



## PHYSICS

# NCERT - FULL MARKS PHYSICS(TAMIL)

## KINETIC THEORY

### Example

1. The density of water is  $1000\text{kgm}^{-3}$ . The density of water vapour at  $100^{\circ}\text{C}$  and 1 atmospheric pressure is  $0.6\text{kgm}^{-3}$ . The

volume of a molecule multiplied by the total number gives what is called, molecular volume.

Estimate the ratio (or fraction) of the molecular volume to the total volume occupied by the water vapour under the above conditions of temperature and pressure.



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**2.** Estimate the volume of a water molecule using the data of one molecule( density of

water =  $1000\text{kg}/\text{m}^3$ ) What is its approximate size?



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3. What is the average distance between atoms (interatomic distance) in water ?



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4. A vessel contains two non-reactive gases neon (monoatomic) and oxygen (diatomic).

The ratio of their partial pressures is 3:2.

Estimate the ratio of

(i) number of molecules, and

(ii) mass density of neon and oxygen in the vessel.

Atomic mass of neon = 20.2 u, and molecular mass of oxygen = 32.0 u.



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5. A flask contains argon and chlorine in the ratio 2:1 by mass. The temperature of the

mixture is  $27^{\circ}C$ . Obtain the ratio of

(i) average kinetic energy per molecule, and

(ii) root mean square speed of the molecules of two gases.

Atomic mass of argon = 39.9 u, Molecular mass of chlorine = 70.9 u.



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**6.** Uranium has two isotopes of masses 235 and 238 units. If both are present in uranium hexa fluoride gas, which would have the larger

average speed ? If atomic mass of fluorine is 19 units, estimate the percentage difference in speed at any temperature.



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7. (a) When a molecule (or an elastic ball) hits a (massive) wall, it rebounds with the same speed. When a ball hits a massive bat held firmly, the same thing happens. However, when the bat is moving towards the ball, the ball rebounds with a different speed. Does the ball

move faster or slower?

(b) When gas in a cylinder is compressed by pushing in a piston. Its temperature rises.

Guess at an explanation of this in terms of kinetic theory using (a) above

(c) What happens when a compressed gas pushes a piston out and expands. What would you observe?

(d) Sachin Tendulkar uses a heavy cricket bat while playing. Does it help him in any way?



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8. A cylinder of fixed capacity 44.8 litre contains helium gas at standard temperature and pressure. What is the amount of heat needed to raise the temperature of the gas in the cylinder by  $15.0^\circ C$ ? [ $R = 8.31 J mol^{-1} K( - 1)$ ]



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9. Estimate the mean free path for a water molecule in water vapour at 373 K. Given diameter of water molecule =  $2\text{\AA}$  and



number density of water molecule (at NTP)

$= 2.7 \times 10^{25} m^{-3}$ . Compare it with

interatomic distance for water  $= 40\text{\AA}$ .



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**10.** A football at  $27^\circ C$  has 0.5 mole of air molecules. Calculate the internal energy of air in the ball.



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11. A room contains oxygen and hydrogen molecules in the ratio 3: 1. The temperature of the room is  $27^{\circ}C$ . The molar mass of  $O_2$  is  $32g\ mol^{-1}$  and for  $H_2$   $2\ g\ mol^{-1}$ . The value of gas constant R is  $8.32\ J\ mol^{-1}\ K^{-1}$ .

(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.



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**12.** Ten particles are moving at the speed of 2, 3, 4, 5, 5, 5, 6, 6, 7 and  $9\text{ms}^{-1}$ . Calculate rms speed, average speed and most probable speed.



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**13.** 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.





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**14.** Find the adiabatic exponent  $\gamma$  for mixture of  $\mu_1$  moles of monoatomic gas and  $\mu_2$  moles of a diatomic gas at normal temperature.



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**15.** An oxygen molecule is travelling in air at 300 K and 1 atm, and the diameter of oxygen molecule is  $1.2 \times 10^{-10} m$ . Calculate the mean free path of oxygen molecule.



