

Previous year questions

(Heat and Thermodynamics)

2020

(a) Write down the fundamental assumptions of kinetic theory of gases.

(b) Show that, $P = \frac{N}{V} k T$, where symbols have their usual meaning.

(c) Write a short note of intermolecular forces.

2. (a) What are the corrections involved in kinetic theory of gases that lead to the equation of state for a real gas.

(b) Argon with density 100 kg/m³ under a pressure

of 10 mpa is in pressure vessel. Consider each pressure to be a pressure of argon under each pressure. Calculate P_{136} N/m² mole. [2, 201 is molar mass of argon]

Wels gas find its temperature [Ans: 0.136 N/m² mole, $b_2 = 3.201$ is molar volume]

- (a) How can the critical points P_c , T_c and ρ_c are fixed by the van der waals constants a and b .
- (b) Using transport phenomena of gases, obtain an expression for thermal conductivity of it.
- (c) Define thermodynamics systems.
- (d) State the zeroth law of thermodynamics.
- (e) write the comparison between heat and work.
- (f) State and prove the first law of thermodynamics.
- Q. What is adiabatic process? Derive the equation of work done during an adiabatic process.
- (g) Define reversible and irreversible processes. Write down the conditions of reversible process for an heat engine.

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(c) What is thermodynamics equilibrium.

(a) State the Kelvin-Planck as well as Clausius version of the second law of thermodynamics.

(b) Show that the Kelvin-Planck and Clausius statements of second law of thermodynamics are equivalent

(c) What is refrigeration? Write down the working mechanism of a refrigerator.

(d) State and prove Carnot's theorem.

(e) Define entropy. Illustrate the Carnot's diagram

cycle in entropy-temperature (S-T) diagram.

(f) Calculate the entropy of one mole of an ideal gas,

(c) Define compound and show their relation.

(b) What do you mean by equilibrium state?
Deduce the relation $PV = \text{constant}$

(c) What is internal energy of half mole?

2019

(c) Show from the kinetic theory of gases that mean kinetic energy of translation of one molecule of a perfect gas is $\frac{3}{2} kT$.

(d) Explain the principle of equal partition of energy.

(e) Define mean free path. Show that the mean free path is inversely proportional

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to the molecules per cm³. compute the diameter of the molecules.

(b) Using the first law of thermodynamics show that $C_P - C_V = \left[P + \left(\frac{\partial V}{\partial T} \right)_P \right] \left(\frac{\partial V}{\partial T} \right)_P$ use this result to show

$$(i) C_P - C_V = R \text{ for an ideal gas}$$

(ii) $C_P - C_V = R \cdot \left(1 + \frac{2k}{3N} \right)$ for an non-ideal gas

Note that $P + \left(\frac{\partial V}{\partial T} \right)_P = T \left(\frac{\partial P}{\partial T} \right)_V$

(iii) $T \left(\frac{\partial U}{\partial T} \right)_V = \text{constant}$

(c) The grams of oxygen are heated at constant

atmosphere pressure from 270 to 127 °C. How much heat is transferred to the oxygen?

Friction of the heat is used to raise the internal energy of the oxygen.

Work done by friction is equal to

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(d)

An ideal gas is originally confined to a volume

within an insulated container of volume V_1 . The remainder of the container is evacuated. The partition is then removed and the gas expands to fill the entire container. If the initial temperature of the gas was T_1 , what was the final temperature?

(e)

A Carnot's refrigerator extracts 35.0 KJ of heat during each cycle. operating with a coefficient of performance of 4.60. What is the energy per cycle transferred as heat to the room and (ii) the work done per cycle.

(f)

Consider a steam engine that operates between a maximum steam temperature of $500^\circ C$ and an ambient temperature of $20^\circ C$. If the

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efficiency of it.

- (a) What are the thermodynamic potential function
- (b) State and explain third law of thermodynamics
- (c) Deduce the four relation of Maxwell.
- (d) Show that $\left(\frac{\partial P}{\partial T}\right)_V + \left(\frac{\partial V}{\partial T}\right)_P = \left(\frac{\partial^2 F}{\partial P \partial T}\right)$
2. (a) What do you mean by transport properties of gas, obtain an expression for thermal conductivity of the gas.
- (b) Write a short note of Andreev curve.
3. (a) Air is compressed adiabatically to half its original volume. If the air was initially

at 24°

and the atmospheric pressure when

calculate the final temperature and pressure

using the equations of state and the ideal gas law.

c) (a) State and prove increase of entropy.

