T_2 - T_1) = 2360 J/mol$$

② initially 0.1 mole of methane is at 1 bar pressure and $80^\circ C$. The gas behaves ideally and the value of $\frac{C_p}{C_v} = 1.31$. The gas allowed to expand reversibly and adiabatically to pressure of 0.1 bar. (a) what are the initial and final volumes of the gas. (b) what is the final temperature (c) calculate ΔU for the process

$$a) pV = nRT \rightarrow V_i = nRT/P_i = 2.39 m^3$$

$$P_f/P_i = \left(\frac{V_i}{V_f} \right)^\gamma \Rightarrow V_f = 17.02 m^3$$

$$b) T_f/T_i = P_f V_f / P_i V_i \Rightarrow T_f = 204.06 K$$

$$c) \Delta u = C_v (T_2 - T_1) = 3979.09 J$$

$$\frac{C_p}{C_v} = 1.31 \rightarrow \frac{C_p}{C_v} - 1 = 0.31 \Rightarrow C_p - C_v = 0.31 C_v$$

$$C_p - C_v = R \Rightarrow C_v = 8.31 / 0.31 = 26.81$$

(2) J L

(a) For a mole of ideal gas at $t = 0^\circ\text{C}$, calculate the work (w) done in an isothermal expansion from v_0 to $10v_0$ in volume

(b) For an ideal gas initially at $t_i = 0^\circ\text{C}$. Find the final temperature t_f in when the volume is expanded to $10v_0$ reversibly and adiabatically

(a) $w = \int_{v_0}^{10v_0} p dv = \int_{v_0}^{10v_0} \frac{nRT}{v} dv = RT \ln 10 = 5.2 \times 10^4 \text{ J}$

(b) at adiabatic $p v^\gamma = \text{const}$

$$T_f = T_i \left(\frac{v_i}{v_f} \right)^{\gamma-1} \quad \gamma = \frac{5}{3} \rightarrow t_f = 50 \text{ K}$$

(2) J L

(a) How much heat is required to rise the temperature of 1000 gm of Nitrogen from -20°C to 100°C at constant pressure.

(b) How much has the internal energy of the Nitrogen increased

(c) How much external work was done

(d) How much heat is required if the volume is kept constant. $C_v = 5 \frac{\text{cal}}{\text{mole} \cdot \text{K}}$, $R = 8.31 \frac{\text{cal}}{\text{mole} \cdot \text{K}}$

(a) $Q = n c_p \Delta T = \frac{1000}{28} (5 + 8.31) 120 = \text{cal}$

(b) $\Delta u = n c_v \Delta T = \frac{1000}{28} \times 5 \times 120 \quad \text{cal}$

(c) $w = Q - \Delta u = \text{cal}$

(d) $Q = n c_v \Delta T = \text{cal}$

(Q3) A gas behaves ideally and its C_v is given by

$$C_v = 21.52 + 8.2 \times 10^{-3} T$$

(a) what is C_p as a function of T

(b) A sample of this gas is initially at $T_1 = 300\text{K}$
 $P_1 = 10\text{ bar}$, $V_1 = 1\text{ m}^3$. It is allowed to expand until
 $P_2 = 1\text{ bar}$ and $V_2 = 10\text{ m}^3$

what are ΔU for this process.

$$C_p - C_v = R = 8.31$$

$$C_p - (21.52 + 8.2 \times 10^{-3} T) = 8.31 \Rightarrow C_p = 29.8345 + 8.2 \times 10^{-3} T$$

$$(b) \Delta U = C_v (T_f - T_i)$$

$$\frac{T_f}{T_i} = \frac{P_f V_f}{P_i V_i} \Rightarrow T_f = \frac{T_i P_f V_f}{P_i V_i} = \frac{300 \times 1 \times 10}{10 \times 1} = 300\text{K}$$

