Kinetic Theory of Gases

Question1

The average kinetic energy of a monatomic molecule is 0.414eV at temperature :

(Use $K_B = 1.38 \times 10^{-23}$J/mol − K)

[27-Jan-2024 Shift 1]

Options:

A.

3000K

B.

3200K

C.

1600K

D.

1500K

Answer: B

Solution:

For monoatomic molecule degree of freedom = 3.

$$\therefore K_{avg} = \frac{3}{2} K_B T$$

$$T = \frac{0.414 \times 1.6 \times 10^{-19} \times 2}{3 \times 1.38 \times 10^{-23}}$$

$$= 3200K$$

Question2

The total kinetic energy of 1 mole of oxyge 27°C is :

[Use universal gas constant (R) = 8.31J/mole K

[27-Jan-2024 Shift 2]

Options:

A.

6845.5J

B.

5942.0J

C.

6232.5J

D.

5670.5J

Answer: C

Solution:

$$\text{Kinetic energy} = \frac{f}{2} nRT$$

$$= \frac{5}{2} \times 1 \times 8.31 \times 300 J$$

$$= 6232.5 J$$

Question3

Two vessels A and B are of the same size and are at same temperature. A contains 1g of hydrogen and B contains 1g of oxygen. P_A and P_B are the pressures of the gases in A and B respectively, then P_A/P_B is:

[29-Jan-2024 Shift 1]

Options:

A.

16

B.

8

C.

4

D.

32

Answer: A

Solution:

$$\frac{P_A V_A}{P_B V_B} = \frac{n_A R T_A}{n_B R T_B}$$

Given $V_A = V_B$

And $T_A = T_B$

$$\frac{P_A}{P_B} = \frac{n_A}{n_B}$$

$$\frac{P_A}{P_B} = \frac{1/2}{1/32} = 16$$

Question4

The temperature of a gas having 2.0×10^{25} molecules per cubic meter at 1.38atm (Given, $k = 1.38 \times 10^{-23} JK^{-1}$) is :

[29-Jan-2024 Shift 2]

Options:

A.

500K

B.

200K

C.

100K

D.

300K

Answer: A

Solution:

$PV = nRT$

$$PV = \frac{N}{N_A} RT$$

N = Total no. of molecules

$$P = \frac{N}{V} kT$$

$$1.38 \times 1.01 \times 10^5 = 2 \times 10^{25} \times 1.38 \times 10^{-23} \times T$$

$$1.01 \times 10^5 = 2 \times 10^2 \times T$$

$$T = \frac{1.01 \times 10^3}{2} \approx 500K$$

Question5

N moles of a polyatomic gas (f = 6) must be mixed with two moles of a monoatomic gas so that the mixture behaves as a diatomic gas. The value of N is :

[29-Jan-2024 Shift 2]

Options:

A.

6

B.

3

C.

4

D.

2

Answer: C

Solution:

$$f_{eq} = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2}$$

For diatomic gas $f_{eq} = 5$

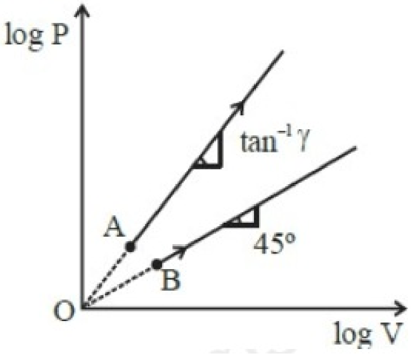
$$5 = \frac{(N)(6) + (2)(3)}{N + 2}$$

$$5N + 10 = 6N + 6$$

$$N = 4$$

Question6

Two thermodynamical process are shown in the figure. The molar heat capacity for process A and B are C_A and C_B. The molar heat capacity at constant pressure and constant volume are represented by C_P and C_V, respectively. Choose the correct statement.



[30-Jan-2024 Shift 1]

Options:

A.

$C_B = \infty$, $C_A = 0$

B.

$C_A = 0$ and $C_B = \infty$

C.

$C_P > C_V > C_A = C_B$

D.

None of above

Answer: D

Solution:

For process A

$\log P = \gamma \log V \Rightarrow P = V^{\gamma}, (\gamma > 1)$

$PV^{-\gamma} =$ Constant

$C_A = C_V + \dfrac{R}{1+\gamma}$.... (i)

Likewise for process B $\longrightarrow PV^{-1} =$ Constant

$C_B = C_v + \dfrac{R}{1+1}$

$C_B = C_v + \dfrac{R}{2}$.......(ii)

$C_P = C_v + R$....... (iii)

By (i), (ii) & (iii)

$C_P > C_B > C_A > C_v$ [No answer matching]

Question7

At which temperature the r.m.s. velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C ?

[30-Jan-2024 Shift 1]

Options:

A.

80K

B.

−73K

C.

4K

D.

20K

Answer: D

Solution:

$$\sqrt{\frac{3RT}{2}} = \sqrt{\frac{3R(320)}{32}}$$

$$T = \frac{320}{16} = 20\text{K}$$

Question8

If three moles of monoatomic gas ($\gamma = 5/3$) is mixed with two moles of a diatomic gas ($\gamma = 7/5$), the value of adiabatic exponent γ for the mixture is:

[30-Jan-2024 Shift 2]

Options:

A.

1.75

B.

1.40

C.

1.52

D.

1.35

Answer: C

Solution:

$f_1 = 3, \quad f_2 = 5$

$n_1 = 3, \quad n_2 = 2$

$$f_{mixture} = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2} = \frac{9+10}{f} = \frac{19}{5}$$

$$\gamma_{mixture} = 1 + \frac{2 \times 5}{19} = \frac{29}{19} = 1.52$$

Question9

The parameter that remains the same for molecules of all gases at a given temperature is :

[31-Jan-2024 Shift 1]

Options:

A.

kinetic energy

B.

momentum

C.

mass

D.

speed

Answer: A

Solution:

$$KE = \frac{f}{2}kT$$

Conceptual

Question10

A gas mixture consists of 8 moles of argon and 6 moles of oxygen at temperature T. Neglecting all vibrational modes, the total internal

energy of the system is

[31-Jan-2024 Shift 2]

Options:

A.

29 RT

B.

20 RT

C.

27 RT

D.

21 RT

Answer: C

Solution:

$U = nC_V T$

$\Rightarrow U = n_1 C_{V_1} T + n_2 C_{V_2} T$

$\Rightarrow 8 \times \frac{3R}{2} \times T + 6 \times \frac{5R}{2} \times T$

$= 27 RT$

Question11

Two moles a monoatomic gas is mixed with six moles of a diatomic gas. The molar specific heat of the mixture at constant volume is :

[1-Feb-2024 Shift 1]

Options:

A.

$\frac{9}{4}R$

B.

$\frac{7}{4}R$

C.

$\frac{3}{2}R$

D.

$\frac{5}{2}R$

Answer: A

Solution:

$$C_V = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$

$$= \frac{2 \times \frac{3}{2}R + 6 \times \frac{5}{2}R}{2+6}$$

$$= \frac{9}{4}R$$

Question12

If the root mean square velocity of hydrogen molecule at a given temperature and pressure is 2km/ s, the root mean square velocity of oxygen at the same condition in km/ s is :

[1-Feb-2024 Shift 2]

Options:

A.

2.0

B.

0.5

C.

1.5

D.

1.0

Answer: B

Solution:

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{2}{V_2} = \sqrt{\frac{32}{2}}$$

$V_2 = 0.5\ km/s$

Question13

Given below are two statements :
Statements I : The temperature of a gas is $-73^{\circ}C$. When the gas is heated to $527^{\circ}C$, the root mean square speed of the molecules is doubled.
Statement II : The product of pressure and volume of an ideal gas will be equal to translational kinetic energy of the molecules.
In the light of the above statements, choose the correct answer from the options given below :
[24-Jan-2023 Shift 1]

Options:

A. Both statement I and Statement II are true

B. Statement I is true but Statement II is false

C. Both Statement I and Statement II are false

D. Statement I is false but Statement II is true

Answer: B

Solution:

Solution:
Statement-I
$T_1 = -73^{\circ}C = 200K$
$T_2 = 527^{\circ}C = 800K$

$$\frac{V_1}{V_2} = \frac{\sqrt{\frac{3RT_1}{M}}}{\sqrt{\frac{3RT_2}{M}}} = \sqrt{\frac{T_1}{T_2}}$$

$$= \sqrt{\frac{200}{800}} = \frac{1}{2}$$

$V_2 = 2V_1$ (True)
Statement-II
$PV = nRT$
Translational KE = $\frac{3}{2}nRT$ (False)

Question14

The root mean square velocity of molecules of gas is [25-Jan-2023 Shift 1]

Options:

A. Proportional to square of temperature (T^2).

B. Inversely proportional to square root of temperature $\sqrt{\frac{1}{T}}$.

C. Proportional to square root of temperature $\sqrt{T}$.

D. Proportional to temperature (T).

Answer: C

Solution:

Solution:
The rms speed of a gas molecule is

$V_{RMS} = \sqrt{\frac{3RT}{M}}$

$V_{RMS} \propto \sqrt{T}$

Question15

At 300K, the rms speed of oxygen molecules is $\sqrt{\frac{\alpha + 5}{\alpha}}$ times to that of its average speed in the gas. Then, the value of α will be (used $\pi = \frac{22}{7}$) [29-Jan-2023 Shift 2]

Options:

A. 32

B. 28

C. 24

D. 27

Answer: B

Solution:

Solution:

$\sqrt{\frac{3RT}{M}} = \sqrt{\frac{\alpha + 5}{\alpha}} \sqrt{\frac{8}{\pi} \frac{RT}{M}}$

$3 = \frac{\alpha + 5}{\alpha} \frac{8}{\pi}$

$\alpha = 28$

Question16

The pressure (P) and temperature (T) relationship of an ideal gas obeys the equation $PT^2 =$ constant. The volume expansion coefficient of the gas will be:
[30-Jan-2023 Shift 1]

Options:

A. $3T^2$

B. $\frac{3}{T^2}$

C. $\frac{3}{T^3}$

D. $\frac{3}{T}$

Answer: D

Solution:

Solution:
$PT^2 =$ constant, Using $PV = nRT$
$P = \frac{nRT}{V}$
$PT^2 = \frac{nRT}{V} \times T^2 =$ constant
$\Rightarrow T^3 = KV$
So, $\frac{d}{dT}(KV) = 3T^2$
$\Rightarrow \frac{KdV}{dT} = 3T^2$
$\Rightarrow dV = \frac{3T^2}{K} dT$
$dV = V\gamma\, dT$
$\Rightarrow \gamma V = \frac{3T^2}{K} \quad \Rightarrow \gamma = \frac{3T^2}{KV} = \frac{3T^2}{T^3} = \frac{3}{T}$

Question17

A flask contains hydrogen and oxygen in the ratio of 2 : 1 by mass at temperature 27°C. The ratio of average kinetic energy per molecule of hydrogen and oxygen respectively is :
[30-Jan-2023 Shift 2]

Options:

A. 2 : 1

B. 1 : 1

C. 1 : 4

D. 4 : 1

Answer: B

Solution:

Solution:

$K_{av} = \frac{5}{2} kT$

Ratio $= 1 : 1$

Question18

The average kinetic energy of a molecule of the gas is [1-Feb-2023 Shift 1]

Options:

A. proportional to absolute temperature

B. proportional to volume

C. proportional to pressure

D. dependent on the nature of the gas

Answer: A

Solution:

Solution:

Basic theory

Translational $K.E$ on average of a molecule is $\frac{3}{2}$ KT which is independent of nature, pressure and volume.