(b) Show that the isothermal work done of

an ideal gas is $W = \frac{P_1 V_1}{R} \ln \frac{V_2}{V_1}$ where (i)

(a) calculate the work done upon expansion

of one mole of gas thermally from volume

to volume V_2 when the equation of state is

$$\left(\frac{P + \frac{a}{V^2}}{\frac{RT}{V} + \frac{b}{V}}$$

where a and b are constants.

Using the definition of entropy.

It shows that a change

in entropy is due to work done.

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Previous year question solution

class 11th
Heat and thermodynamics

2020

10. (a) Basic assumption of the kinetic theory of gases:

gas particles do not interact with each other.

1. A confined gas or a material consists of an extremely large number of identical molecules.

2. The gas molecules can be treated as an ideal particle, i.e., it has mass but its structure and size can be ignored as compared with the intermolecular separation in a dilute gas and the dimensions of the container.

3. The molecules are continuously moving at random with velocities colliding with each other and with the walls of the container and the motion obey Newton's law of motion.

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(4) the pressure exerted by a gas due to the continuous movement of the molecules with the walls of the container.

(5) between the successive collisions the molecule move in straight line uniform velocities

(6) the distribution of velocities among the molecules do not change with time.

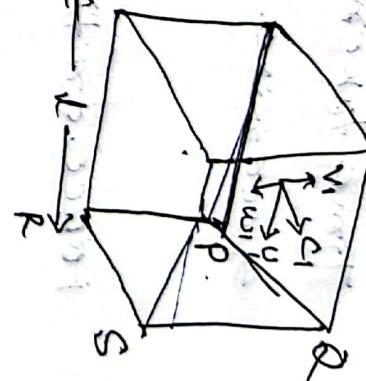
(7) when molecules collide with each other no energy is gained or lost.

(8) the kinetic energy of gases increase with increased temperature.

(9) the molecules are in continuous random motion:

(10) there are no forces of attraction or repulsion between the molecules.

(b) Let us consider a diatomic gas inside a cube of side L . Let us consider --- (n) the velocity of a molecule of mass m .



Let (v_1, v_2, v_3) , $(v_{1'}, v_{2'}, v_{3'})$ be the rectangular components v_1, v_2, v_3 in the respective directions. Then $v_2' = -v_2 + v_1 + v_3$ and so on.

Now momentum of the first molecules along x -axis $= m v_1$

$$x \text{-axis} = m v_1$$

After collision with face ~~PARS~~, it comes back with same velocity. So, momentum along x -

axis after collision $= -m v_1$
= $-m v_1 - (m v_1)$

Now the change in momentum of the molecule

$$= -m v_1 - (m v_1)$$

$$= -2 m v_1$$

The momentum imputed to the face

Time taken by the molecule between two successive collisions $t = \frac{2L}{u_i}$

Force on the surface perpendicular to 1st molecule

$$F_1 = \frac{dp}{dt} = \frac{2mu_1}{L}$$

Similarly force due to the 2nd molecule

$$F_2 = \frac{mu_2^2}{L}$$

Total force along x-axis,

$$F_x = F_1 + F_2 + \dots + F_n$$

$$F_x = \frac{m}{L} (u_1^2 + u_2^2 + \dots + u_n^2)$$

Pressure exerted along x-axis

$$P_x = \frac{F_x}{L^2} = \frac{m}{L^3} (u_1^2 + u_2^2 + \dots + u_n^2)$$

Similarly pressure exerted along y-axis

$$P_y = \frac{m}{L^3} (v_1^2 + v_2^2 + \dots + v_n^2)$$

and so on to get pressures on y and z axes

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and pressure exerted along τ -axis

$$P_x = \frac{m}{k_B} (w_1^2 + w_2^2 + w_n^2)$$

The gas is uniform throughout the tube

Therefore, $P_x = P_y = P_z = P$

$$\Rightarrow P_z = \frac{m}{3k_B} [(v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2)]$$