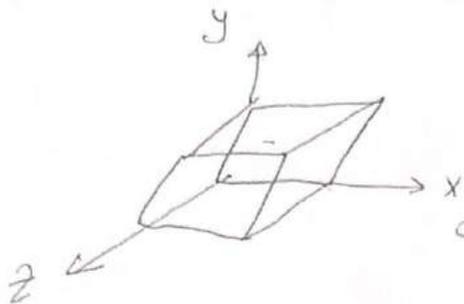
$$\therefore \Delta U = C_v (300 - 300) = 0$$

① Assumptions of Kinetic theory (حفظ)

- ۱۔ کل گاز کیموی کل ہیزیا کے عین اعنا رہا
نقاط کتلیہ غیر متفاعله
- ۲۔ ہا عدد کیر منا، کیزیا کے فرق عنوا ہیا
ولا سرعہ مختلفہ
- ۳۔ کیزیا کے متباعدہ منو ہا ہیا
- ۴۔ کیزیا کے تخصیق لقانون اعنا ہیا، اللہ سکری
و متفاعله فقط عذو متبادرہ
- ۵۔ وان، لفظا متا ہے تصادمات سرینہ
- ۶۔ لفظ، تاثیر ہو سنہ لفظا دم، کیزیا کے
مع ہیرا ان الوعاء
- ۷۔ ہیس ہا ان تاثیر لیا ذبہ کل ہرہ، کیزیا کے
- ۸۔ ہما ان ہیم کیزیا کے ہر ہرہ یا المقارنہ ہا ہین
المافہ ہین کیزیا کے، فان ہجم، الذی یثقلہ
کیزیا کے عین اھالہ مقارنہ یا ہجم، اکلہ للوواء

استنتاج معادله الغاز المثالي من النظرية الحركية (2)
 نظرياً

Derivation of ideal gas equation from the kinetic theory



* نظرياً لدينا وعاء مكعب
 طول ضلعه a وفيه

N من الجزيئات
 وسرعة الجزيئات U
 بينت تحليلاً اني نتو كسر كجانب
 U_x, U_y, U_z

* القوة المبذولة على الجدران بواسطة تصادم الجزيئات، والوقت
 بين زيارته الجدار x (هي)

الزمن Δt - بين تصادمين،
 $F_x = \frac{\Delta(mv_x)}{\Delta t}$ او معدل التغير في الزخم

المسافة $\leftarrow 2a$
 السرعة U_x
 $\Delta t = \frac{2a}{U_x}$

$\Delta(mv_x)$ هو مقدار التغير في الزخم $= 2mU_x$

$$\therefore F_x = \frac{2mU_x}{2a/U_x} = \frac{2mU_x^2}{2a} = \frac{mU_x^2}{a}$$

القوة المبذولة

$$\text{وهذا } P = \frac{mU_x^2}{a \cdot a^2} = \frac{mU_x^2}{a^3} = \frac{mU_x^2}{V} \quad (1)$$

وبما ان التصادم بين الجزيئات هو تصادم مرن فان السرعة U_x دائمة للجزئيه لانه لا يتبدل

$$P = P_1 + P_2 + P_3 = \sum P_i \quad (2)$$

(3)

من المعادله 2 و 2

$$P_i = \frac{m v_{xi}^2}{V} \Rightarrow P = \sum \frac{m v_{xi}^2}{V} \quad (3)$$

$$= \frac{m}{V} \sum v_{xi}^2$$

من المعادله 1 و 2، لكن في هذه الحالة سوف
نحسب فقط السرعة في الاتجاه x

$$v_x^2 = \frac{\sum v_{xi}^2}{N}$$

$$\sum v_{xi}^2 = v_x^2 N \quad (4)$$

من المعادله 3 و 4

$$\therefore P = \frac{m N v_x^2}{V} \quad (5)$$

لكل جسيم

$$U_1 = v_{x1}^2 + v_{y1}^2 + v_{z1}^2$$

$$U_2 = v_{x2}^2 + v_{y2}^2 + v_{z2}^2$$

$$U_3 = v_{x3}^2 + v_{y3}^2 + v_{z3}^2$$

$$U^2 = \frac{\sum U_i^2}{N} = \frac{\sum v_{xi}^2}{N} + \frac{\sum v_{yi}^2}{N} + \frac{\sum v_{zi}^2}{N}$$