Question19

The number of air molecules per cm^3 increased from 3×10^{19} to 12×10^{19}. The ratio of collision frequency of air molecules before and after the increase in the number respectively is: [6-Apr-2023 shift 1]

Options:

A. 0.25

B. 0.75

C. 1.25

D. 0.50

Answer: A

Solution:

Solution:
Collision frequency is given by $Z = n\pi d^2 V_{avg}$, where n is number of molecules per unit volume.
$\frac{z_1}{z_2} = \frac{n_1}{n_2} = \frac{3}{12} = \frac{1}{4} = 0.25$

Question20

The temperature of an ideal gas is increased from 200K to 800K. If r.m.s. speed of gas at 200K is v_0. Then, r.m.s. speed of the gas at 800K will be:
[6-Apr-2023 shift 2]

Options:

A. $4v_0$

B. $2v_0$

C. v_0

D. $\frac{v_0}{4}$

Answer: B

Solution:

Solution:
using $v_{rms} = \sqrt{\frac{3RT}{m}}$
$v_0 = \sqrt{\frac{3R \times 200}{m}}$ . . . (1)
$(v') = \sqrt{\frac{3R \times 800}{m}}$ . . . (2)
dividing (2) by (1)
$\frac{v'}{v_0} = \sqrt{\frac{800}{200}} = \sqrt{4} = 2$
or $v' = 2v_0$

Question21

The temperature at which the kinetic energy of oxygen molecules becomes double than its value at 27°C is
[8-Apr-2023 shift 2]

Options:

A. 1227°C

B. 627°C

C. 327°C

D. 927°C

Answer: C

Solution:

Solution:

KE of O_2 molecules $= 5 \times \left(\frac{1}{2}KT\right)$

$(KE)_{27^\circ C} = 5 \times \frac{1}{2}k(27 + 273) = \frac{5}{2}k \times 300$

$(KE)_T = 2\left(\frac{5}{2}k\right) \times 300 = \frac{5}{2}k(600)$

i.e. $T = 600K$

$= 600 - 273$

$T = 327^\circ C$

Question22

Match List I with List II :

List I	List II
(A) 3 Translational degrees of freedom	(I) Monoatomic gases
(B) 3 Translational, 2 rotational degrees of freedoms	(II) Polyatomic gases
(C) 3 Translational, 2 rotational and 1 vibrational degrees of freedom	(III) Rigid diatomic gases
(D) 3 Translational, 3 rotational and more than one vibrational degrees of freedom	(IV) Nonrigid diatomic gases

Choose the correct answer from the options given below : [10-Apr-2023 shift 1]

Options:

A. (A)-(I), (B)-(III), (C)-(IV), (D)-(II)

B. (A)-(I), (B)-(IV), (C)-(III), (D)-(II)

C. (A)-(IV), (B)-(II), (C)-(I), (D)-(III)

D. (A)-(IV), (B)-(III), (C)-(II), (D)-(I)

Answer: A

Solution:

Solution:
Fact Based

Type of gas	No of degree of freedom
1 Monoatomic	3 (Translational)
2. Diatomic + rigid	3 (Translational +2 Rotational $= 5$)
3. Diatomic + non - rigid	3 (Trans) +2 (Rotational) +1 (vibrational)
4. Polyatomic	3 (Trans) +2 (Rotational) + more than 1 (vibrational)

Question23

A gas mixture consists of 2 moles of oxygen and 4 moles of neon at temperature T. Neglecting all vibrational modes, the total internal energy of the system will be,
[10-Apr-2023 shift 2]

Options:

A. $4\ RT$

B. $11\ RT$

C. $8\ RT$

D. $16\ RT$

Answer: B

Solution:

Solution:

Internal energy of $O_2 = \frac{5}{2}nRT = \frac{5}{2} \times 2\ RT = 5\ RT$

Internal energy of Ne $= nRT = \frac{3}{2} \times nRT = \frac{3}{2} \times 4\ RT = 6\ RT$

Total energy of mixture (system) $= 5RT + 6RT = 11RT$

Question24

Three vessels of equal volume contain gases at the same temperature and pressure. The first vessel contains neon (monoatomic), the second contains chlorine (diatomic) and third contains uranium hexafluoride (polyatomic). Arrange these on the basis of their root mean square speed (v_{rms}) and choose the correct answer from the options given below

:

[11-Apr-2023 shift 1]

Options:

A. $V_{rms}(mono) > v_{rms}(dia) > v_{rms}(poly)$

B. $V_{rms}(dia) < v_{rms}(poly) < v_{rms}(mono)$

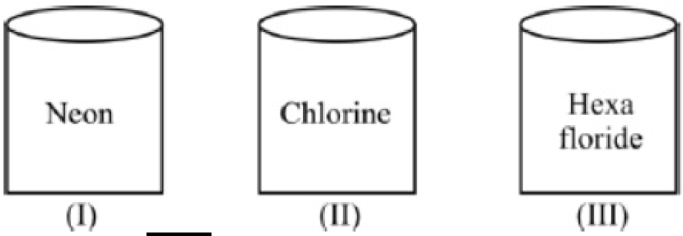
C. $V_{rms}(mono) < v_{rms}(.dia) < v_{rms}(poly)$

D. $V_{mms}(mono) = v_{mms}(dia) = v_{mas}(poly)$

Answer: A

Solution:

Solution:



$VRMS = \sqrt{\frac{\gamma RT}{m}}$

$\gamma = 1 + \frac{2}{f}$ so $r_{monochromic} > r_{diatomic} > r_{poly}$.

$V_{mono} > V_{diatomic} > V_{poly.}$

Ans.(1)

Question25

The root mean square speed of molecules of nitrogen gas at 27°C is approximately : (Given mass of a nitrogen molecule $= 4.6 \times 10^{-26}$ kg and take Boltzmann constant $k_B = 1.4 \times 10^{-23} JK^{-1}$)

[11-Apr-2023 shift 2]

Options:

A. 1260m / s

B. 91m / s

C. 523m / s

D. 27.4m / s

Answer: C

Solution:

$$V_{rms} = \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3RT}{mN_A}} = \sqrt{\frac{3KT}{m}}$$
$$= \sqrt{\frac{3 \times 1.4 \times 10^{-23} \times 300}{4.6 \times 10^{-26}}}$$
$$= \sqrt{\frac{9 \times 1.4 \times 10^{5}}{4.6}}$$
$$= \sqrt{2.73 \times 10^{5}}$$
$$= \sqrt{27.3 \times 10^{4}}$$
$$= 522.4 ms^{-1}$$
$$= 523 ms^{-1}$$

Question26

If the r. m. s speed of chlorine molecule is 490m / s at 27°C, the r . m . s speed of argon molecules at the same temperature will be (Atomic mass of argon = 39.9u, molecular mass of chlorine = 70.9u) [12-Apr-2023 shift 1]

Options:

A. 651.7m / s

B. 451.7m / s

C. 551.7m / s

D. 751.7m / s

Answer: A

Solution:

Solution:

Molar mass of chlorine = 70.9u

Atomic mass of argon = 39.9u

$$V_{rms} = \sqrt{\frac{3RT}{m}}$$
$$V_{rms} \propto \sqrt{\frac{1}{m}}$$
$$\frac{V_{rmschlorine}}{V_{rmsarg\,on}} = \sqrt{\frac{m_{arg\,on}}{m_{chlorine}}}$$
$$\frac{490}{V_{rmsargon}} = \sqrt{\frac{39.9}{70.9}}$$
$$V_{rmsargon} = 490 \times 1.33$$
$$V_{msargon} = 651.7 m / sec$$

Question27

The rms speed of oxygen molecule in a vessel at particular temperature is $\left(1 + \frac{5}{x}\right)^{\frac{1}{2}}$v, where v is the average speed of the molecule. The value of x will be: (Take $\pi = \frac{22}{7}$)

[13-Apr-2023 shift 1]

Options:

A. 28

B. 27

C. 8

D. 4

Answer: A

Solution:

Solution:

$V_{mms} = \sqrt{\frac{3RT}{M}}$

$V_{avg} = v = \sqrt{\frac{8RT}{\pi M}}$

$V_{mms} = \sqrt{\frac{3\pi}{8} v}$

$V_{mms} = \sqrt{\frac{3}{8} \times \frac{22}{7} v} = \left(\frac{33}{28}\right)^{1/2} v$

$V_{mms} = \left(1 + \frac{5}{28}\right)^{1/2} v$

$x = 28$

Question28

The mean free path of molecules of a certain gas at STP is 1500d, where d is the diameter of the gas molecules. While maintaining the standard pressure, the mean free path of the molecules at 373K is approximately :
[13-Apr-2023 shift 2]

Options:

A. 750d

B. 1500d

C. 1098d

D. 2049d

Answer: D

Solution:

Solution:

mean free path λ

$\lambda = \frac{RT}{\sqrt{2} C d^2 N_A P}$

$\lambda \propto T$

$$\frac{1500d}{\lambda} = \frac{273}{373}$$
$\lambda = 2049d$

Question29

A flask contains Hydrogen and Argon in the ratio 2 : 1 by mass. The temperature of the mixture is 30°C. The ratio of average kinetic energy per molecule of the two gases (K argon/ K hydrogen) is :
(Given : Atomic Weight of Ar = 39.9)
[15-Apr-2023 shift 1]

Options:

A. 2

B. 39.9

C. 1

D. $\frac{39.9}{2}$

Answer: C

Solution:

Solution:

Kinetic energy per molecule $= \frac{3}{2}k_B T$

$\propto \frac{k_{Ar}}{k_{H_2}} = \frac{T}{T} = 1$

Question30

The relation between root mean square speed (v_{rms}) and most probable sped (v_p) for the molar mass M of oxygen gas molecule at the temperature of 300K will be:
[25-Jun-2022-Shift-1]

Options:

A. $v_{rms} = \sqrt{\frac{2}{3}}v_p$

B. $v_{rms} = \sqrt{\frac{3}{2}}v_p$

C. $v_{rms} = v_p$

D. $v_{rms} = \sqrt{\frac{1}{3}}v_p$

Answer: B

Solution:

Solution:

$v_{rms} = \sqrt{\frac{3RT}{M}}$

$v_p = \sqrt{\frac{2RT}{M}}$

$\Rightarrow v_{rms} = \sqrt{\frac{3}{2}} v_p$

Question31

When a gas filled in a closed vessel is heated by raising the temperature by 1°C, its pressure increases by 0.4%. The initial temperature of the gas is ____K.
[25-Jun-2022-Shift-2]

Answer: 250

Solution:

Solution:

$PV = nRT$

So $\frac{dP}{P} \times 100 = \frac{dT}{T} \times 100$

$0.4 = \frac{1}{T} \times 100$

$\Rightarrow T = 250K$

Question32

A flask contains argon and oxygen in the ratio of 3 : 2 in mass and the mixture is kept at 27°C. The ratio of their average kinetic energy per molecule respectively will be :
[26-Jun-2022-Shift-2]

Options:

A. 3 : 2

B. 9 : 4

C. 2 : 3

D. 1 : 1

Answer: D

Solution:

Solution:
$KE_{avg} = \frac{3}{2}kT$ (At lower temperature)
As temperature is same for both the gases.
⇒ Both gases will have same average kinetic energy.
$\Rightarrow \frac{(KE_{avg})_{arg\ on}}{(KE_{avg})_{oxygen}} = \frac{1}{1}$

Question33

A mixture of hydrogen and oxygen has volume $2000cm^3$, temperature 300K, pressure 100 kPa and mass 0.76g. The ratio of number of moles of hydrogen to number of moles of oxy in the mixture will be: [Take gas constant .$R = 8.3JK^{-1}mol^{-1}$] [27-Jun-2022-Shift-1]

Options:

A. $\frac{1}{3}$

B. $\frac{3}{1}$

C. $\frac{1}{16}$

D. $\frac{16}{1}$

Answer: B

Solution:

Solution:
$P_1V = n_1RT$
$P_2V = n_2RT$
$\Rightarrow (100\,kPa)V = (n_1 + n_2)RT$
$\Rightarrow n_1 + n_2 = \frac{(100\,kPa)(2000cm^3)}{8.3 \times 300}$
Also, $n_1 \times 2 + n_2 \times 32 = 0.76$
Solving (1) and (2),
$n_1 = 0.06$
$n_2 = 0.02$
$\Rightarrow \frac{n_1}{n_2} = 3$

Question34

According to kinetic theory of gases,
A. The motion of the gas molecules freezes at $0^{\circ}C$.

B. The mean free path of gas molecules decreases if the density of molecules is increased.
C. The mean free path of gas molecules increases if temperature is increased keeping pressure constant.
D. Average kinetic energy per molecule per degree of freedom is $\frac{3}{2}k_BT$ (for monoatomic gases).
Choose the most appropriate answer from the options given below :
[27-Jun-2022-Shift-2]

Options:

A. A and C only

B. B and C only

C. A and B only

D. C and D only

Answer: B

Solution:

Solution:
According to kinetic theory of gases,
A. The motion of the gas molecules freezes at 0K.
B. The mean free path decreases on increasing the number density of the molecules as
$\mu = \frac{1}{\sqrt{2}\pi nd^2} \Rightarrow \mu \propto \frac{1}{n}$.
C. The mean free path increases on increasing the volume. Now if temperature is increased by keeping the pressure constant the volume should increase that is mean free path increases.
D. K.E.avg per molecule per degree of freedom is $\frac{1}{2}k_BT$.