$$= \frac{m}{3k_B} [(v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2)]$$

$$= \frac{m}{3k_B} [(v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2) + (c_1^2 + c_2^2 + c_n^2)]$$

$$= \frac{m}{3k_B} [(v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2) + (c_1^2 + c_2^2 + c_n^2)]$$

$$= \frac{m}{3k_B} [(c_1^2 + c_2^2 + c_n^2) + (v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2)]$$

$$= \frac{m}{3k_B} [(c_1^2 + c_2^2 + c_n^2) + (v_1^2 + v_2^2 + v_n^2) + (w_1^2 + w_2^2 + w_n^2)]$$

Newton's equa)

$$P = \frac{m}{3\sqrt{c^3}} \quad P = \frac{m}{\gamma}$$

$$P = \frac{1}{3} \rho c^2$$

(c) write short note on intermolecular force.

An intermolecular force is the force that mediates interaction between molecules, including the electromagnetic forces of attraction or repulsion which act between atoms and other

types of neighbouring particles - e.g atoms or ions. Intermolecular forces - the forces which hold molecules together. For example the covalent bond involving sharing electron pairs between atoms

is much stronger than the force present between neighboring molecules. Both sets of forces are essential parts of force fields frequently used in.

2.(a) State van der waals equation of state derived by making some modification of the assumption on the kinetic theory of gases.

Firstly, In kinetic theory, size of the gas molecules was ignored. Hence the available volume occupied by a gas molecule within a container was that of the container. Actually, the molecules are small but they have some finite size. At low pressure their are only few molecules hence the volume occupied by them may be ignored. At high pressure, the volume occupied by them can't be ignored. Hence the available volume will be decreased.

Volume correction: Let there are n molecules of gas within a enclosure of volume, V . If r be the radius of the each molecule then the

occupied by each molecule of the gas (v)
be a regular cube of side length

$$a = \frac{4}{3} \pi r^3 n^{-1}$$

$$V = \left(\frac{4}{3} \pi r^3 n^{-1} \right)^3$$

$$\text{exp. vol.} = \frac{9}{3} \pi r^3 a^3$$

then $a = 2.8 \times 10^{-10} \text{ m}$ is the diameter of a molecule

Volume available to first molecule = $V - N \cdot \frac{4}{3} \pi r^3 n^{-1} V^2$

for further molecules \therefore $V - (N-1) \cdot \frac{4}{3} \pi r^3 n^{-1} V^2$

thus total volume available $= V - N \cdot \frac{4}{3} \pi r^3 n^{-1} V^2$

Average space (or volume) available to each molecule will be $\frac{V - N \cdot \frac{4}{3} \pi r^3 n^{-1} V^2}{N}$

$$= \frac{V - \frac{4}{3} \pi r^3 n^{-1} V^2 + (V - N \cdot \frac{4}{3} \pi r^3 n^{-1} V^2)}{N}$$

$$= V - \frac{4}{N} \cdot \frac{\pi r^3 n^{-1}}{2} \cdot [N - 1] \quad (1)$$

constant is same for all molecules
thus $\frac{4}{N} \cdot \frac{\pi r^3 n^{-1}}{2} = \frac{4}{N} \cdot \frac{\pi r^3 n^{-1}}{2}$

$$= \frac{4}{N} \cdot \frac{\pi r^3 n^{-1}}{2} \cdot [N - 1] \therefore \text{molecules have different sizes}$$

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$$= V - \frac{n(\pi r)}{2}$$

$$= V - 4\pi r$$

If there are n mole of gas,

$$N = n N_A$$

Average space available to each molecule will be

$$\pi r_{\text{max}}^2 = V - n b \quad [\text{where } b = 4\pi r_{\text{max}}^3]$$

thus, the equation of state of the gas will be

$$P(V-nb) = nRT$$

For one mole of the gas,

$$P(V-b) = RT + b$$

pressure correction: the pressure correction

$$= \left(P + \frac{b}{V} \right)$$

After volume correction the equation of state

will be

$$P(V-b) = RT + \frac{b}{V} + \frac{b^2}{V^2} + \frac{b^3}{V^3} + \dots$$

$$P(V-b) = \frac{RT}{V} + \frac{b}{V} + \frac{b^2}{V^2} + \frac{b^3}{V^3} + \dots$$

$$P = \frac{RT}{V-b} + \frac{b^2}{V^2} \quad [\text{where reduction of pressure is considered}]$$

$$\left(\frac{P+\frac{\alpha}{V^2}}{V-b}\right) (V-b) = RT \quad (n)$$

For n mole of gas,

$$\left(\frac{P+\frac{\alpha}{V^2}}{V-b}\right) (V-b) = nRT = \text{Ans} \quad (n)$$