السرعة متساوية في جميع الاتجاهات x, y, z

$$\sigma^2 v_x^2 = v_y^2 = v_z^2$$

$$\sum_{i=1}^3 \text{direction } i: \frac{U^2}{3} = 3 v_x^2 \Rightarrow v_x^2 = \frac{U^2}{3}$$

من المعادله 5 و 6

①

احتمالاً در اینجا $PV^\gamma = \text{const}$

در فرآیند $Q=0$ و $dQ=0$

$$dU = dW$$

$$n C_V dT = -P dV \quad \text{--- (b)}$$

$$P = \frac{RT}{V} \quad \text{--- (c)}$$

نوع 1 و 2

$$C_V dT = -R T \frac{dV}{V}$$

$$C_V \int_{T_1}^{T_2} \frac{dT}{T} = -R \int_{V_1}^{V_2} \frac{dV}{V}$$

$$\Rightarrow -\ln \frac{V_2}{V_1} = \frac{C_V}{R} \ln \frac{T_2}{T_1}$$

در فرآیند $Q=0$

$$\ln \left(\frac{V_1}{V_2} \right)^{\frac{R}{C_V}} = \ln \frac{T_2}{T_1}$$

در اینجا C_P و C_V

$$R = C_P - C_V \Rightarrow \frac{R}{C_V} = \left(\frac{C_P}{C_V} \right) - 1$$

$$\frac{R}{C_V} = \gamma - 1$$

$$\therefore \ln \left(\frac{V_1}{V_2} \right)^{\gamma-1} = \ln \frac{T_2}{T_1}$$

$$\left(\frac{V_1}{V_2} \right)^{\gamma-1} = \frac{T_2}{T_1}$$

$$T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$$

$$T_1 P_1^{1-\gamma} = T_2 P_2^{1-\gamma}$$

$$PV = RT$$
$$T = \frac{PV}{R}$$

$$\frac{P_2 V_2}{R} (V_2)^{\gamma-1} = \frac{P_1 V_1}{R} (V_1)^{\gamma-1}$$

$$P_2 V_2^\gamma = P_1 V_1^\gamma \Rightarrow PV^\gamma = \text{const}$$

(2)

دست، الكدره T_1 لايوه على ان نقول

$$T V^{\gamma-1} = \text{const.}, \quad P V^{\gamma} = \text{const}$$

$$T P^{\frac{1-\gamma}{\gamma}} = \text{const}$$

$$P V^{\gamma} = \text{const} \quad \text{لأنه ثابت}$$

$$P V = \text{const.}$$

كذلك، السقف.

$$W = p du = -R C_V dT$$

$$P dV = -R C_V dT$$

$$W = -C_V (T_2 - T_1) = C_V (T_1 - T_2)$$

$$= C_V T_1 \left[1 - \frac{T_2}{T_1} \right] \quad \text{بالسقف}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}}$$

$$\therefore W = C_V T_1 \left(1 - \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} \right)$$

$$\text{الآن } P V^{\gamma} = \text{const}$$

$$\gamma P V^{\gamma-1} dV + V^{\gamma} dP = 0$$

$$\gamma P dV + V dP = 0$$

$$V dP = -\gamma P dV \quad \text{--- (1)}$$

$$P V = n R T$$

$$P dV + V dP = R dT$$

$$V dP = R dT - V dP \quad \text{--- (2)}$$

السقف

(3)

$$RdT - PdV = -\gamma PdV$$

Applying

$$\frac{RdV}{V} = \frac{PdV}{V} - \gamma \frac{PdV}{V}$$

$$RdT = PdV - \gamma PdV \Rightarrow RdT = PdV(1-\gamma)$$

$$\therefore PdV = \frac{RdT}{1-\gamma}$$

$$W = -\int_{V_1}^{V_2} PdV = -\int_{T_1}^{T_2} \frac{nRdT}{1-\gamma}$$

$$W = \frac{nR(T_2 - T_1)}{1-\gamma}$$

من أجل قيم T_2, T_1 يجب أن يكون W سلب
أو موجب، ← سلب يعني أن العمل قد انجز
موجب = أن العمل انجز