Question35

Given below are two statements :
Statement I : When μ amount of an ideal gas undergoes adiabatic change from state (P_1, V_1, T_1) to state (P_2, V_2, T_2), then work done is $W = \frac{\mu R(T_2 - T_1)}{1 - \gamma}$, where $\gamma = \frac{C_p}{C_v}$ and R = universal gas constant.
Statement II : In the above case, when work is done on the gas, the temperature of the gas would rise.
Choose the correct answer from the options given below :
[28-Jun-2022-Shift-1]

Options:

A. Both Statement I and Statement II are true.

B. Both Statement I and Statement II are false.

C. Statement I is true but Statement II is false.

D. Statement I is false but Statement II is true.

Answer: A

Solution:

Solution:

$W = \frac{\mu R(T_2 - T_1)}{1 - r}$ for a polytropic process for adiabatic process $r = \gamma$

⇒ Statement I is true.

In an adiabatic process

$\Delta U = -\Delta W$

⇒ If work is done on the gas

⇒ ΔW is negative

⇒ ΔU is positive or temperature increases

⇒ Statement II is true

Question36

What will be the effect on the root mean square velocity of oxygen molecules if the temperature is doubled and oxygen molecule dissociates into atomic oxygen? [28-Jun-2022-Shift-2]

Options:

A. The velocity of atomic oxygen remains same

B. The velocity of atomic oxygen doubles

C. The velocity of atomic oxygen becomes half

D. The velocity of atomic oxygen becomes four times

Answer: B

Solution:

Solution:

As $v_{rms} = \sqrt{\frac{3RT}{M_0}}$

T is doubled and oxygen molecule is dissociated into atomic oxygen molar mass is halved.

So, $v_{rms}' = \sqrt{\frac{3RT \times 2T_0}{M_0 / 2}} = 2v_{rms}$

So velocity of atomic oxygen is doubled.

Question37

A vessel contains 16g of hydrogen and 128g of oxygen at standard temperature and pressure. The volume of the vessel in cm^3 is : [29-Jun-2022-Shift-2]

Options:

A. 72×10^5

B. 32×10^{5}

C. 27×10^{4}

D. 54×10^{4}

Answer: C

Solution:

Solution:
Total number of moles are
$n = n_{H_2} + n_{O_2}$
$= \frac{16}{2} + \frac{128}{32}$
$= 12$ moles
Using $PV = nRT$
$V = \frac{nRT}{P}$
$= \frac{12 \times 8.31 \times 273.15}{10^5} m^3$
$= 0.27 m^3 = 27 \times 10^4 cm^3$

Question38

Following statements are given :
(A) The average kinetic energy of a gas molecule decreases when the temperature is reduced.
(B) The average kinetic energy of a gas molecule increases with increase in pressure at constant temperature.
(C) The average kinetic energy of a gas molecule decreases with increase in volume.
(D) Pressure of a gas increases with increase in temperature at constant pressure.
(E) The volume of gas decreases with increase in temperature.
Choose the correct answer from the options given below :
[25-Jul-2022-Shift-1]

Options:

A. (A) and (D) only

B. (A), (B) and (D) only

C. (B) and (D) only

D. (A), (B) and (E) only

Answer: A

Solution:

Solution:
Because $KE \propto T$ so A is correct, B is incorrect, statement C cannot be said, statement D is contradicting itself, statement E is incorrect (Isothermal process)

So no answer correct (Bonus)
If the statement of D would have been.
"Pressure of gas increases with increase in temperature at constant volume, "then statement D would have been correct, so in that case answer would have been 'A'.

Question39

Sound travels in a mixture of two moles of helium and n moles of hydrogen. If rms speed of gas molecules in the mixture is $\sqrt{2}$ times the speed of sound, then the value of n will be : [25-Jul-2022-Shift-2]

Options:

A. 1

B. 2

C. 3

D. 4

Answer: B

Solution:

Solution:

Molar mass $M - \frac{2 \times 4 + n \times 1}{2 + n}$..... (i)

Also, $\gamma = \frac{n_1 C_{P_1} + n_2 C_{P_2}}{n_1 C_{V_1} + n_2 C_{V_2}} = \frac{2 \times 5R + n \times 7R}{2 \times 3R + n \times 5R}$

$\Rightarrow \gamma = \frac{10 + 7n}{6 + 5n}$...... (ii)

Given that $V_{rms} = \sqrt{2} V_{sound}$

$\Rightarrow \sqrt{\frac{3RT}{M}} = \sqrt{2}\sqrt{\frac{\gamma RT}{M}}$

$\Rightarrow \gamma = \frac{3}{2}$

$\Rightarrow n = 2$

Question40

A gas has n degrees of freedom. The ratio of specific heat of gas at constant volume to the specific heat of gas at constant pressure will be : [26-Jul-2022-Shift-2]

Options:

A. $\frac{n}{n + 2}$

B. $\frac{n + 2}{n}$

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

D. $\frac{n}{n-2}$

Answer: A

Solution:

Solution:

$C_v = \frac{nR}{2}\ C_p = \frac{(n+2)R}{2}$

$\frac{C_v}{C_p} = \frac{n}{n+2}$

Question41

Same gas is filled in two vessels of the same volume at the same temperature. If the ratio of the number of molecules is 1 : 4, then A. The r.m.s. velocity of gas molecules in two vessels will be the same.
B. The ratio of pressure in these vessels will be 1 : 4.
C. The ratio of pressure will be 1 : 1.
D. The r.m.s. velocity of gas molecules in two vessels will be in the ratio of 1 : 4.
Choose the correct answer from the options given below :
[27-Jul-2022-Shift-1]

Options:

A. A and C only

B. B and D only

C. A and B only

D. C and D only

Answer: C

Solution:

Solution:

A. $V_{Rms} = \sqrt{\frac{3RT}{M_w}} \Rightarrow V_{Rms}$ is same

B. $\frac{P_1}{P_2} = \frac{N_1}{N_2} \Rightarrow$ B is correct

----

Question42

Which statements are correct about degrees of freedom ?
(A) A molecule with n degrees of freedom has n^2 different ways of storing energy.

(B) Each degree of freedom is associated with $\frac{1}{2}$ RT average energy per mole.
(C) A monatomic gas molecule has 1 rotational degree of freedom where as diatomic molecule has 2 rotational degrees of freedom.
(D) CH_4 has a total of 6 degrees of freedom.
Choose the correct answer from the options given below :
[27-Jul-2022-Shift-2]

Options:

A. (B) and (C) only

B. (B) and (D) only

C. (A) and (B) only

D. (C) and (D) only

Answer: B

Solution:

Solution:
Statement A is incorrect, statement B is correct by equipartition of energy. Statement C is incorrect as monoatomic does not have any rotational degree of freedom and CH4 is a polyatomic gas so it has 6 degree of freedom. So only B and D are correct.

Question43

Statement I : The average momentum of a molecule in a sample of an ideal gas depends on temperature.
Statement II : The rms speed of oxygen molecules in a gas is v. If the temperature is doubled and the oxygen molecules dissociate into oxygen atoms, the rms speed will become 2v.
In the light of the above statements, choose the correct answer from the options given below:
[28-Jul-2022-Shift-1]

Options:

A. Both Statement I and Statement II are true

B. Both Statement I and Statement II are false

C. Statement I is true but Statement II is false

D. Statement I is false but Statement II is true

Answer: D

Solution:

$[P_{avg} = 0]$
(due to random motion)

$v_{rms} = \sqrt{\frac{3RT}{M}}$

$T_{new} = 2T$

$M_{new} = \frac{M}{2}$

$\frac{v_{new}}{v} = \frac{\sqrt{\frac{2T}{M/2}}}{\sqrt{\frac{T}{M}}}$

$v_{new} = 2v$

Question44

A vessel contains 14g of nitrogen gas at a temperature of 27°C. The amount of heat to be transferred to the gas to double the r.m.s speed of its molecules will be :
Take R = 8.32Jmol^{-1}k^{-1}
[28-Jul-2022-Shift-2]

Options:

A. 2229J

B. 5616J

C. 9360J

D. 13, 104J

Answer: C

Solution:

Solution:
$n = 0.5$
$T = 300$
For v_{rms} to be doubled $T' = 4 \times 300 = 1200$
⇒ Heat transferred
$= (0.5)\left(\frac{5}{2}\right)(8.32)(900)$
$= 9360J$

Question45

At a certain temperature, the degrees of freedom per molecule for gas is 8 . The gas performs 150J of work when it expands under constant pressure. The amount of heat absorbed by the gas will be ________ J.
[28-Jul-2022-Shift-2]

Answer: 750

Solution:

$W = nR\Delta T = 150J$

$Q = \left(\frac{f}{2} + 1\right) nR\Delta T = \left(\frac{8}{2} + 1\right) 150 = 750J$

Question46

The pressure P_1 and density d_1 of diatomic gas $\left(\gamma = \frac{7}{5}\right)$ changes suddenly to $P_2 (> P_1)$ and d_2 respectively during an adiabatic process. The temperature of the gas increases and becomes _______ times of its initial temperature. (given $\frac{d_2}{d_1} = 32$)
[29-Jul-2022-Shift-1]

Answer: 4

Solution:

$P_1 V_1^{\gamma} = P_2 V_2^{2}$

$\frac{P_1}{d_1^{\gamma}} = \frac{P_2}{d_2^{\gamma}}$

$\frac{d_1 T_1}{d_1^{\gamma}} = \frac{d_2 T_2}{d_2^{\gamma}}$

$T_2 = \left(\frac{d_2}{d_1}\right)^{\gamma - 1} T_1$

$= (32)^{\frac{2}{5}} T_1$

$T_2 = 4T_1$

Question47

One mole of a monoatomic gas is mixed with three moles of a diatomic gas. The molecular specific heat of mixture at constant volume is $\frac{\alpha^2}{4}$ RJ / molK; then the value of α will be _______ . (Assume that the given diatomic gas has no vibrational mode).
[29-Jul-2022-Shift-1]

Answer: 3

Solution:

Solution:

$C_V = \frac{f}{2}R$

total degree of freedoms

$= 1 \times 3 + 3 \times 5 = 18$

$\frac{\alpha^2}{4} = \frac{18}{2n} = \frac{18}{2 \times 4}$

$\Rightarrow \alpha^2 = 9$

$\alpha = 3$

Question48

The root mean square speed of smoke particles of mass 5×10^{-17} kg in their Brownian motion in air at NTP is approximately. [Given $k = 1.38 \times 10^{-23} JK^{-1}$]
[29-Jul-2022-Shift-2]

Options:

A. $60\,mm\,s^{-1}$

B. $12\,mm\,s^{-1}$

C. $15\,mm\,s^{-1}$

D. $36\,mm\,s^{-1}$

Answer: C

Solution:

Solution:

At NTP, $T = 298K$

$v_{rms} = \sqrt{\frac{3RT}{M}}$

$= \sqrt{\frac{3kN_A \times 298}{5 \times 10^{-17} \times N_A}}$

$\simeq 15\,mm / s$

Question49

0.056 kg of Nitrogen is enclosed in a vessel at a temperature of $127^{\circ}C$. Th amount of heat required to double the speed of its molecules is _____k cal.
Take $R = 2\,cal\,mole^{-1}\,K^{-1}$)
[24-Jun-2022-Shift-1]

Answer: 12

Solution:

Solution:
Because the vessel is closed, it will be an isochoric process.
To double the speed, temperature must be 4 times ($v \alpha \sqrt{T}$)
So, $T_f = 1600K$, $T_i = 400K$
number of moles are $\frac{56}{28} = 2$
so $Q = nCv \Delta T = 2 \times \frac{5}{2} \times 2 \times 1200$
$= 12000 \, cal = 12K \, cal$

Question50

The potential energy (U) of a diatomic molecule is a function dependent on r (interatomic distance) as $U = \frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3$ where, α and β are positive constants. The equilibrium distance between two atoms will be $\left(\frac{2\alpha}{\beta}\right)^{\frac{a}{b}}$, where a = ...
[25 Feb 2021 Shift 1]

Answer: 1

Solution:

Solution:
Given, potential energy, $U = \frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3$
As we know for equilibrium, differentiation of potential energy with respect to distance $\left(\frac{du}{dr}\right) = 0$
$\Rightarrow \frac{d}{dr}\left(\frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3\right) = 0$
$\Rightarrow \frac{d}{dr}(\alpha r^{-10} - \beta r^{-5} - 3) = 0$
$-10\alpha r^{-11} + 5\beta r^{-6} - 0 = 0$
$\Rightarrow 10\alpha r^{-11} = 5\beta r^{-6}$
$\Rightarrow 2\alpha r^{-11} = \beta r^{-6}$
$\Rightarrow \frac{2\alpha}{\beta} = \frac{r^{-6}}{r^{-11}} = r^5 \Rightarrow r = \left(\frac{2\alpha}{\beta}\right)^{1/5}$
$\Rightarrow a = 1$
$\Rightarrow \frac{d}{dr}\left(\frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3\right) = 0$
$\Rightarrow \frac{d}{dr}(\alpha r^{-10} - \beta r^{-5} - 3) = 0$
$\Rightarrow -10\alpha r^{-11} + 5\beta r^{-6} - 0 = 0$
$\Rightarrow 10\alpha r^{-11} = 5\beta r^{-6}$
$\Rightarrow 2\alpha r^{-11} = \beta r^{-6}$
$\Rightarrow \frac{2\alpha}{\beta} = \frac{r^{-6}}{r^{-11}} = r^5 \Rightarrow r = \left(\frac{2\alpha}{\beta}\right)^{1/5}$

$\Rightarrow$ a = 1

Question51

The root mean square speed of molecules of a given mass of a gas at $27^{\circ}C$ and 1 atmosphere pressure is $200 ms^{-1}$. The root mean square speed of molecules of the gas at $127^{\circ}C$ and 2 atmosphere pressure is $\frac{x}{\sqrt{3}} ms^{-1}$. The value of x will be [24 Feb 2021 Shift 2]

Answer: 400

Solution:

Solution:
Given, $T_1 = 27^{\circ}C = 27 + 273 = 300K$,
$p_1 = 1atm, v_1 = 200ms^{-1}, T_2 = 127^{\circ}C = 400K$,
$p_2 = 2atm, v_2 = ?$
As we know that,
Root mean square speed, $v_{rms} = \sqrt{\frac{3RT}{m}}$

$\therefore \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{300}{400}} = \sqrt{\frac{3}{4}}$

$\Rightarrow v_2 = \sqrt{\frac{4}{3}} v_1 = \frac{2}{\sqrt{3}} \times 200 = \frac{400}{\sqrt{3}} ms^{-1}$

$\Rightarrow \frac{x}{\sqrt{3}} = \frac{400}{\sqrt{3}} \Rightarrow x = 400$

Question52

On the basis of kinetic theory of gases, the gas exerts pressure because its molecules [24 Feb 2021 Shift 2]

Options:

A. continuously lose their energy till it reaches wall

B. are attracted by the walls of container

C. continuously stick to the walls of container

D. suffer change in momentum when impinge on the walls of container

Answer: D

Solution:

Solution:
On the basis of kinetic theory of gases, the gas exerts pressure because its molecules contain uniform speed, random motion and perform elastic collision with each other, as well as with the walls of container. As a result of which gaseous molecules suffer change in momentum when impinge on the walls of container.

Question53

A container is divided into two chambers by a partition. The volume of first chamber is 4.5L and second chamber is 5.5L. The first chamber contain 3.0mol of gas at pressure 2.0atm and second chamber contain 4.0mol of gas at pressure 3.0atm. After the partition is removed and the mixture attains equilibrium, then the common equilibrium pressure existing in the mixture is $x \times 10^{-1}$ atm. Value of x is ....
[26 Feb 2021 Shift 1]

Answer: 25.5

Solution:

Solution:
Given, volume of 1 st chamber, $V_1 = 4.5L$
Volume of 2 nd chamber, $V_2 = 5.5L$
$n_1 = 3mol$
$p_1 = 2atm$
$n_2 = 4mol$
$p_2 = 3atm$
By using ideal gas equation, $pV = nRT$
$\therefore\ p_1V_1 + p_2V_2 = p(V_1 + V_2)$
$\Rightarrow 2 \times 4.5 + 3 \times 5.5 = p \times 10$
$\Rightarrow 9 + 16.5 = 10p \Rightarrow \frac{25.5}{10} = p$
$\therefore p = 25.5 \times 10^{-1} atm$
Hence, $x = 25.5 atm$

Question54

The internal energy (U), pressure (p) and volume (V) of an ideal gas are related as $U = 3pV + 4$. The gas is
[26 Feb 2021 Shift 2]

Options:

A. diatomic only

B. polyatomic only

C. Either monoatomic or diatomic

D. monoatomic only

Answer: B

Solution:

Solution:
Given, ideal gas equation, $U = 3pV + 4$
Here, $U =$ internal energy,
$p =$ pressure
and $V =$ volume.
By ideal gas equation, $pV = nR\Delta T$
$= R\Delta T \; (\because n = 1) \ldots$ (i)
$\Delta U = nC_v \Delta T = 3pV + 4$
$= n\frac{f}{2}R\Delta T = 3pV + 4$
$\Rightarrow fR\Delta T = 6pV + 8$
$\Rightarrow f \cdot pV = 6pV + 8$ [From Eq. (i)]
$\Rightarrow f = 6 + \frac{8}{pV}$
[From Eq. (i)] As, degree of freedom is more than 6 .
$\therefore$ Gas is polyatomic.

Question55

Given below are two statements:
Statement I In a diatomic molecule, the rotational energy at a given temperature obeys Maxwell's distribution.
Statement II In a diatomic molecule, the rotational energy at a given temperature equals the translational kinetic energy for each molecule.
In the light of the above statements, choose the correct answer from the options given below.
[25 Feb 2021 Shift 2]

Options:

A. Both Statement I and Statement II are true.

B. Both Statement I and Statement II are false.

C. Statement I is true but Statement II is false.

D. Statement I is false but Statement II is true.

Answer: C

Solution:

Solution:
According to Statement 1: In diatomic molecule the rotational energy at a given temperature obeys Maxwell's distribution is correct.
But, according to Statement 2: In diatomic molecule, the rotational energy at a given temperature equals translational energy for each molecule is false.
Because kinetic energy (KE) of gaseous molecule is $\frac{f}{2}K_BT$.
where, f is the degree of freedom, and f (diatomic atom) = 5 = [3 (translational) and 2 (rotational)]
Therefore, translational KE of gas $= \frac{3}{2}K_BT \ldots$ (i)
and rotational KE of gas $= 2/2K_BT = K_BT \ldots$ (ii)
$\because$ Eq. (i) is not equal to Eq. (ii)
Hence, option (c) is the correct.

Question56

A diatomic gas having $C_p = \frac{7}{2}R$ and $C_V = \frac{5}{2}R$, is heated at constant pressure. The ratio $dU : dQ : dW$ is
[25 Feb 2021 Shift 1]

Options:

A. 5 : 7 : 3

B. 5 : 7 : 2

C. 3 : 7 : 2

D. 3 : 5 : 2

Answer: B

Solution:

Solution:
Given, $C_p = 7/2R$, $C_V = 5/2R$
Since, change in internal energy $(dU) = nC_V dT$
Heat change $(dQ) = nC_p dT$
Work done $(dW) = nRdT$
$\therefore\ dU : dQ : dW = nC_V dT : nC_p dT : nRdT$
$= C_V : C_p : R = \frac{5}{2}R : \frac{7}{2}R : R$
$= 5R : 7R : 2R$
$= 5 : 7 : 2$

Question57

Consider a sample of oxygen behaving like an ideal gas. At 300K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be (Molecular weight of oxygen is 32g/mol; $R = 8.3 J K^{-1} mol^{-1}$)
[18 Mar 2021 Shift 2]

Options:

A. $\sqrt{\frac{3}{3}}$

B. $\sqrt{\frac{8}{3}}$

C. $\sqrt{\frac{3\pi}{8}}$

D. $\sqrt{\frac{8\pi}{3}}$

Answer: C

Solution:

Solution:
The expression of the root mean square velocity of the gas molecules,

$V_{ms} = \sqrt{\frac{3RT}{M}}$

The expression of the average velocity of the gas molecules,

$v_{aw} = \sqrt{\frac{8RT}{\pi M}}$

$\frac{v_{rms}}{v_{av}} = \frac{\sqrt{\frac{3RT}{M}}}{\sqrt{\frac{8RT}{\pi M}}} = \sqrt{\frac{3\pi}{8}}$

Question58

The volume V of an enclosure contains a mixture of three gases, 16g of oxygen, 28g of nitrogen and 44g of carbon dioxide at absolute temperature T . Consider R as universal gas constant. The pressure of the mixture of gases is [16 Mar 2021 Shift 1]

Options:

A. $\frac{88RT}{V}$

B. $\frac{3RT}{V}$

C. $\frac{5}{2}\frac{RT}{V}$

D. $\frac{4RT}{V}$

Answer: C

Solution:

Solution:
From ideal gas equation,
$pV = (n_1 + n_2 + n_3)RT$
where, $n_1 =$ number of moles of oxygen $= \frac{16}{32}$

$n_2 =$ number of moles of nitrogen $= \frac{28}{28}$

$n_3 =$ number of moles of carbon dioxide $= \frac{44}{44}$

$\Rightarrow pV = \left[\frac{16}{32} + \frac{28}{28} + \frac{44}{44}\right]RT = \left[\frac{1}{2} + 1 + 1\right]_{RT}$

$= \frac{5}{2}RT \Rightarrow p = \frac{5}{2}\frac{RT}{V}$

This is the required pressure of the mixture of the gases.

Question59

Calculate the value of mean free path (λ) for oxygen molecules at temperature $27^{\circ}C$ and pressure $1.01 \times 10^{5}Pa$. Assume the molecular diameter 0.3nm and the gas is ideal.
($k = 1.38 \times 10^{-23} J K^{-1}$)
[16 Mar 2021 Shift 2]

Options:

A. 58nm

B. 32nm

C. 86nm

D. 102nm

Answer: D

Solution:

Solution:
Given,
Pressure of the gas, $p = 1.01 \times 10^{5} Pa$
Absolute temperature of gas, $T = 27^{\circ}C$
$= 27 + 273 = 300K$
Molecular diameter, $d = 0.3nm = 0.3 \times 10^{-9} m$
Boltzmann constant, $k_B = 1.38 \times 10^{-23} J / K$
Mean free path, $\lambda = \frac{k_B T}{\sqrt{2} \pi d^{2} p}$ ....(i)
Substituting the given values in Eq. (i), we get
$\lambda = \frac{1.38 \times 10^{-23} \times 300}{\sqrt{2} \times 3.14 \times (0.3 \times 10^{-9})^{2} \times 1.01 \times 10^{5}}$
$= 102nm$

Question60

What will be the average value of energy along one degree of freedom for an ideal gas in thermal equilibrium at a temperature T? (k_B is Boltzmann constant)
[18 Mar 2021 Shift 1]

Options:

A. $\frac{1}{2} k_B T$

B. $\frac{2}{3} k_B T$

C. $\frac{3}{2} k_B T$

D. $k_B T$

Answer: A

Solution:

Solution:
We know that,
The average value of energy of an ideal gas in thermal equilibrium temperature T,
$E = \frac{f}{2} k_B T$
Given, degree of freedom, $f = 1$
Energy per degree of freedom, $E = \frac{1}{2} k_B T$

Question61

If one mole of the polyatomic gas is having two vibrational modes and β is the ratio of molar specific heats for polyatomic gas $\left(\beta = \frac{C_p}{C_V}\right)$, then the value of β is
[17 Mar 2021 Shift 2]

Options:

A. 1.02

B. 1.2

C. 1.25

D. 1.35

Answer: B

Solution:

Solution:
For polyatomic gas molecule has 3 rotational degrees of freedom, 3 translational degrees of freedom, and 2 vibrational modes.
So, number of vibrational degrees of freedom $= 2(2) = 4$
∴ Total number of degrees of freedom,
$f = 3 + 3 + 4 = 10$
Here, ratio of molar specific heats is given as
$\beta = \frac{C_p}{C_v}$
In terms of degrees of freedom, $\beta = 1 + \frac{2}{f}$
Substituting the value of f in above equation, we get
$\beta = 1 + \frac{2}{10} \Rightarrow \beta = 1.2$

Question62

Two ideal polyatomic gases at temperatures T_1 and T_2 are mixed so that there is no loss of energy. If f_1 and f_2, m_1 and m_2, n_1 and n_2 be the degrees of freedom, masses, number of molecules of the first and

second gas respectively, the temperature of mixture of these two gases is
[17 Mar 2021 Shift 1]

Options:

A. $\frac{n_1T_1 + n_2T_2}{n_1 + n_2}$

B. $\frac{n_1f_1T_1 + n_2f_2T_2}{n_1f_1 + n_2f_2}$

C. $\frac{n_1f_1T_1 + n_2f_2T_2}{f_1 + f_2}$

D. $\frac{n_1f_1T_1 + n_2f_2T_2}{n_1 + n_2}$

Answer: B

Solution:

Solution:
According to question, two ideal atomic gases at temperatures T_1 and T_2 are mixed.
Let the final temperature of this mixture be T.
As per question there is no loss of energy, it means
$\Delta U = 0$...(i)
As, we know, $\Delta U = \frac{f_1n_1R\Delta T}{2} + \frac{f_2n_2R\Delta T}{2}$....(ii)
From Eqs. (i) and (ii), we get
$\frac{f_1n_1R\Delta T}{2} + \frac{f_2n_2R\Delta T}{2} = 0$
$\Rightarrow f_1n_1R\Delta T + f_2n_2R\Delta T = 0$
$\Rightarrow f_1n_1R(T_1 - T) + f_2n_2R(T_2 - T) = 0$
$\Rightarrow f_1n_1(T_1 - T) + f_2n_2(T_2 - T) = 0$
$\Rightarrow f_1n_1T_1 - f_1n_1T + f_2n_2T_2 - f_2n_2T = 0$
$\Rightarrow f_1n_1T + f_2n_2T = f_1n_1T_1 + f_2n_2T_2$
$\Rightarrow T(f_1n_1 + f_2n_2) = f_1n_1T_1 + f_2n_2T_2$
$T = \frac{f_1n_1T_1 + f_2n_2T_2}{f_1n_1 + f_2n_2}$

Question63

A polyatomic ideal gas has 24 vibrational modes. What is the value of γ ? [17 Mar 2021 Shift 1]

Options:

A. 1.03

B. 1.30

C. 1.37

D. 10.3

Answer: A

Solution:

Solution:
Since we know that, the heat capacity ratio γ for an ideal gas can be related to the degrees of freedom of gas molecules (f) by formula

$\gamma = 1 + \frac{2}{f}$.....(i)

As each vibrational mode has 2 degrees of freedom, hence total vibrational degrees of freedom $= 2 \times 24 = 48$

$\Rightarrow f = 3$ (rotational) $+3$ (translational) $+48$ (vibrational)

$\Rightarrow f = 3 + 3 + 48 \Rightarrow f = 54$

Now, put the value of f in Eq. (i), we get

$\gamma = 1 + \frac{2}{54} \Rightarrow \gamma = 1 + \frac{1}{27}$

$\Rightarrow \gamma = \frac{28}{27}$ or $\gamma = 1.03$

Question64

The number of molecules in one litre of an ideal gas at $300K$ and 2 atmospheric pressure with mean kinetic energy $2 \times 10^{-9}J$ per molecules is :
[27 Jul 2021 Shift 1]

Options:

A. 0.75×10^{11}

B. 3×10^{11}

C. 1.5×10^{11}

D. 6×10^{11}

Answer: C

Solution:

Solution:

$KE = \frac{3}{2}kT$

$PV = \frac{N}{N_A}RT$

$N = \frac{PV}{kT}$

$= N = 1.5 \times 10^{11}$

Question65

A system consists of two types of gas molecules A and B having same number density $2 \times 10^{25} / m^3$. The diameter of A and B are 10Å and 5Å respectively. They suffer collision at room temperature. The ratio of average distance covered by the molecule A to that of B between two successive collision is ______ $\times 10^{-2}$

[25 Jul 2021 Shift 2]

Answer: 25

Solution:

Solution:
∵ mean free path

$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

$\frac{\lambda_1}{\lambda_2} = \frac{d_2^2 n_2}{d_1^2 n_1}$

$= \left(\frac{5}{10}\right)^2 = 0.25 = 25 \times 10^{-2}$

Question66

For a gas $C_P - C_V = R$ in a state P and $C_P - C_V = 1.10R$ in a state Q, T_P and T_Q are the temperatures in two different states P and Qrespectively. Then
[25 Jul 2021 Shift 1]

Options:

A. $T_P = T_Q$

B. $T_P < T_Q$

C. $T_P = 0.9T_Q$

D. $T_P > T_Q$

Answer: D

Solution:

Solution:
$C_P - C_V = R$ for ideal gas and gas behaves as ideal gas at high temperature
so $T_P > T_Q$

Question67

Consider a mixture of gas molecule of types A, B and C having masses $m_A < m_B < m_C$. The ratio of their root mean square speeds at normal temperature and pressure is :
[20 Jul 2021 Shift 1]

Options:

A. $v_A = v_B = v_C = 0$

B. $\frac{1}{v_A} > \frac{1}{v_B} > \frac{1}{v_C}$

C. $v_A = v_B \neq v_C$

D. $\frac{1}{v_A} < \frac{1}{v_B} < \frac{1}{v_C}$

Answer: D

Solution:

Solution:

$V_{RMS} = \sqrt{\frac{3RT}{M}}$

$m_A < m_B < m_C$

$\Rightarrow v_A > v_B > v_C$

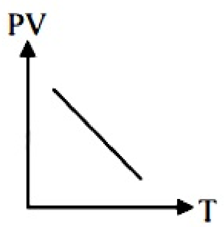
$\Rightarrow \frac{1}{v_A} < \frac{1}{v_B} < \frac{1}{v_C}$

Question68

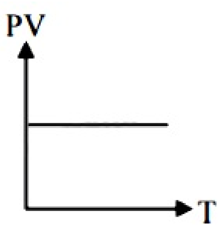
Which of the following graphs represent the behavior of an ideal gas ? Symbols have their usual meaning. [20 Jul 2021 Shift 2]

Options:

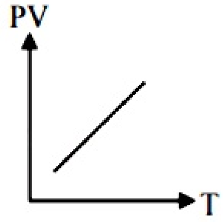
A.



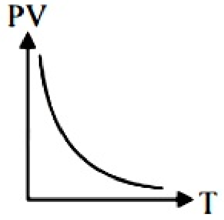
B.



C.



D.



Answer: C

Solution:

Solution:
$PV = nRT$
$PV \propto T$
Straight line with positive slope (nR)

Question69

What will be the average value of energy for a monoatomic gas in thermal equilibrium at temperature T ?
[22 Jul 2021 Shift 2]

Options:

A. $\frac{2}{3}k_B T$

B. $k_B T$

C. $\frac{3}{2}k_B T$

D. $\frac{1}{2}k_B T$

Answer: C

Solution:

Solution:
As per Equi-partition law :
Each degree of freedom contributes
$\frac{1}{2}k_B T$ Average Energy
In monoatomic gas D.O.F. $= 3$
$\Rightarrow$ Average energy $= 3 \times \frac{1}{2}k_B T = \frac{3}{2}k_B T$

Question70

The correct relation between the degrees of freedom f and the ratio of specific heat γ is :
[20 Jul 2021 Shift 2]

Options:

A. $f = \frac{2}{\gamma - 1}$

B. $f = \frac{2}{\gamma + 1}$

C. $f = \frac{\gamma + 1}{2}$

D. $f = \frac{1}{\gamma + 1}$

Answer: A

Solution:

Solution:

$\gamma = 1 + \frac{2}{f}$

$f = \frac{2}{\gamma - 1}$

Question71

For an ideal gas the instantaneous change in pressure p with volume V is given by the equation $\frac{dp}{dV} = -ap$. If $p = p_0$ at V = 0 is the given boundary condition, then the maximum temperature one mole of gas can attain is
(Here R is the gas constant)
[31 Aug 2021 Shift 1]

Options:

A. $\frac{p_0}{aeR}$

B. $\frac{ap_0}{cR}$

C. infinity

D. 0°C

Answer: A

Solution:

Solution:
Given,

Change in pressure with volume $\frac{dp}{dV} = -ap$

At $V = 0$, $p = p_0$

Number of mole n = 1

Gas constant, $R = 8.314 JK^{-1}$

From given equation,

$\frac{dp}{p} = -adV$

$\int_{p_0}^{p} \frac{dp}{p} = -a \int_{0}^{V} dV$

$\Rightarrow [\ln p]_{p_0}^{p} = -a[V]_0^V$

$\Rightarrow \ln\left(\frac{p}{p_0}\right) = -a(V - 0)$

Taking anti log on both side,

$\Rightarrow \frac{p}{p_0} = e^{-aV}$

$\Rightarrow p = p_0 e^{-aV}$

By using ideal gas law,

pV = nRT

$\Rightarrow (p_0 e^{-aV})V = nRT$

$\Rightarrow \frac{1}{nR}(p_0 e^{-aV})V = T$

$\Rightarrow \frac{1}{R}(p_0 e^{-aV})V = T$ [∵ n = 1]...(i)

For maximum temperature (T_{max}),

On differentiating both side with respect to V, we get

$\Rightarrow \frac{1}{nR}[p_0 . e^{-aV} . (-aV)V + p_0 e^{-aV}] = \frac{dT}{dV} = 0$

$\Rightarrow p_0 e^{-aV}(1 - aV^2) = 0$

$\Rightarrow 1 = aV^2$

$\Rightarrow V^2 = \frac{1}{a}$

$\Rightarrow V = \frac{1}{a}$

Substituting the value in Eq. (i), we get

$T = \frac{1}{R}\left(p_0 e^{-a.\frac{1}{a}}\right)\frac{1}{a} = \frac{p_0 e^{-1}}{R}\left(\frac{1}{a}\right) = \frac{p_0}{eRa}$

Question72

A mixture of hydrogen and oxygen has volume $500 cm^3$, temperature 300K, pressure 400 kPa and mass 0.76g. The ratio of masses of oxygen to hydrogen will be [31 Aug 2021 Shift 2]

Options:

A. 3 : 8

B. 3 : 16

C. 16 : 3

D. 8 : 3

Answer: C

Solution:

Solution:
Given,
Volume, $V = 500cm^3 = 5 \times 10^2 \times 10^{-6} m^3$
$= 5 \times 10^{-4} m^3$
Pressure, $p = 400\,kPa = 4 \times 10^5\,Pa$
Temperature, T = 300 K
Total mass, m = 0.76 g
We know that,
Molar mass of hydrogen, M_1= 2 g
Molar mass of oxygen, M_2 = 32 g
Let n_1 and n_2 be the number of moles of hydrogen and oxygen, respectively.
Total number of moles of mixture, $n = n_1 + n_2$
By using ideal gas equation, pV = nRT
Substituting the values, we get
$4 \times 10^5 \times 5 \times 10^{-4} = n \times 8.314 \times 300$
n= 0.08 mol
Then,$n_1 + n_2 = 0.08$
Let mass of hydrogen in mixture = m_1
and mass of oxygen in oxygen = m_2
$n_1 M_1 + n_2 M_2 = m \left[\because n = \frac{m}{M} \Rightarrow m = nM \right]$
Substituting the values, we get
$2n_1 + 32n_2 = 0.76$
$n_1 + 16n_2 = 0.38$ ...(ii)
Solving Eqs. (i) and (ii), we get
$n_1 = 0.06$ and $n_2 = 0.02$
∴ Ratio of masses,
$\frac{m_2}{m_1} = \frac{n_2 M_2}{n_1 M_1} = 0.02 \times 320.06 \times 2 = \frac{16}{3}$
i.e. $m_2 : m_1 = 16 : 3$

Question73

If the rms speed of oxygen molecules at 0°C is 160m / s, find the rms speed of hydrogen molecules at 0°C.
[27 Aug 2021 Shift 2]

Options:

A. 640m / s

B. 40m / s

C. 80m / s

D. 332m / s

Answer: A

Solution:

Solution:
Given, rms speed of oxygen$(v_{rms})_{O_2} = 160$ m / s
Let rms speed of hydrogen $= (v_{rms})_{H_2}$
Since, $v_{rms} = \sqrt{\frac{3RT}{M}}$
where, R = universal gas constant,
T = temperature
and M = molecular mass.

$\therefore \quad \frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}}$

$\Rightarrow \quad \frac{160}{(v_{rms})_{H_2}} = \sqrt{\frac{1}{16}}$

$\Rightarrow \quad \frac{160}{(v_{rms})_{H_2}} = \frac{1}{4}$

$\Rightarrow \ (v_{rms})_{H_2} = 160 \times 4$

$= 640 ms^{-1}$

Question74

An ideal gas is expanding such that pT^3 = constant. The coefficient of volume expansion of the gas is
[27 Aug 2021 Shift 1]

Options:

A. $\frac{1}{T}$

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

C. $\frac{4}{T}$

D. $\frac{3}{T}$

Answer: C

Solution:

Solution:
Given, pT^3 = constant ...(i)
From ideal gas equation, we have
$pV = nRT$
$\Rightarrow p = \frac{nRT}{V}$
From Eq. (i), we get
$\therefore \left(\frac{nRT}{V}\right) T^3 = \text{constant}$
$\Rightarrow nRT^4V^{-1} = \text{constant}$
Differentiate above expression, we get
$nR\left[4T^3V^{-1}\,dT - \frac{T^4}{V^2}\,dV\right] = 0$
$\Rightarrow 4\,dT = \frac{T}{V}\,dV$ ...(ii)
We know that, $dV = \gamma\, VdT$
Here, γ = coefficient of volume expansion.
$\Rightarrow \gamma = \frac{dV}{VdT}$ ...(iii)
From Eq. (ii),
$\frac{4}{T} = \frac{dV}{VdT}$ ...(iv)
On comparing Eqs. (iii) and (iv), we get
$\gamma = \frac{4}{T}$
Thus, the coefficient of volume expansion is $\frac{4}{T}$.