$\left(\frac{P+\frac{\alpha}{V^2}}{V-b}\right) (V-b) = nRT$ This equation is called the van der waals equation of state for real gas.

2. (c) For lone of the gas, the van der waals equation is,

$$\left(\frac{P+\frac{\alpha}{V^2}}{V-b}\right) (V-b) = RT \quad (1)$$

$$\Rightarrow \left(\frac{PV^2+\alpha}{V^2}\right) (V-b) = RT$$

$$\Rightarrow (PV^2+\alpha) (V-b) = RTV^2$$

$$\Rightarrow PV^2 - PV^2b + \alpha V - \alpha b = RTV^2$$

$$\Rightarrow V^2 - V^2b - \frac{RT}{P} \approx V^2 + \frac{\alpha}{P} V - \frac{\alpha b}{P} = 0$$

$$\Rightarrow V^2 - \left(b + \frac{RT}{P}\right) V + \frac{\alpha}{P} V - \frac{\alpha b}{P} = 0 \quad (n)$$

At the critical temperature, all the roots become equal for a particular value of pressure, so we should have,

$$\Rightarrow (V - V_c)^2 = 0 \quad (\text{iv})$$

$$\Rightarrow V^3 - 3V^2 V_c + 3V V_c^2 - V_c^3 = 0 \quad (\text{v})$$

At the critical point $P \rightarrow P_c$ or $V \rightarrow V_c$, the equation (v) becomes,

$$V^3 - (b + \frac{R T_c}{P_c}) V^2 + \frac{a}{P_c} V - \frac{ab}{P_c} = 0 \quad (\text{vi})$$

At critical point the equations (iv) and (vi) must be identical.

$$3V^2 b + \frac{RT_c}{P_c} = 0 \quad (\text{v})$$

$$and 3V^2 = \frac{ab}{P_c} \quad (\text{vii})$$

$$and also \frac{V^3}{P_c} = \frac{ab}{P_c} \quad (\text{viii})$$

Dividing equation (vii) by (viii) we get,

$$\frac{1}{3} V_c = b$$

$$V_c = 3b$$

Putting the value of V_c in eqn (v) we

gets,

$$3(3b)^2 = \frac{\alpha}{P_c}$$

$$\Rightarrow P_c = \frac{\alpha}{27b^2} \quad (\text{Ans})$$

Putting the value of P_c and V_c in eqn (v)

$$2XL8b) = b + \frac{RT_c}{P_c}$$

$$\Rightarrow T_c = \frac{P_c}{R} (C_9b - b) = \frac{\alpha}{R} + \frac{1}{V} \left(\frac{\alpha}{3b} + b \right) =$$