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## Exercises

1. Estimate the fraction of molecular volume to the actual volume occupied by oxygen gas at STP. Take the diameter of an oxygen molecule to be  $3\text{\AA}$ .



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2. Molar volume is the volume occupied by 1 mole of any (Ideal) gas at standard temperature and pressure (STP ,  $0^{\circ}C$ , 1 atmospheric pressure). Show that it is 22.4 litres. Take  $R = 8.31 J mol^{-1} K^{-1}$ .



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3. Fig shows of  $PV/T$  versus  $P$  for  $1.00 \times 10^{-3} kg$  of oxygen gas at two different temperatures.

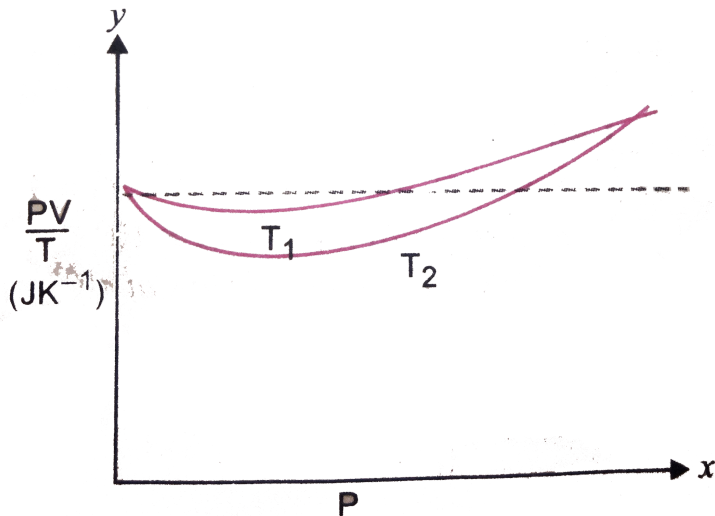
(a) What does the dotted plot signify ?

(b) Which is true :  $T_1 < T_2$  or  $T_2 < T_1$  ?

(c) What is the value of  $PV/T$  where the curves meet on the Y-axis ?

(d) If we obtained similar plot for  $1.00 \times 10^{-3} \text{ kg}$  of hydrogen, would we get the same value of  $PV/T$  at the point where the curves meet on the y-axis ? If not, what mass of hydrogen yield the same value of  $PV/T$  (for low pressure high temperature region of the plot) ? (Molecular mass of  $H = 2.02u$ , of

$$O = 32.0u, R = 8.31Jmol^{-1}K^{-1}$$



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4. An oxygen cylinder of volume 30 litres has an initial gauge pressure of 15 atm. And a temperature of  $27^{\circ}C$ . After some oxygen is



withdrawn from the cylinder, the gauge pressure drops to 11 atm. And its temperature drops to  $17^{\circ}C$ . Estimate the mass of oxygen taken out of the cylinder.

( $R = 8.1 \text{ J mole}^{-1} \text{ K}^{-1}$ , molecular mass of  $O_2 = 32u$ ).



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5. An air bubble of volume  $1.0 \text{ cm}^3$  rises from the bottom of a lake 40 m deep at a temperature of  $12^{\circ}C$ . To what volume does it

grow when it reaches the surface, which is at a temperature of  $35^{\circ}C$ . ? Given

$$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}.$$



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**6.** Estimate the total number of air molecules (inclusive of oxygen, nitrogen, water vapour and other constituents) in a room of capacity  $25.0 \text{ m}^3$  at a temperature of  $27^{\circ}C$  and 1 atm pressure. (Boltzmann constant  $= 1.38 \times 10^{-23} \text{ JK}^{-1}$ ).



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7. Estimate the average thermal energy of a helium atom at (i) room temperature ( $27^{\circ}C$ ) (ii) the temperature on the surface of the sun (6000K), (iii) the temperature of 10 million kelvin (the typical core temperature in the case of a star)



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8. Three vessels of equal capacity have gases at the same temperature and pressure. The first vessel contains neon (monoatomic), the second contains chlorine (diatomic), and the third contains uranium hexafluoride (polyatomic). Do the vessels contain equal number of respective molecules? Is the root mean square speed of molecules the same in the three cases? If not, which case is  $v_{rms}$  the largest?