Question75

A balloon carries a total load of 185 kg at normal pressure and temperature of 27°C. What load will the balloon carry on rising to a height at which the barometric pressure is 45 cm of Hg and the temperature is −7°C?
[Assuming, the volume constant.]
[27 Aug 2021 Shift 1]

Options:

A. 181.46 kg

B. 214.15 kg

C. 219.07 kg

D. 123.54 kg

Answer: D

Solution:

Solution:
Given, initial load, $M_1 = 185\,\text{kg}$
Initial pressure, $p_1 = 76\,\text{cm}$ of Hg
Initial temperature, $T_1 = 27°C = (273 + 27)K = 300K$
Final pressure at height, $p_2 = 45\,\text{cm}$ of Hg
Final temperature, $T_2 = -7°C = [273 + (-7)]K = 266K$
Volume of balloon is constant, $V_1 = V_2 = V$
We know that, for air,
$p = \rho RT$
Now, for initial condition, we can write
$\rho_1 = \rho_1 RT_1$ ...(i)
Similarly, for final condition, we can write
$P_2 = \rho_2 RT_2$ ...(ii)
Dividing Eq. (i) by Eq. (ii), we get
$$\frac{p_1}{p_2} = \frac{\rho_1 T_1}{\rho_2 T_2}$$
Substituting the given values in above expression, we get
$$\frac{76\,\text{cm of Hg}}{45\,\text{cm of Hg}} = \frac{\rho_1}{\rho_2}\left(\frac{300K}{266K}\right)$$
$$\Rightarrow \frac{\rho_1}{\rho_2} = \frac{76 \times 266}{45 \times 300}$$
We know that, density of balloon can be written as
$$\rho \frac{M}{V}$$
As, volume is constant ρ ∝ M
We can write,
$$\frac{\rho_1}{\rho_2} = \frac{M_1}{M_2} = \frac{76 \times 266}{45 \times 300}$$
$$\Rightarrow \frac{M_1}{M_2} = \frac{20216}{13500}$$
Substituting the value of M_1 in above expression, we get
$$M_2 = 185 \times \frac{13500}{20216} = 123.54\,\text{kg}$$
Thus, the load carried by balloon will be 123.54 kg.

Question76

A cylindrical container of volume $4.0 \times 10^{-3} m^3$ contains one mole of hydrogen and two moles of carbon dioxide. Assume the temperature of the mixture is 400K. The pressure of the mixture of gases is [Take, gas constant $= 8.3 J mol^{-1} K^{-1}$] [26 Aug 2021 Shift 2]

Options:

A. 249×10^1 Pa

B. 24.9×10^3 Pa

C. 24.9×10^5 Pa

D. 24.9 Pa

Answer: C

Solution:

Solution:
Given, volume of container, $V = 4.0 \times 10^{-3} m^3$
Gas constant, $R = 8.3 J\ mol^{-1} K^{-1}$
Number of moles of hydrogen, $n_1 = 1$
Number of moles of carbon dioxide, $n_2 = 2$
Temperature of mixture, T = 400 K
Using Dalton's law to calculate the pressure of mixture as follows
$p = p_1 + p_2$
$= \frac{n_1 RT}{V} + \frac{n_2 RT}{V}$
$= \frac{RT}{V}(n_1 + n_2) = \frac{RT}{V}(1 + 2) = \frac{3RT}{V}$
$= \frac{3 \times 8.3 \times 400}{4.0 \times 10^{-3}} = 24.9 \times 10^5$ Pa
Thus, the pressure of mixture of gases is 24.9×10^5 Pa.
Thus, the pressure of mixture of gases is 24.9×10^5 Pa.

Question77

The rms speeds of the molecules of hydrogen, oxygen and carbondioxide at the same temperature are v_H, v_O and v_{CO_2} respectively, then [26 Aug 2021 Shift 1]

Options:

A. $v_H > v_O > v_{CO_2}$

B. $v_{CO_2} > v_O > v_H$

C. $v_H = v_O > v_{CO_2}$

D. $v_H = v_O = v_{CO_2}$

Answer: A

Solution:

Solution:
The rms speed of the molecule of gas is given by
$v_{rms} = \sqrt{\frac{3RT}{M}}$
According to the, question T is constant.
Moreover R is also a constant. So, we get
$v_{rms} \propto \frac{1}{\sqrt{M}}$
$(M_H)M_{hydrogen} = 1.00784u \approx 1u$
$(M_O)M_{oxygen} = 15.999u \approx 16u$
$(M_{CO_2})M_{carbon\,dioxide} = 44u$
$(v_{rms})_{hydrogen} > (v_{rms})_{oxygen} > (v_{rms})_{carbon\,dioxide}$
$\Rightarrow v_H > v_O > v_{CO_2}$

Question78

The temperature of 3.00 mol of an ideal diatomic gas is increased by 40.0°C without changing the pressure of the gas. The molecules in the gas rotate but do not oscillate. If the ratio of change in internal energy of the gas to the amount of workdone by the gas is $\frac{x}{10}$, then the value of x (round off to the nearest integer) is ....
(Given, R = 8.31$Jmol^{-1}K^{-1}$)
[1 Sep 2021 Shift 2]

Answer: 25

Solution:

Given, the number of diatomic moles, n = 3 mol
The increase in temperature of the diatomic mole,
ΔT = 40ºC
Now, the degree of freedom,
f = linear + rotational + no oscillation
f = 3 + 2 + 0
f = 5
Change in internal energy,
$\Delta U = nC_V\Delta T$
where,
$C_V = \frac{f}{2}R = \frac{5}{2}R$
Substituting the value in Eq. (i), we get
$\Delta U = \frac{5R}{2}n\Delta T$
Now, work done by the gas for isobaric process,
$W = p\Delta V = nR\Delta T$
The ratio of the change in internal energy to the work done by thegas,
$\frac{\Delta U}{W} = \frac{\frac{5}{2}nR\Delta T}{nR\Delta T}$

$\frac{\Delta U}{W} = \frac{5}{2}$
Multiply and divide the above equation with 5, we get
$\frac{\Delta U}{W} = \frac{5 \times 5}{2 \times 5} = \frac{25}{10}$
Comparing with given equation, $\frac{\Delta U}{W} = \frac{x}{10}$
The value of the x = 25.

Question79

Consider two ideal diatomic gases A and B at some temperature T . Molecules of the gas A are rigid, and have a mass m. Molecules of the gas B have an additional vibrational mode, and have a mass $\frac{m}{4}$. The ratio of the specific heats ($C_V{}^A$ and $C_V{}^B$) of gas A and B, respectively is: [9 Jan 2020 I]

Options:

A. 7 : 9

B. 5 : 9

C. 3 : 5

D. 5 : 7

Answer: D

Solution:

Solution:
Specific heat of gas at constant volume
$C_v = \frac{1}{2} f R$; f = degree of freedom
For gas A (diatomic)
f = 5(3 translational +2 rotational)
$\therefore C_v{}^A = \frac{5}{2} R$
For gas B (diatomic) in addition to (3 translational +2 rotational) 2 vibrational degree of freedom.
$\therefore C_v{}^B = \frac{7}{2} R$ Hence $\frac{C_v{}^A}{C_v{}^B} = \frac{\frac{5}{2} R}{\frac{7}{2} R} = \frac{5}{7}$

Question80

Two gases-argon (atomic radius 0.07 nm, atomic weight 40) and xenon (atomic radius 0.1 nm, atomic weight 140) have the same number density and are at the same temperature. The ratio of their respective mean free times is closest to: [9 Jan 2020 II]

Options:

A. 3.67

B. 1.83

C. 2.3

D. 1.09

Answer: D

Solution:

Solution:

Mean free path of a gas molecule is given by $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

Here, n = number of collisions per unit volume
d = diameter of the molecule
If average speed of molecule is v then

Mean free time, $\tau = \frac{\lambda}{v}$

$\Rightarrow \tau = \frac{1}{\sqrt{2}\pi n d^2 v} = \frac{1}{\sqrt{2}\pi n d^2}\sqrt{\frac{M}{3RT}}\left(\because v = \sqrt{\frac{3RT}{M}}\right)$

$\therefore \tau \propto \frac{\sqrt{M}}{d^2} \therefore \frac{\tau_1}{\tau_2} = \frac{\sqrt{M_1}}{d_1^2} \times \frac{d_2^2}{\sqrt{M_2}}$

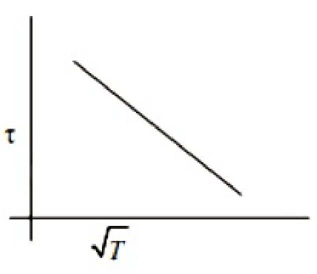
$= \sqrt{\frac{40}{140}} \times \left(\frac{0.1}{0.07}\right)^2 = 1.09$

Question81

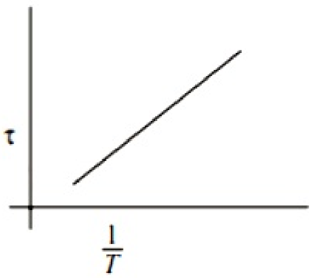
The plot that depicts the behavior of the mean free time τ (time between two successive collisions) for the molecules of an ideal gas, as a function of temperature (T), qualitatively, is: (Graphs are schematic and not drawn to scale)
[8 Jan. 2020 I]

Options:

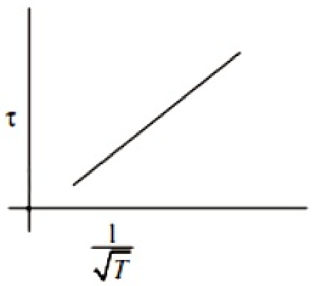
A.



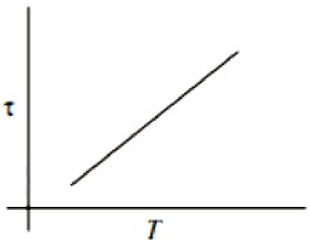
B.



C.



D.



Answer: C

Solution:

Solution:

Relaxation time $(\tau) \propto \frac{\text{mean free path}}{\text{speed}} \Rightarrow \tau \propto \frac{1}{v}$ and, $v \propto \sqrt{T}$

$\therefore \tau \propto \frac{1}{\sqrt{T}}$

Hence graph between τ v / s $\frac{1}{\sqrt{T}}$ is a straight line which is correctly depicted by graph shown in option (c).

Question82

Consider a mixture of n moles of helium gas and 2n moles of oxygen gas (molecules taken to be rigid) as an ideal gas. Its C_P / C_V value will be: [8 Jan. 2020 II]

Options:

A. 19/13

B. 67/45

C. 40/27

D. 23/15

Answer: A

Solution:

Solution:
Helium is a monoatomic gas and Oxygen is a diatomic gas.