$$T_c = \frac{\alpha}{27b^2 R} + 8b$$

$$= \frac{8\alpha}{27bR}$$

Thus, the critical temperature

$$(v) \quad T_c = \frac{8\alpha}{27bR}$$

the critical pressure, $P_c = \frac{\alpha}{27b^2}$

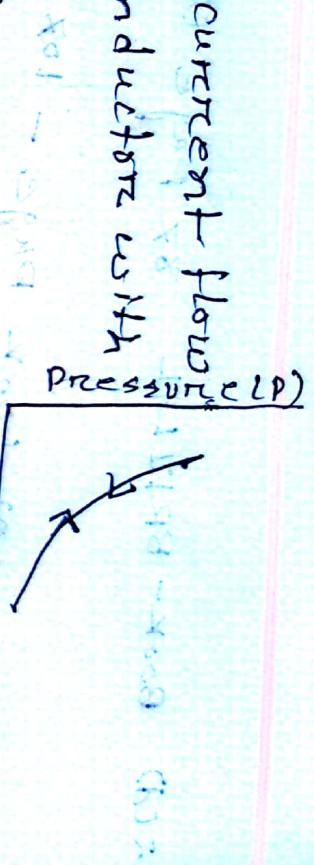
the critical volume, $V_c = 3b$

Ans

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- (c) Book - BRIT LAL 8x page (Nos)
3. (a) BRIT LAL book page - 10x
- (b) BRIT LAL book page - 10x
- (d) BRIT LAL book page - 11x
- (c) BRIT LAL book page - 110
- (e) BRIT LAL book page - 118 - 122
- (f) reversible process: A process in which the system and surrounding can be returned to the original conditions from the final state without producing any changes in the thermodynamic properties of the universal if the process reversed.
- BRIT LAL - 132 page

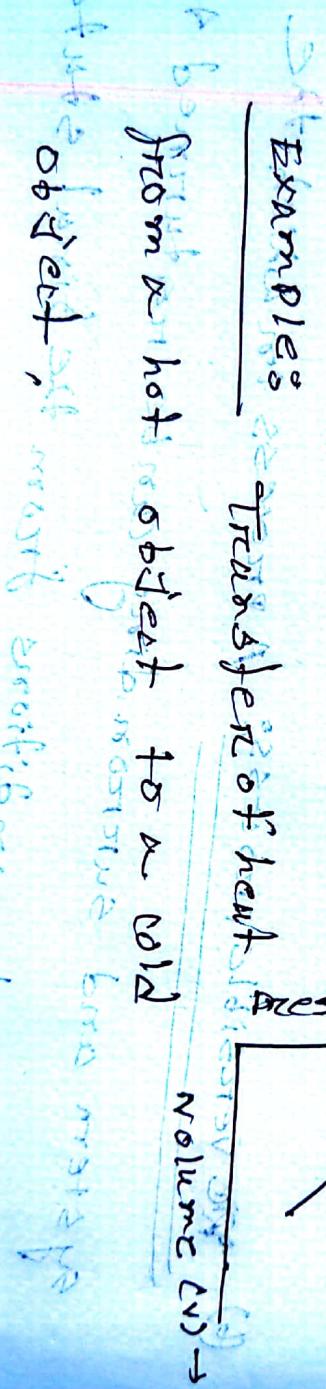
Example: current flowing through a conductor with resistance.



Irreversible processes

An irreversible process is a process in which both the system and surrounding do not return to their original condition unless the process is initiated.

→ Examples → transfer of heat from a hot object to a cold object, rust formation, aging etc.



Condition of ~~irreversible~~ processes: nothing can go back to its original state.

- (1) For the process is carried out infinitesimally slowly.

2. At any stage, the equilibrium is not disturbed.
3. It takes infinite time for completion.
4. Work obtained in this process is maximum.
5. It is an ideal process.
6. (a) PDF (second law of thermodynamics)
- (b) PDF (second law of thermodynamics)
- (c) PDF (second law of thermodynamics)
7. (a) BRILAL — page - 140
BRILAL — page - 134 vi absent
- (b) BRILAL — page - 140
BRILAL — page - 134 vi absent
- (c) BRILAL book page - 113
8. (a) BRILAL book (page) — 148 - 119 absent
- (b) BRILAL book (page) — 148 - 119 absent
- (c) BRILAL book page - 113

• correct and not write in
• (e) BRIAL Book (page) → 13 lesson 11.3

(d)

Principle of equal partition of energy:

The equipartition theorem relates the temperature of system with its average energies. The

original idea of equipartition was that, in thermal equilibrium, energy is shared equally among all of its various forms, for example

the average kinetic energy per degree of freedom in the translational motion of a molecule

Should equal that of its rotational motions.

At temperature T , the average energy of any quadratic degrees of freedom is $1/2 kT$.