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9. At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the r.m.s. speed of a helium gas atom at  $-20^{\circ}C$  ? (Atomic mass of Ar = 39.9 u, of He = 4.0 u).



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10. Estimate the mean free path and collision frequency of a nitrogen molecule in a cylinder containing nitrogen at 2.0 atm and

temperature  $17^{\circ}C$ . Take the radius of a nitrogen molecule to be roughly  $1.0\text{\AA}$ . Compare the collision time with the time molecule moves freely between two successive collision ( $M_{of}N_2 = 28$ )



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## Additional Exercise

1. A metre long narrow bore held horizontally (and close at one end) contains a 76 cm long

mercury thread, which traps a 15 cm column of air. What happens if the tube is held vertically with the open end at the bottom?



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2. From a certain apparatus, the diffusion rate of hydrogen has an average value of  $28.7\text{cm}^3 / \text{s}$ . The diffusion of another gas under the same condition is measured to have an average rate of  $7.2\text{cm}^3 / \text{s}$ . Identify the gas.



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3. A gas in equilibrium has uniform density and pressure throughout its volume. This is strictly true only if there are no external influences. A gas column under gravity, for example, does not have uniform density (and pressure). As you might expect, its density decreases with height. The precise dependence is given by the so-called law of atmospheres

$$n_2 = n_1 \exp\left[ - mg(h_2 - h_1) / k_B T \right]$$

where  $n_2, n_1$  refer to number density at



heights  $h_2$  and  $h_1$  respectively. Use this relation to derive the equation for sedimentation equilibrium of a suspension in a liquid column:

$$n_2 = n_1 \exp\left[ - mgN_A(\rho - \rho')(h_2 - h_1) / \rho RT \right]$$

where  $\rho$  is the density of the suspended particle, and  $\rho'$ , that of surrounding medium. [ $N_A$  is Avogadro's number, and R the universal gas constant.] [Hint : Use Archimedes principle to find the apparent weight of the suspended particle.]



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4. Given below are densities of some solids and liquids. Give rough estimates of the size of their atoms :

Substance	Atomic Mass (u)	Density ( $10^3 \text{ Kg m}^{-3}$ )
Carbon (diamond)	12.01	2.22
Gold	197.00	19.32
Nitrogen (liquid)	14.01	1.00
Lithium	6.94	0.53
Fluorine (liquid)	19.00	1.14

[Hint : Assume the atoms to be 'tightly packed' in a solid or liquid phase, and use the known value of Avogadro's number. You should, however, not take the actual numbers you obtain for various atomic sizes too literally. Because of the crudeness of the tight packing

approximation, the results only indicate that atomic sizes are in the range of a few Å].

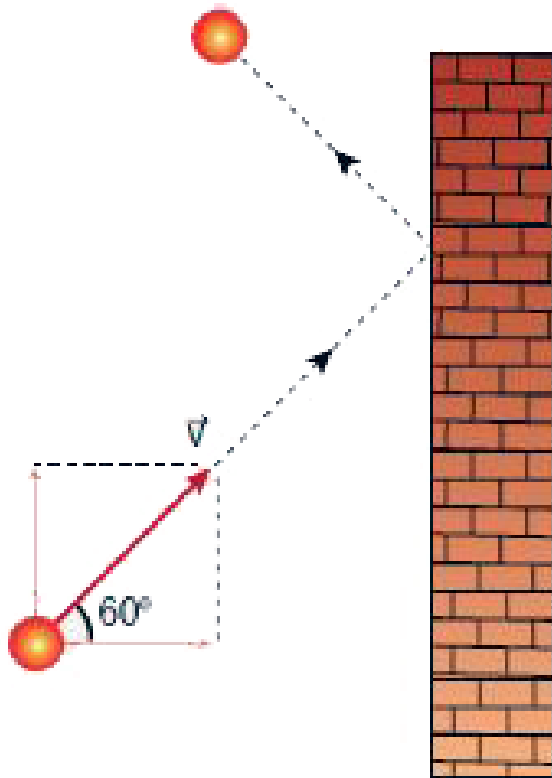


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## Evaluation Multiple Choice Questions