Q1: calculate the temperature after adiabatic compression of a gas to 10 atmospheres pressure from initial conditions of 1 atmosphere and 300 K. (a) for air (b) for Helium

$$T_B = \left(\frac{P_B}{P_A} \right)^{\frac{\gamma-1}{\gamma}} T_A = 10^{\frac{\gamma-1}{\gamma}} \times 300$$

(a) for air $\gamma = \frac{C_p}{C_v} = 1.4 \Rightarrow T_B = 5.8 \times 10^2 \text{ K}$

(b) = He $\gamma = \frac{C_p}{C_v} = \frac{5}{3} \Rightarrow T_B = 7.5 \times 10^2 \text{ K}$

Q2: (a) For a mole of ideal gas at $t_i = 0^\circ \text{C}$, Find the work done and expanded from V_0 to $10 V_0$.

(b) For an ideal gas initially at $t_i = 0^\circ \text{C}$ Find the final temperature t_f , when the volume is expanded to $10 V_0$ reversibly and adiabatically.

(a) $w = \int P dV = \int \frac{RT}{V} dV = RT \ln \frac{V_f}{V_i} = 8.31 \times 273 \ln 10 = 5.2 \times 10^3 \text{ J}$

(b) $T_f = T_i \left(\frac{V_i}{V_f} \right)^{\gamma-1} = 273 \left(\frac{1}{10} \right)^{\frac{5}{3}-1} = 59 \text{ K}$

Q1: The experience of pumping air into bicycle tyre using hand pump. Consider the air inside the pump as a thermodynamic system having volume V at atmospheric pressure and room temperature, 27°C . Assume that the nozzle of the tyre is blocked (treated as an adiabatic compression) and you push the pump to a volume $1/4$ of V . Calculate the final temperature of air in the pump.

Solution

Here, the process is adiabatic compression. The volume is given and temperature is to be found. we can use the equation (8.38)

$$T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}.$$

$$T_i = 300 \text{ K} \quad (273+27^\circ\text{C} = 300 \text{ K})$$

$$T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}.$$

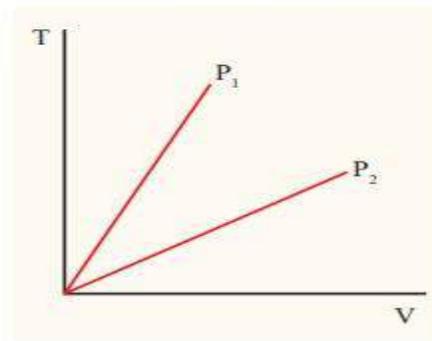
$$T_i = 300 \text{ K} \quad (273+27^\circ\text{C} = 300 \text{ K})$$

$$V_i = V \ \& \ V_f = \frac{V}{4}$$

$$T_f = T_i \left(\frac{V_i}{V_f} \right)^{\gamma-1} = 300 \text{ K} \times 4^{1.4-1} = 300\text{K} \times 1.741$$

$$T_2 \approx 522 \text{ K or } 2490\text{C}$$

Q2: The following graph shows a V-T graph for isobaric processes at two different pressures. Identify which one occurs at higher pressure.



Solution

From the ideal gas equation,

$$V = (nR/P)T$$

V-T graph is a straight line passing the origin.

The slope = $\mu R/P$

The slope of V-T graph is inversely proportional to the pressure. If the slope is greater, lower is the pressure.

Here P_1 has larger slope than P_2 . So $P_2 > P_1$.

Suppose the graph is drawn between T and V (Temperature along the x-axis and Volume along the y-axis) then will we still have $P_2 > P_1$?

Q3: One mole of an ideal gas initially kept in a cylinder at pressure 1 MPa and temperature 27°C is made to expand until its volume is doubled.