For helium, $C_{V_1} = \frac{3}{2}R$ and $C_{P_1} = \frac{5}{2}R$

For oxygen, $C_{V_2} = \frac{5}{2}R$ and $C_{P_2} = \frac{7}{2}R$

$\gamma = \frac{N_1 C_{P_1} + N_2 C_{P_2}}{N_1 C_{V_1} + N_2 C_{V_2}}$

$\Rightarrow \gamma = \frac{n\frac{5}{2}R + 2n \cdot \frac{7}{2}R}{n\frac{3}{2}R + 2n\frac{5}{2}R} = \frac{19nR \times 2}{2(13nR)}$

$\therefore \left(\frac{C_P}{C_V}\right)_{\text{mixture}} = \frac{19}{13}$

Question83

Two moles of an ideal gas with $\frac{C_p}{C_V} = \frac{5}{3}$ are mixed with 3 moles of another ideal gas with $\frac{C_p}{C_V} = \frac{4}{3}$. The value of $\frac{C_p}{C_V}$ for the mixture is: [7 Jan. 2020 I]

Options:

A. 1. 45

B. 1.50

C. 1.47

D. 1.42

Answer: D

Solution:

Solution:

Using, $\gamma_{\text{mixture}} = \frac{n_1 C_{p_1} + n_2 C_{p_2}}{n_1 C_{v_1} + n_2 C_{v_2}}$

$\Rightarrow \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1} = \frac{n_1 + n_2}{\gamma_m - 1}$

$\Rightarrow \frac{3}{\frac{4}{3} - 1} + \frac{2}{53 - 1} = \frac{5}{\gamma_m - 1}$

$\Rightarrow \frac{9}{1} + \frac{2 \times 3}{2} = \frac{5}{\gamma_m - 1} \Rightarrow \gamma_m - 1 = \frac{5}{12}$

$\Rightarrow \gamma_m = \frac{17}{12} = 1.42$

Question84

Initially a gas of diatomic molecules is contained in a cylinder of volume V_1 at a pressure P_1 and temperature $250K$. Assuming that 25% of the molecules get dissociated causing a change in number of moles. The pressure of the resultinggas at temperature $2000K$, when contained in a volume $2V_1$ is given by P_2. The ratio P_2 / P_1 is
[NA Sep. 06, 2020 (I)]

Answer: 5

Solution:

Using ideal gas equation, $PV = nRT$
$\Rightarrow P_1V_1 = nR \times 250 \quad [\because T_1 = 250K]$ ....(i)
$P_2\left(2V_1 = \frac{5n}{4}R \times 2000 \quad [\because T_2 = 2000K]\right.$ ....(ii)
Dividing eq. (i) by(ii),
$\frac{P_1}{2P_2} = \frac{4 \times 250}{5 \times 2000} \Rightarrow \frac{P_1}{P_2} = \frac{1}{5}$
$\therefore \frac{P_2}{P_1} = 5$

Question85

The change in the magnitude of the volume of an ideal gas when a small additional pressure ΔP is applied at a constant temperature, is the same as the change when the temperature is reduced by a small quantity ΔT at constant pressure. The initial temperature and pressure of the gaswere 300 K and 2 atm. respectively. If $|\Delta T| = C|\,|\Delta P|$,then value of C in (K/atm.) is __________.
[NA Sep. 04, 2020 (II)]

Answer: 150

Solution:

In first case,
From ideal gas equation
$PV = nRT$
$P\Delta V + V\Delta P = 0$ (As temperature is constant)
$\Delta V = -\frac{\Delta P}{P}V$ ...(i)
In second case, using ideal gas equation again

$P\Delta V = -nR\Delta T$

$\Delta V = -\frac{nR\Delta T}{P}$...(ii)

Equating (i) and (ii), we get

$\frac{nR\Delta T}{P} = -\frac{\Delta P}{P}V \Rightarrow \Delta T = \Delta P\frac{V}{nR}$

Comparing the above equation with $|\Delta T| = C|\Delta P|$, we have

$C = \frac{V}{nR} = \frac{\Delta T}{\Delta P} = \frac{300K}{2atm} = 150K / atm$

Question86

Number of molecules in a volume of $4cm^3$ of a perfect monoatomic gas at some temperature T and at a pressure of 2cm of mercury is close to? (Given, mean kinetic energy of a molecule (at T) is 4×10^{-14} erg, $g = 980cm / s^2$, density of mercury $= 13.6g / cm^3$) [Sep. 05, 2020 (I)]

Options:

A. 4.0×10^{18}

B. 4.0×10^{16}

C. 5.8×10^{16}

D. 5.8×10^{18}

Answer: A

Solution:

Solution:

Given: $K.E_{mean} = \frac{3}{2}kT = 4 \times 10^{-14}$

$P = 2cm$ of Hg, $V = 4cm^3$

$N = \frac{PV}{KT} = \frac{P\rho gV}{KT}\frac{2 \times 13.6 \times 980 \times 4}{\frac{8}{3} \times 10^{-14}} \simeq 4 \times 10^{18}$

Question87

Nitrogen gas is at 300°C temperature. The temperature (in K) at which the rms speed of a H_2 molecule would be equal to the rms speed of a nitrogen molecule, is ____________. (Molar mass of N_2 gas 28 g); [NA Sep. 05, 2020 (II)]

Answer: 41

Solution:

Room mean square speed is given by $v_{rms} = \sqrt{\frac{3RT}{M}}$

Here, M = Molar mass of gas molecule
T = temperature of the gas molecule
We have given $v_{N_2} = v_{H_2}$

$\therefore \sqrt{\frac{3RT_{N_2}}{M_{N_2}}} = \sqrt{\frac{3RT_{H_2}}{M_{H_2}}}$

$\Rightarrow \frac{T_{H_2}}{2} = \frac{573}{28} \Rightarrow T_{H_2} = 41K$

Question88

Molecules of an ideal gas are known to have three translational degrees of freedom and two rotational degrees of freedom. The gas is maintained at a temperature of T.
The total internal energy, U of a mole of this gas, and the value of $\gamma \left(= \frac{C_p}{C_v} \right)$ are given, respectively, by:
[Sep. 06, 2020 (I)]

Options:

A. $U = \frac{5}{2}RT$ and $\gamma = \frac{6}{5}$

B. $U = 5RT$ and $\gamma = \frac{7}{5}$

C. $U = \frac{5}{2}RT$ and $\gamma = \frac{7}{5}$

D. $U = 5RT$ and $\gamma = \frac{6}{5}$

Answer: C

Solution:

Solution:
Total degree of freedom $f = 3 + 2 = 5$
Total energy, $U = \frac{nfRT}{2} = \frac{5RT}{2}$
And $\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f} = 1 + \frac{2}{5} = \frac{7}{5}$

Question89

In a dilute gas at pressure P and temperature T , the mean time between successive collisions of a molecule varies with T is:
[Sep. 06, 2020 (II)]

Options:

A. T

B. $\frac{1}{\sqrt{T}}$

C. $\frac{1}{T}$

D. $\sqrt{T}$

Answer: B

Solution:

Solution:

Mean free path, $\lambda = \frac{1}{\sqrt{2}\pi n d^2}$

where, d = diameter of the molecule

n = number of molecules per unit volume

But, mean time of collision, $\tau = \frac{\lambda}{v_{rms}}$

But $v_{rms} = \sqrt{\frac{3kT}{R}}$

$\therefore \tau = \frac{\lambda}{\sqrt{\frac{3kT}{m}}} \Rightarrow t \propto \frac{1}{\sqrt{T}}$

Question90

Match the C_p / C_v ratio for ideal gases with different type of molecules :

Column-I	Column-II
Molecule Type	C_p / C_v
(A) Monatomic	(I) 7/5
(B) Diatomic rigid molecules	(II) 9/7
(C) Diatomic non-rigid molecules	(III) 4/3
(D) Triatomic rigid molecules	(IV) 5/3

[Sep. 04, 2020 (I)]

Options:

A. (A)-(IV), (B)-(II), (C)-(I), (D)-(III)

B. (A)-(III), (B)-(IV), (C)-(II), (D)-(I)

C. (A)-(IV), (B)-(I), (C)-(II), (D)-(III)

D. (A)-(II), (B)-(III), (C)-(I), (D)-(IV)

Answer: C

Solution:

As we know,
$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$, where f = degree of freedom
(A) Monatomic, $f = 3$
$\therefore \gamma = 1 + \frac{2}{3} = \frac{5}{3}$
(B) Diatomic rigid molecules, $f = 5$
$\therefore \gamma = 1 + \frac{2}{5} = \frac{7}{5}$
(C) Diatomic non-rigid molecules, $f = 7$
$\therefore \gamma = 1 + \frac{2}{7} = \frac{9}{7}$
(D) Triatomic rigid molecules, $f = 6$
$\therefore \gamma = 1 + \frac{2}{6} = \frac{4}{3}$

Question91

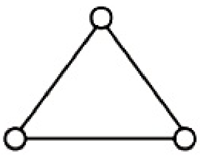
A closed vessel contains 0.1 mole of a monatomic ideal gas at 200 K. If 0.05 mole of the same gas at 400 K is added to it, the final equilibrium temperature (in K) of the gas in the vessel will be close to _________. [NA Sep. 04, 2020 (I)]

Answer: 266.67

Solution:

Solution:
Here work done on gas and heat supplied to the gas are zero.
Let T be the final equilibrium temperature of the gas in the vessel.
Total internal energy of gases remain same.
i.e., $u_1 + u_2 = u_1' + u_2'$
or, $n_1 C_v \delta T_1 + n_2 C_v \Delta T_2 = (n_1 + n_2) C_v T$
$\Rightarrow (0.1) C_v (200) + (0.05) C_v (400) = (0.15) C_v T$
$\therefore T = \frac{800}{3} = 266.67 K$

Question92



Consider a gas of triatomic molecules. The molecules are assumed to be triangular and made of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is : [Sep. 03, 2020 (I)]

Options:

A. $\frac{5}{2}RT$

B. $\frac{3}{2}RT$

C. $\frac{9}{2}RT$

D. 3RT

Answer: D

Solution:

Solution:
Here degree of freedom, $f = 3 + 3 = 6$ for triatomic nonlinear molecule.
Internal energy of a mole of the gas at temperature T ,
$U = \frac{f}{2}nRT = \frac{6}{2}RT = 3RT$

Question93

To raise the temperature of a certain mass of gas by 50°C at a constant pressure, 160 calories of heat is required. When the same mass of gas is cooled by 100°C at constant volume, 240 calories of heat is released. How many degrees of freedom does each molecule of this gas have (assume gas to be ideal)? [Sep. 03, 2020 (II)]

Options:

A. 5

B. 6

C. 3

D. 7

Answer: B

Solution:

Solution:
Let C_p and C_v be the specific heat capacity of the gas at constant pressure and volume.
At constant pressure, heat required
$\Delta Q_1 = nC_p\Delta T$
$\Rightarrow 160 = nC_p . 50$ ...(i)
At constant volume, heat required
$\Delta Q_2 = nC_v\Delta T$
$\Rightarrow 240 = nC_v . 100$...(ii)
Dividing (i) by (ii), we get
$\frac{160}{240} = \frac{C_p}{C_v} \cdot \frac{50}{100} \Rightarrow \frac{C_p}{C_v} = \frac{4}{3}$
$\gamma = \frac{C_p}{C_v} = \frac{4}{3} = 1 + \frac{2}{f}\Big($ Here ,$f =$ degree of freedom)
$\Rightarrow f = 6.$

Question94

A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Assuming the gases to be ideal and the oxygen bond to be rigid, the total internal energy (in units of RT) of the mixture is : [Sep. 02, 2020 (I)]

Options:

A. 15

B. 13

C. 20

D. 11

Answer: A

Solution:

Solution:
Total energy of the gas mixture,

$$E_{mix} = \frac{f_1 n_1 RT_1}{2} + \frac{f_2 n_2 RT_2}{2}$$

$$= 3 \times \frac{5}{2}RT + \frac{5}{2} \times 3RT = 15RT$$

Question95

An ideal gas in a closed container is slowly heated. As its temperature increases, which of the following statements are true?
(1) The mean free path of the molecules decreases
(2) The mean collision time between the molecules decreases
(3) The mean free path remains unchanged
(4) The mean collision time remains unchanged
[Sep. 02, 2020 (II)]

Options:

A. (2) and (3)

B. (1) and (2)

C. (3) and (4)

D. (1) and (4)

Answer: A

Solution:

As we know mean free path

$\lambda = \frac{1}{\sqrt{2}\left(\frac{N}{V}\right)\pi d^{2}}$

Here, N = no. of molecule
V = volume of container
d = diameter of molecule
But $PV = nRT = nNKT$

$\Rightarrow \frac{N}{V} = \frac{P}{KT} = n$

$\lambda = \frac{1}{\sqrt{2}} \frac{KT}{\pi d^{2} P}$

For constant volume and hence constant number density n of gas molecules $\frac{P}{T}$ is constant.

So mean free path remains same.
As temperature increases no. of collision increases so relaxation time decreases.