1. A particle of mass  $m$  is moving with speed  $u$  in a direction which makes  $60^\circ$  with respect to  $x$  axis. It undergoes elastic collision with the wall. What is the change in momentum in  $x$

and y direction ?



A.  $\Delta p_x = -mu, \Delta p_y = 0$

B.  $\Delta p_x = -2mu, \Delta p_y = 0$

C.  $\Delta p_x = 0, \Delta p_y = mu$

D.  $\Delta p_x = mu, \Delta p_y = 0$

**Answer: A**



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2. A sample of ideal gas is at equilibrium which of the following quantity is zero ?

A. rms speed

B. average speed

C. average velocity

D. most probable speed

**Answer: C**



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3. An ideal gas is maintained at constant pressure. If the temperature of an ideal gas increases from 100K to 1000K then the rms speed of the gas molecules

A. increases by 5 times

B. increases by 10 times

C. remains same

D. increases by 7 times

**Answer: B**



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4. Two identically sized rooms A and B are connected by an open door. If the room A is air conditioned such that its temperature is  $4^{\circ}$

lesser than room B, which room has more air in it?

A. Room A

B. Room B

C. Both room has same air

D. Cannot be determined

**Answer: A**



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5. The average translational kinetic energy of gas molecules depends on

A. number of moles and T

B. only on T

C. P and T

D. P only

**Answer: A**



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6. If the internal energy of an ideal gas  $U$  and volume  $V$  are doubled then the pressure

A. doubles

B. remains same

C. halves

D. quadruples

**Answer: B**



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7. The ratio  $\gamma = \frac{C_p}{C_v}$  for a gas mixture consisting of 8 g of helium and 17 g of oxygen is

A. 23 / 15

B. 15 / 23

C. 27 / 11

D. 17 / 27

**Answer: C**



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8. A container has one mole of monoatomic ideal gas. Each molecule has  $f$  degrees of freedom. What is the ratio of  $\gamma = \frac{C_p}{C_v}$

A.  $f$

B.  $\frac{f}{2}$

C.  $\frac{f}{f + 2}$

D.  $\frac{f + 2}{f}$

**Answer: D**



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9. If the temperature and pressure of a gas is doubled the mean free path of the gas molecules

A. remains same

B. doubled

C. tripled

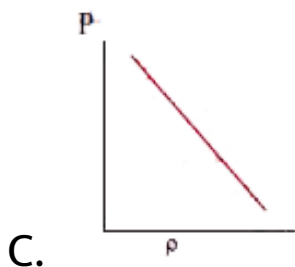
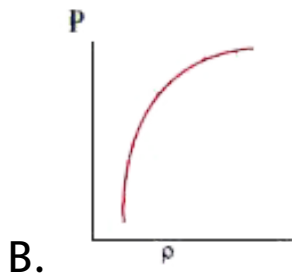
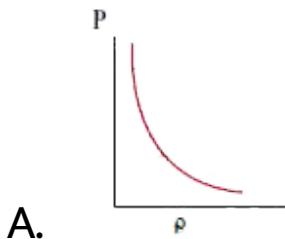
D. quadrapoled

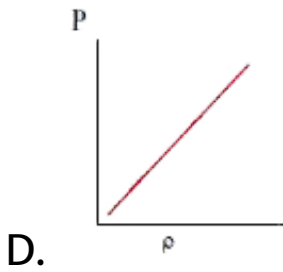
**Answer: A**



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10. Which of the following shows the correct relationship between the pressure and density of an ideal gas at constant temperature?