(a) How much work is done if the expansion is (i) adiabatic (ii) isobaric (iii) isothermal?

(b) Identify the processes in which change in internal energy is least and is maximum.

(c) Show each process on a PV diagram.

(d) Name the processes in which the heat

(Take $\gamma = 5/3$ and $R=8.3 \text{ J mol}^{-1} \text{ K}^{-1}$)

Solution

(a) (i) In an adiabatic process the work done by the system is

$$W_{\text{adia}} = \frac{\mu R}{\gamma - 1} [T_i - T_f]$$

To find the final temperature T_f , we can use adiabatic equation of state.

$$T_f V_f^{\gamma-1} = T_i V_i^{\gamma-1}$$
$$T_f = T_i \left(\frac{V_i}{V_f} \right)^{\gamma-1} = 300 \times \left(\frac{1}{2} \right)^{\frac{2}{3}}$$

$$= 0.63 \times 300 \text{K} = 189.8 \text{K}$$

$$W = 1 \times 8.3 \times \frac{3}{2} (300 - 189.8) = 1.37 \text{kJ}$$

(ii) In an isobaric process the work done by the system

$$W = P \Delta V = P(V_f - V_i)$$

and $V_f = 2V_i$ so $W = 2PV_i$

To find V_i , we can use the ideal gas law for initial state. $P_i V_i = RT_i$

$$V_i = \frac{RT_i}{P_i} = 8.3 \times \frac{300}{1} \times 10^{-6} = 24.9 \times 10^{-4} \text{m}^3$$

The work done during isobaric process,

$$W = 2 \times 10^6 \times 24.9 \times 10^{-4} = 4.9 \text{ kJ}$$

(iii) In an isothermal process the work done by the system,

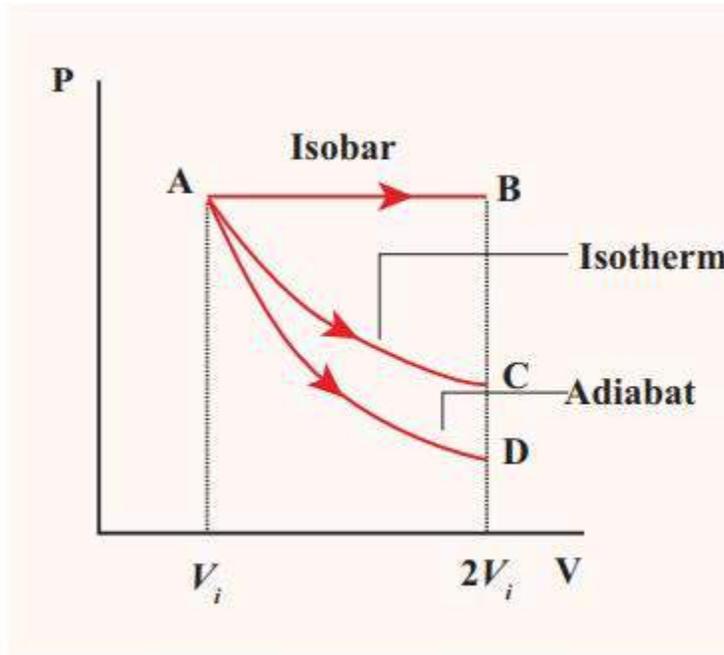
$$W = \mu RT \ln \left(\frac{V_f}{V_i} \right)$$

In an isothermal process the initial room temperature is constant.

$$W = 1 \times 8.3 \times 300 \times \ln(2) = 1.7kJ$$

(b) Comparing all three processes, we see that the work done in the isobaric process is the greatest, and work done in the adiabatic process is the least.

(c) The PV diagram is shown in the Figure.



The area under the curve AB = Work done during the isobaric process

The area under the curve AC = Work done during the isothermal process

The area under the curve AD = Work done during the adiabatic process

From the PV diagram the area under the curve AB is more, implying that the work done in isobaric process is highest and work done in adiabatic process is least.