For a system of N molecules each with f degrees of freedom

$$\text{U}_{\text{thermal}} = N_f \frac{1}{2} kT$$

2. (a)

$$\text{BRILLOUIN PAGE} \rightarrow 83 \quad \nu_{\text{f}}(v) = g(v)$$

3. If v and T are chosen as the independent variables,

$$\frac{\partial g}{\partial v} + \frac{\partial g}{\partial T} \nu^2 \left(\frac{\partial^2 g}{\partial v^2} \right)^{-1} = \frac{\partial g}{\partial T}$$

Differentiating equation (1),

$$\left[\frac{\partial^2 g}{\partial v^2} + 2 \frac{\partial^2 g}{\partial v \partial T} \nu^2 \right] dT = \left(\frac{\partial^2 g}{\partial T^2} \right) \nu^2 dT + \left(\frac{\partial^2 g}{\partial v \partial T} \right)_T d\nu$$

If an amount of heat S is supplied to a thermodynamic system, say an ideal gas and if the initial system say at constant pressure

volume increases by $d\nu$ according to the first law of thermo-

$$P_2 \text{ then according to the first law of thermodynamics}$$

$$dS = \nu \left(\frac{\partial \nu}{\partial T} \right) dT + \nu \left(\frac{\partial \nu}{\partial P} \right) dP$$

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$\text{d}Q = \text{d}u + \text{d}v$ (1)

$$\text{d}u = P \cdot \text{d}v$$

$$\text{d}Q = \text{d}u + P \cdot \text{d}v$$

Work done by gas is compressible

Substituting the value of $\text{d}u$ from eq (1)

$$\text{d}Q = \left(\frac{\partial u}{\partial T}\right)_V \text{d}T + \left(\frac{\partial v}{\partial T}\right)_P \text{d}P + \text{d}v$$

Dividing both sides by $\text{d}T$ we get v & P .

$$\frac{\text{d}Q}{\text{d}T} = \left(\frac{\partial u}{\partial T}\right)_V + \left(\frac{\partial v}{\partial T}\right)_P + \frac{\text{d}v}{\text{d}T}$$

$$\text{d}Q = \left(\frac{\partial u}{\partial T}\right)_V \text{d}T + \left[\left(\frac{\partial v}{\partial T}\right)_P + \left(\frac{\partial v}{\partial T}\right)_V\right] \text{d}P$$

If the gas is heated at constant volume
(By definition of heat capacity at constant volume)

$$\text{d}Q = \left(\frac{\partial u}{\partial T}\right)_V \text{d}T$$

$$\frac{\text{d}Q}{\text{d}T} = \left(\frac{\partial u}{\partial T}\right)_V$$

Integrating we get

$$\left(\frac{\partial u}{\partial T}\right)_V = \left(\frac{\partial v}{\partial T}\right)_V = C_V$$

When the gas is heated at constant pressure

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from equation (i) $\left(\frac{\partial U}{\partial T}\right)_V + \left(\frac{\partial Q}{\partial V}\right)_T = 0$

$$C_P = \left(\frac{\partial U}{\partial T}\right)_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right] \left(\frac{\partial V}{\partial T}\right)_P$$

$$C_V = C_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right] \left(\frac{\partial V}{\partial T}\right)_P$$

$$C_P - C_V = \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right] \left(\frac{\partial V}{\partial T}\right)_P$$

From Joule's experiments for an ideal gas on opening the stopcock, no work was done and no heat transfer took place. So $\delta Q = dU + 0$. Therefore $dU = 0$. Even though the temperature is constant while the internal energy changes, there is no change in the internal energy.

$$\left(\frac{\partial U}{\partial T}\right)_V = 0$$

From the ideal gas equation

$$\frac{PV = RT}{P(V-T)} = R$$

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$$C_P - C_V = P \left(\frac{\partial V}{\partial T} \right) P + \left(\frac{\partial V}{\partial T} \right)_P + \left(\frac{\partial V}{\partial T} \right)_P$$

isothermal process

$$\left(\frac{\partial V}{\partial T} \right)_T = 0$$

$$P \left(\frac{\partial V}{\partial T} \right)_T \left[1 + \left(\frac{V}{T} \right) + q \right] + v \left(\frac{\partial V}{\partial T} \right)_T = 0$$

$$C_P - C_V = P \left[\frac{\partial V}{\partial T} \right] P = P$$

$$\boxed{C_P - C_V = \frac{P}{T} \left[1 + \left(\frac{V}{T} \right) + q \right]} = 10 - 9.0$$