**Answer: D**

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11. A sample of gas consists of  $\mu_1$  moles of monoatomic molecules,  $\mu_2$  moles of diatomic molecules and  $\mu_3$  moles of linear triatomic molecules. The gas is kept at high

temperature. What is the total number of degrees of freedom?

A.  $[3\mu_1 + 7(\mu_2 + \mu_3)]N_A$

B.  $[3\mu_1 + 7\mu_2 + 6\mu_3]N_A$

C.  $[7\mu_1 + 3(\mu_2 + \mu_3)]N_A$

D.  $[3\mu_1 + 6(\mu_2 + \mu_3)]N_A$

**Answer: A**



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12. If  $S_P$  and  $S_V$  denote the specific heats of nitrogen gas per unit mass at constant pressure and constant volume respectively, then

A.  $S_P - S_V = 28R$

B.  $S_P - S_V = R/28$

C.  $S_P - S_V = R/14$

D.  $S_P - S_V = R$

**Answer: B**



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13. Which of the following gases will have least rms speed at a given temperature ?

A. Hydrogen

B. Nitrogen

C. Oxygen

D. Carbon dioxide

**Answer: D**



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14. For a given gas molecule at a fixed temperature, the area under the Maxwell-Boltzmann distribution curve is equal to

A.  $\frac{PV}{kT}$

B.  $\frac{kT}{PV}$

C.  $\frac{P}{NkT}$

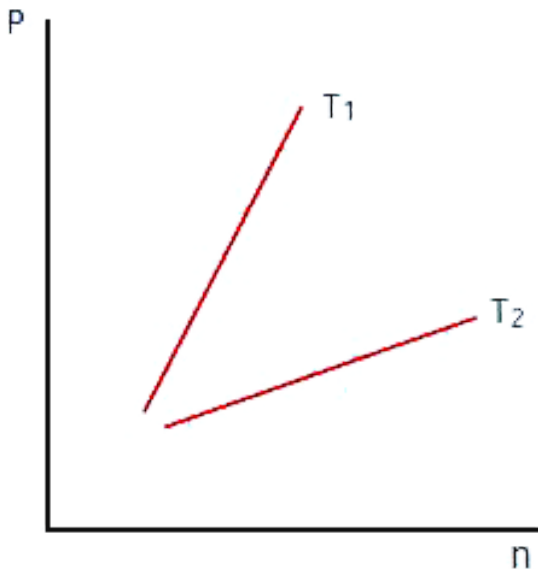
D.  $PV$

**Answer: A**



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15. The following graph represent the pressure versus number density for ideal gas at two different temperatures  $T_1$  and  $T_2$ . The graph implies



A.  $T_1 = T_2$

B.  $T_1 > T_2$

C.  $T_1 < T_2$

D. Cannot be determined

**Answer: B**



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**Evaluation Numerical Problems**

1. 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  $20^\circ\text{C}$ .



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2. If the rms speed of methane gas in the jupiter's atmosphere is  $471.8\text{ms}^{-1}$ , show that the surface temperature of jupiter is sub-zero.



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3. Calculate the temperature at which the rms velocity of a gas triples its value at S.T.P.



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4. A gas is at temperature  $80^{\circ}C$  and pressure  $5 \times 10^{-10} Nm^{-2}$ . What is the number of molecules per  $m^3$  if boltzmann's constant is  $1.38 \times 10^{-23} JK^{-1}$ .



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5. From kinetic theory of gases, show that Moon cannot have an atmosphere (Assume

$$k = 1.38 \times 10^{-23} JK^{-1} \quad \text{Temperature}$$

$$T = 0^\circ C = 273K)$$



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6. If  $10^{20}$  oxygen molecules per second strike  $4cm^2$  of wall at an angle of  $30^\circ$  with the normal when moving at a speed of  $2 \times 10^3 ms^{-1}$ , find the pressure exerted on the wall. (mass of 1 atom =  $1.67 \times 10^{-27} kg$ )





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



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8. Estimate the total number of air molecules in a room of capacity  $25m^3$  at a temperature of  $27^\circ C$ .



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