(d) In an adiabatic process no heat enters into the system or leaves from the system. In an isobaric process the work done is more so heat supplied should be more compared to an isothermal process.

Q4: A fresh air is composed of nitrogen N_2 (78%) and oxygen O_2 (21%). Find the rms speed of N_2 and O_2 at 20°C .

Solution:

For Nitrogen,

Molar mass $m = 0.0280 \text{ kg/mol}$

Temperature $T = 20^\circ\text{C} = 20 + 273 = 293\text{K}$

$$\begin{aligned}
 R &= 8.314 \text{ J mol}^{-1} \text{ K}^{-1} \\
 V_{\text{rms}} &= \sqrt{\frac{3RT}{m}} \\
 &= \sqrt{\frac{3 \times 8.31 \times 293}{0.0280}} = \sqrt{2610 \times 10^2} \\
 &= 511 \text{ ms}^{-1} \\
 V_{\text{rms}} \text{ of } N_2 &= 511 \text{ ms}^{-1} \\
 \text{For } O_2 \\
 \text{Molar mass } M &= 0.0320 \text{ kg mol}^{-1}. \\
 V_{\text{rms}} &= \sqrt{\frac{3 \times 8.31 \times 293}{0.0320}} = \sqrt{2280 \times 10^2} \\
 V_{\text{rms}} \text{ of } O_2 &= 478 \text{ ms}^{-1}
 \end{aligned}$$

Q 5. A gas is at temperature 80°C and pressure $5 \times 10^{-10} \text{ Nm}^{-2}$. What is the number of molecules per m^3 , if Boltzmann's constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$

Solution:

Temperature of gas $T = 80^\circ\text{C} = 80 + 273 = 353\text{K}$

Pressure of gas $P = 5 \times 10^{-10} \text{ Nm}^{-2}$

Boltzmann's constant $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

Volume of gas $V = 1 \text{ m}^3$

No. of molecules $n = ?$

$$\begin{aligned}
 n &= \frac{PV}{kT} = \frac{5 \times 10^{-10} \times 1}{1.38 \times 10^{-23} \times 353} = \frac{5 \times 10^{-10}}{487 \times 10^{-23}} \\
 n &= 0.1026 \times 10^{13} \text{ (or) } 1.02 \times 10^{11}
 \end{aligned}$$

Q6: During an adiabatic process, the pressure of a mixture of monatomic and diatomic gases is found to be proportional to the cube of the temperature. Find the value of $\gamma = (C_p/C_v)$

Solution

In an adiabatic process, $P^{1-\gamma} T^\gamma = \text{constant}$
 $P \propto T^3$
 $P T^3 = \text{constant} \quad \dots(1)$
 $P T^{1-\gamma} = \text{constant} \quad \dots(2)$
 From (1) and (2)
 $\frac{\gamma}{1-\gamma} = (-3)$
 $\gamma = -3 + 3\gamma$
 $3 = 3\gamma - \gamma$
 $\gamma = \frac{3}{2}$

Q7: Calculate the mean free path of air molecules at STP. The diameter of N_2 and O_2 is about $3 \times 10^{-10} \text{ m}$

Solution

Diameters of N_2 & O_2
 $d = 3 \times 10^{-10} \text{ m}$
 n - number density using ideal gas law
 $n = \frac{N}{V} = \frac{P}{kT} = \frac{101.3 \times 10^3}{1.381 \times 10^{-23} \times 273}$
 $= \frac{101.3 \times 10^3}{377.01 \times 10^{-23}} = 0.2687 \times 10^{26}$
 $\lambda = \frac{1}{\sqrt{2} \pi n d^2}$
 $\lambda = \frac{1}{3.14 \times 1.414 \times 0.2687 \times 10^{26} \times (3 \times 10^{-10})^2}$
 $= \frac{1}{10.74 \times 10^6} = 0.0931 \times 10^{-6}$
 $\lambda = 9.31 \times 10^{-8} \text{ m}$

Q8: Estimate the total number of air molecules in a room of capacity 25 m³ at a temperature of 27°C.