Ques 20 (b) 1. As ν is not constant taking $P_V = RT$ is wrong as ν is not constant

$$0 + \nu b = 0 \Rightarrow \nu = 0 \Rightarrow \text{At pressure}$$

$\nu = \frac{RT}{P}$ is constant
But R is constant
 P is constant
 T is constant

For $\nu = \text{constant}$ $P_V^\nu = \text{constant}$

Also $P \left(\frac{RT}{P} \right)^\nu = \text{constant}$

$$P \left(\frac{RT}{P} \right)^\nu = \text{constant} + \nu \left(\frac{\partial V}{\partial T} \right)$$

$$\frac{R^\nu T^\nu}{P^{\nu-1}}$$

~~is not constant~~

Ans 10.0

$$\frac{P^{\nu-1}}{T^\nu}$$

~~$\nu = \frac{\partial V}{\partial T}$~~

$$T P C_V P^\nu = \text{constant}$$

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x. (a) BRUTAL page - 219

(b) BRUTAL page - 208

2021 $\frac{W}{V} = \text{constant}$ in traps

10 (a)

BRUTAL pages 50 = 0.50

2 (b)

BRUTAL pages 50 = 0.50

processes in which work is done

for moving gas,

$PV = nRT$

or, $P = \frac{nRT}{V}$

work done for volume changes from V_1 to V_2

$$W = \int_{V_1}^{V_2} P dV = \int_{V_1}^{V_2} \frac{nRT dV}{V} = nRT \int_{V_1}^{V_2} \frac{dV}{V}$$

nRT

$$\begin{aligned} W &= nRT \left[\ln V \right]_{V_1}^{V_2} \\ &= nRT \left[\ln \left(\frac{V_2}{V_1} \right) \right] \\ &= nRT \ln \left(\frac{V_2}{V_1} \right) \end{aligned}$$

We know, \ln isothermal process adiabatic

$\frac{V_2}{V_1} = k$

$$N = Q = \alpha RT \ln\left(\frac{V_2}{V_1}\right)$$

(P) *Boyle's Law*

$$\text{So that } N = \alpha RT \ln \frac{V_2}{V_1}$$

1805

4. (c) In adiabatic process

$$dQ = 0 = dU + dW$$

$$dU = -dW$$

$$dU = -dW$$

Adiabatic compression

If the first internal energy is u_1 and second is u_2 then we have, v_2

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

Proof:
 ~~from first law of thermodynamics~~
 ~~constant volume specific heat capacity~~
 $V_2 < V_1$

$$\frac{du_2 - u_1}{V_2 - V_1} = \frac{dT_2 - T_1}{V_2 - V_1}$$

$$\therefore u_2 > u_1$$

$$\frac{du_2 - u_1}{V_2 - V_1} = \frac{v_2 \frac{dT_2 - T_1}{V_2 - V_1}}{V_2 - V_1}$$

$$\frac{du_2 - u_1}{V_2 - V_1} = \frac{v_2 \frac{1}{\gamma+1} (T_2^{\gamma+1} - T_1^{\gamma+1})}{V_2 - V_1}$$

$$N = \int_{V_1}^{V_2} \frac{K}{V^\gamma} dV = K \int_{V_1}^{V_2} V^{-\gamma} dV = K \left[\frac{V^{1-\gamma}}{1-\gamma} \right]_{V_1}^{V_2}$$

$$= K \left[\frac{V_2^{1-\gamma}}{1-\gamma} - \frac{V_1^{1-\gamma}}{1-\gamma} \right]$$

$$= \frac{1}{1-\gamma} \left[\kappa v_2^{1-\gamma} - \kappa v_1^{1-\gamma} \right]$$

$$= \frac{1}{1-\gamma} \left[p_2 v_2^\gamma v_2^{1-\gamma} - p_1 v_1^\gamma v_1^{1-\gamma} \right]$$

$$= \frac{1}{1-\gamma} \left[p_2 v_2 - p_1 v_1 \right]$$

$$= \frac{1}{1-\gamma} \left[R T_1 - R T_2 \right] \quad [\because P V = R T]$$

$$W = -\frac{P}{\gamma-1} \left[T_1 - T_2 \right]$$

MATH