Solution:

Volume of the room $V = 25.0\text{m}^3$

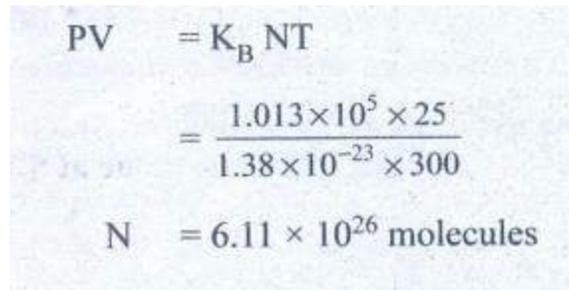
Temperature of the room $T = 27^\circ\text{C} = 300\text{K}$

Pressure in the room $P = \text{estimate}$

$$= 1 \times 1.013 \times 10^5 \text{ Pa}$$

The ideal gas equation relating pressure (P), volume (v) absolute temperature (T) can be written is

$$PV = K_B NT$$


$$\begin{aligned} PV &= K_B NT \\ N &= \frac{1.013 \times 10^5 \times 25}{1.38 \times 10^{-23} \times 300} \\ N &= 6.11 \times 10^{26} \text{ molecules} \end{aligned}$$

Q9: A football at 27°C has 0.5 mole of air molecules. Calculate the internal energy of air in the ball.

Solution

The internal energy of ideal gas = $\frac{3}{2} NkT$. The number of air molecules is given in terms of number of moles so, rewrite the expression as follows

$$NK = nR$$

Temperature $T = 273 + 27 = 300\text{K}$

$$U = \frac{3}{2} \times 0.5 \times 8.31 \times 300 = 1869.75\text{J}$$

Q10: A room contains oxygen and hydrogen molecules in the ratio 3:1. The temperature of the room is 27°C. The molar mass of O₂ is 32 g mol⁻¹ and for H₂ 2 g mol⁻¹. The value of gas constant R is 8.32 J mol⁻¹K⁻¹

Calculate

(a) rms speed of oxygen and hydrogen molecule

(b) Average kinetic energy per oxygen molecule and per hydrogen molecule

(c) Ratio of average kinetic energy of oxygen molecules and hydrogen molecules

Solution

(a) Absolute Temperature

$$T = 27^\circ\text{C} = 27 + 273 = 300 \text{ K.}$$

Gas constant $R = 8.32 \text{ J mol}^{-1}\text{K}^{-1}$

For Oxygen molecule: Molar mass

$$M = 32 \text{ gm} = 32 \times 10^{-3} \text{ kg mol}^{-1}$$

$$\begin{aligned} M &= 32 \text{ gm} = 32 \times 10^{-3} \text{ kg mol}^{-1} \\ \text{rms speed } v_{rms} &= \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.32 \times 300}{32 \times 10^{-3}}} \\ &= 483.73 \text{ m s}^{-1} \approx 484 \text{ m s}^{-1} \end{aligned}$$

For Hydrogen molecule:

$$\text{Molar mass } M = 2 \times 10^{-3} \text{ kg mol}^{-1}$$

$$\begin{aligned} \text{rms speed } v_{rms} &= \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.32 \times 300}{2 \times 10^{-3}}} \\ &= 1934 \text{ m s}^{-1} = 1.93 \text{ km s}^{-1} \end{aligned}$$

Note that the rms speed is inversely proportional to \sqrt{M} and the molar mass of oxygen is 16 times higher than molar mass of hydrogen. It implies that the rms speed of hydrogen is 4 times greater than rms speed of oxygen at the same temperature.

$$1934/484 \approx 4 .$$

(b) The average kinetic energy per molecule is $3/2 kT$. It depends only on absolute temperature of the gas and is independent of the nature of molecules. Since both the gas molecules are at the same temperature, they have the same average kinetic energy per molecule. k is Boltzmann constant.

$$\frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = 6.21 \times 10^{-21} \text{ J}$$

(c) Average kinetic energy of total oxygen molecules = $3/2 N_0 kT$

Where N_0 - number of oxygen molecules in the room

Average kinetic energy of total hydrogen molecules = $\frac{3}{2} N_H kT$

where N_H - number of hydrogen molecules in the room.

It is given that the number of oxygen molecules is 3 times more than number of hydrogen molecules in the room. So the ratio of average kinetic energy of oxygen molecules with average kinetic energy of hydrogen molecules is 3:1

Q11: Ten particles are moving at the speed of 2, 3, 4, 5, 5, 5, 6, 6, 7 and 9 m s⁻¹. Calculate rms speed, average speed and most probable speed.

Solution

The average speed

$$\bar{v} = \frac{2+3+4+5+5+5+6+6+7+9}{10} = 5.2 \text{ m s}^{-1}$$

To find the rms speed, first calculate the mean square speed \bar{v}^2

$$\bar{v}^2 = \frac{2^2+3^2+4^2+5^2+5^2+5^2+6^2+6^2+7^2+9^2}{10}$$

$$= 30.6 \text{ m}^2 \text{ s}^{-2}$$

The rms speed

$$v_{rms} = \sqrt{\bar{v}^2} = \sqrt{30.6} = 5.53 \text{ m s}^{-1}$$

The most probable speed is 5 ms⁻¹ because three of the particles have that speed.

Q12: Calculate the rms speed, average speed and the most probable speed of 1 mole of hydrogen molecules at 300 K. Neglect the mass of electron.

Solution

The hydrogen atom has one proton and one electron. The mass of electron is negligible compared to the mass of proton.

Mass of one proton = $1.67 \times 10^{-27} \text{ kg}$.

One hydrogen molecule = 2 hydrogen atoms = $2 \times 1.67 \times 10^{-27} \text{ kg}$.

The average speed

$$\bar{v} = \sqrt{\frac{8kT}{\pi m}} = 1.60 \sqrt{\frac{kT}{m}}$$

$$= 1.60 \sqrt{\frac{(1.38 \times 10^{-23}) \times (300)}{2(1.67 \times 10^{-27})}} = 1.78 \times 10^3 \text{ m s}^{-1}$$

(Boltzmann Constant $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$)

The rms speed $v_{rms} = \sqrt{\frac{3kT}{m}} = 1.73 \sqrt{\frac{kT}{m}}$

$$= 1.73 \sqrt{\frac{(1.38 \times 10^{-23}) \times (300)}{2(1.67 \times 10^{-27})}} = 1.93 \times 10^3 \text{ m s}^{-1}$$

Most probable speed $v_{mp} = \sqrt{\frac{2kT}{m}} = 1.41 \sqrt{\frac{kT}{m}}$

$$= 1.41 \sqrt{\frac{(1.38 \times 10^{-23}) \times (300)}{2(1.67 \times 10^{-27})}} = 1.57 \times 10^3 \text{ m s}^{-1}$$

Note that $v_{rms} > \bar{v} > v_{mp}$

Q13: Find the adiabatic exponent γ for mixture of μ_1 moles of monoatomic gas and μ_2 moles of a diatomic gas at normal temperature.

The specific heat of one mole of a monoatomic

gas $C_v = \frac{3}{2} R$

For μ_1 mole, $C_v = \frac{3}{2} \mu_1 R$ $C_p = \frac{5}{2} \mu_1 R$

The specific heat of one mole of a diatomic gas

$$C_v = \frac{5}{2} R$$

For μ_2 mole, $C_v = \frac{5}{2} \mu_2 R$ $C_p = \frac{7}{2} \mu_2 R$

The specific heat of the mixture at constant

volume $C_v = \frac{3}{2} \mu_1 R + \frac{5}{2} \mu_2 R$

The specific heat of the mixture at constant

pressure $C_p = \frac{5}{2} \mu_1 R + \frac{7}{2} \mu_2 R$

The adiabatic exponent $\gamma = \frac{C_p}{C_v} = \frac{5\mu_1 + 7\mu_2}{3\mu_1 + 5\mu_2}$