Question96

A mixture of 2 moles of helium gas (atomic mass = 4u), and 1 mole of argon gas (atomic mass = 40u) is kept at 300 K in a container. The ratio of their rms speeds $\left[\frac{V_{rms}(\text{helium})}{V_{rms}(\text{argon})}\right]$ is close to

[9 Jan. 2019 I]

Options:

A. 3.16

B. 0.32

C. 0.45

D. 2.24

Answer: A

Solution:

Solution:

Using $\frac{V_{1\,rms}}{V_{2\,rms}} = \sqrt{\frac{M_2}{M_1}}$

$\frac{V_{rms}(He)}{V_{rms}(Ar)} = \sqrt{\frac{M_{Ar}}{M_{He}}} = \sqrt{\frac{40}{4}} = 3.16$

Question97

A vertical closed cylinder is separated into two parts by a frictionless piston of mass m and of negligible thickness. The piston is free to move along the length of the cylinder. The length of the cylinder above the piston is l_1, and that below the piston is l_2, such that $l_1 > l_2$. Each part

of the cylinder contains n moles of an ideal gas at equal temperature T. If the piston is stationary, its mass, m, will be given by:
(R is universal gas constant and g is the acceleration due to gravity)
[12 Jan. 2019 II]

Options:

A. $\frac{RT}{ng}\left[\frac{l_1 - 3l_2}{l_1 l_2}\right]$

B. $\frac{RT}{g}\left[\frac{2l_1 + l_2}{l_1 l_2}\right]$

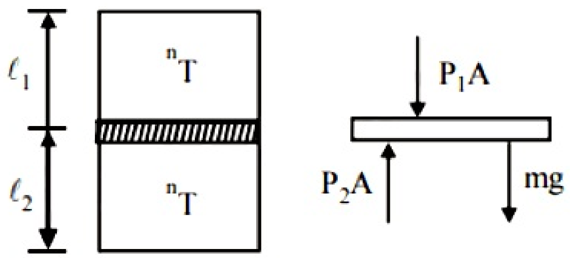
C. $\frac{nRT}{g}\left[\frac{1}{l_2} + \frac{1}{l_1}\right]$

D. $\frac{nRT}{g}\left[\frac{l_1 - l_2}{l_1 l_2}\right]$

Answer: D

Solution:

Solution:
Clearly from figure,
$P_2A = P_1A + mg$
or, $\frac{nRT\ .A}{Al_2} = \frac{nRT\ .A}{Al_1} + mg$



$\Rightarrow nRT\left(\frac{1}{l_2} - \frac{1}{l_1}\right) = mg$

$\therefore m = \frac{nRT}{g}\left(\frac{l_1 - l_2}{l_1 . l_2}\right)$

Question98

An ideal gas occupies a volume of $2m^3$ at a pressure of 3×10^6Pa. The energy of the gas:
[12 Jan. 2019 I]

Options:

A. 9×10^6J

B. 6×10^4J

C. 10^8J

D. $3 \times 10^{2} J$

Answer: A

Solution:

Solution:
Energy of the gas, E
$= \frac{f}{2} nRT = \frac{f}{2} PV$
$= \frac{f}{2}(3 \times 10^{6})(2) = f \times 3 \times 10^{6}$
Considering gas is monoatomic i.e., $f = 3$
Energy ,$E = 9 \times 10^{6} J$

Question99

An ideal gas is enclosed in a cylinder at pressure of 2 atm and temperature, 300K. The mean time between two successive collisions is 6×10^{-8}s. If the pressure is doubled and temperature is increased to 500K, the mean time between two successive collisions wiil be close to: [12 Jan. 2019 II]

Options:

A. $2 \times 10^{-7} s$

B. $4 \times 10^{-8} s$

C. $0.5 \times 10^{-8} s$

D. $3 \times 10^{-6} s$

Answer: B

Solution:

Solution:
Using, $\tau = \frac{1}{2 n \pi d^{2} V_{avg}}$
$\therefore t \propto \frac{\sqrt{T}}{P} \left[\therefore n = \frac{\text{no. of molecule}}{\text{Volume}} \right]$
or, $\frac{t_1}{6 \times 10^{-8}} = \frac{\sqrt{500}}{2P} \times \frac{P}{\sqrt{300}} \approx 4 \times 10^{-8}$

Question100

A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total internal energy of the system is : [11 Jan. 2019 I]

Options:

A. 15 RT

B. 12 RT

C. 4 RT

D. 20 RT

Answer: A

Solution:

Solution:
$U = \frac{f_1}{2} n_1 RT + \frac{f_2}{2} n_2 RT$
Considering translational and rotational modes, degrees of freedom $f_1 = 5$ and $f_2 = 3$
$\therefore u = \frac{5}{2}(3RT) + \frac{3}{2} \times 5RT$
$U = 15RT$

Question101

In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation $VT = K$, where K is a constant. In this process the temperature of the gas is increased by ΔT. The amount of heat absorbed by gas is (R is gas constant): [11 Jan. 2019 II]

Options:

A. $\frac{1}{2} R\Delta T$

B. $\frac{1}{2} K R\Delta T$

C. $\frac{3}{2} R\Delta T$

D. $\frac{2K}{3} \Delta T$

Answer: A

Solution:

Solution:
According to question $VT = K$
we also know that $PV = nRT$
$\Rightarrow T = \left(\frac{PV}{nR}\right)$
$\Rightarrow V\left(\frac{PV}{nR}\right) = k \Rightarrow PV^2 = K$
$\because C = \frac{R}{1-x} + C_V$ (For polytropic process)
$C = \frac{R}{1-2} + \frac{3R}{2} = \frac{R}{2}$

$\therefore \Delta Q = nC\Delta T$
$= \frac{R}{2} \times \Delta T$ [here ,n = 1 mole]

Question102

Two kg of a monoatomic gas is at a pressure of 4×10^4 N / m^2. The density of the gas is 8kg / m^3. What is the order of energy of the gas due to its thermal motion?
[10 Jan 2019 II]

Options:

A. 10^3J

B. 10^5J

C. 10^4J

D. 10^6J

Answer: C

Solution:

Solution:

Thermal energy of N molecule $= N\left(\frac{3}{2}kT\right)$

$= \frac{N}{N_A}\frac{3}{2}RT = \frac{3}{2}(nRT) = \frac{3}{2}PV$

$= \frac{3}{2}P\left(\frac{m}{\rho}\right) = \frac{3}{2}P\left(\frac{2}{8}\right)$

$= \frac{3}{2} \times 4 \times 10^4 \times \frac{2}{8} = 1.5 \times 10^4$J

therefore, order $= 10^4$J

Question103

A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about: [Take R = 8.3 J/K mole]
[9 Jan. 2019 II]

Options:

A. 0.9 kJ

B. 6 kJ

C. 10 kJ

D. 14 kJ

Answer: C

Solution:

Solution:
Heat transferred,
$Q = nC_y \Delta T$ as gas in closed vessel
To double the rms speed, temperature should be 4 times i.e., $T' = 4T$ as $v_{rms} = \sqrt{3RT / M}$
$\therefore Q = \frac{15}{28} \times \frac{5 \times R}{2} \times (4T - T)$
$\left[\therefore \frac{CP}{CV} = \gamma_{diatomic} = \frac{7}{5} \& C_p - C_v = R\right]$ or, $Q = 10000J = 10kJ$

Question104

The number density of molecules of a gas depends on their distance r from the origin as, $n(r) = n_0 e^{-\alpha r4}$. Then the total number of molecules is proportional to :
[12 April 2019 II]

Options:

A. $n_0 \alpha^{-3/4}$

B. $\sqrt{n_0} \alpha^{1/2}$

C. $n_0 \alpha^{1/4}$

D. $n_0 \alpha^{-3}$

Answer: A

Solution:

Solution:
$N = \int \rho(dv)$
$= \int_0^r n_0 e^{-\alpha r^4} \times 4\pi r^2 dr = 4p\, n_0 \int_0^r r^2 \left(e^{-\alpha r^4}\right) dr$
$\propto n_0 a^{-3/4}$

Question105

For a given gas at 1 atm pressure, rms speed of the molecules is 200 m/s at 127°C. At 2 atm pressure and at 227°C, the rms speed of the molecules will be:
[9 April 2019 I]

Options:

A. 100 m/s

B. $80\sqrt{5}$ m/s

C. $100\sqrt{5}$ m/s

D. 80 m/s

Answer: C

Solution:

Solution:

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \frac{(273+127)}{(273+237)} = \sqrt{\frac{400}{500}} = \sqrt{\frac{4}{5}} = \frac{2}{\sqrt{5}}$

$\therefore v_2 = \frac{\sqrt{5}}{2} v_1 = \frac{\sqrt{5}}{2} \times 200 = 100\sqrt{5} m/s$

Question106

If 10^{22} gas molecules each of mass 10^{-26}kg collide with a surface (perpendicular to it) elastically per second over an area $1m^2$ with a speed $10^4 m/s$, the pressure exerted by the gas molecules will be of the order of :
[8 April 2019 I]

Options:

A. $10^4 N/m^2$

B. $10^8 N/m^2$

C. $10^3 N/m^2$

D. $10^{16} N/m^2$

E. (Bouns)

Answer: E

Solution:

Solution:
Rate of change of momentum during collision

$= \frac{mv - (-mv)}{\Delta t} = \frac{2mv}{\Delta t} N$

so pressure $P = \frac{N \times (2mv)}{\Delta t \times A}$

$= \frac{10^{22} \times 2 \times 10^{-26} \times 10^4}{1 \times 1} = 2N/m^2$

Question107

The temperature, at which the root mean square velocity of hydrogen

molecules equals their escape velocity from the earth, is closest to :
[Boltzmann Constant $k_B = 1.38 \times 10^{-23} J / K$
Avogadro Number $N_A = 6.02 \times 10^{26} / kg$
Radius of Earth : $6.4 \times 10^6 m$
Gravitational acceleration on Earth $= 10 ms^{-2}$]
[8 April 2019 II]

Options:

A. 800K

B. $3 \times 10^5 K$

C. $10^4 K$

D. 650K

Answer: C

Solution:

Solution:

$v_{ms} = v_e$

$$\sqrt{\frac{3RT}{M}} = 11.2 \times 10^3$$

or $\sqrt{\frac{3kT}{m}} = 11.2 \times 10^3$

or $\sqrt{\frac{3 \times 1.38 \times 10^{-23} T}{2 \times 10^{-3}}} = 11.2 \times 10^3 \therefore v = 10^4 K$

Question108

Two moles of helium gas is mixed with three moles of hydrogen molecules (taken to be rigid). What is the molar specific heat of mixture at constant volume?
(R = 8.3 J/mol K)
[12 April 2019 I]

Options:

A. 19.7 J/mol L

B. 15.7 J/mol K

C. 17.4 J/mol K

D. 21.6 J/mol K

Answer: C

Solution:

$$[C_v]_{min} = \frac{n_1[C_{v_1}] + n_2[C_{v_2}]}{n_1 + n_2}$$
$$= \left[2 \times \frac{3R}{2} + 3 \times \frac{5R}{2} 2 + 3\right]$$
$$= 2.1R = 2.1 \times 8.3 \ = 17.4J \ / mol \ - k$$

Question109

A diatomic gas with rigid molecules does 10 J of work when expanded at constant pressure. What would be the heat energy absorbed by the gas, in this process ?
[12 April 2019 II]

Options:

A. 25 J

B. 35 J

C. 30 J

D. 40 J

Answer: B

Solution:

Solution:

$$F \ = \frac{C_v}{C_p} = \frac{1}{r} = \frac{1}{\left(\frac{7}{5}\right)} = \frac{5}{7}$$

or $\frac{W}{Q} = 1 - \frac{5}{7} = \frac{2}{7}$

or $Q = \frac{7}{2}W \ = \frac{7 \times 10}{2} = 35J$

Question110

A $25 \times 10^{-3} m^3$ volume cylinder is filled with 1 mol of O_2 gas at room temperature (300 K) . The molecular diameter of O_2 , and its root mean square speed, are found to be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule?
[10 April 2019 I]

Options:

A. $\sim 10^{12}$

B. $\sim 10^{11}$

C. $\sim 10^{10}$

D. $\sim 10^{13}$

Answer: C

Solution:

Solution:
$V = 25 \times 10^{-3} m^3$, $N = 1$ mole of O_2
$T = 300K$
$V_{rms} = 200 m/s$
$\therefore \lambda = \frac{1}{\sqrt{2} N \pi r^2}$
Average time $\frac{1}{\tau} = \langle V \rangle \lambda = 200 . N \pi r^2 . \sqrt{2}$
$= \frac{\sqrt{2} \times 200 \times 6.023 \times 10^{23}}{25 \times 10^{-3}} . \pi \times 10^{-18} \times 0.09$
The closest value in the given option is $= 10^{10}$

Question111

When heat Q is supplied to a diatomic gas of rigid molecules, at constant volume its temperature increases by ΔT. The heat required to produce the same change in temperature, at a constant pressure is : [10 April 2019 II]

Options:

A. $\frac{2}{3}Q$

B. $\frac{5}{3}Q$

C. $\frac{7}{5}Q$

D. $\frac{3}{2}Q$

Answer: C

Solution:

Solution:
Amount of heat required (Q) to raise the temperature at constant volume
$Q = nC_v \Delta T$ ...(i)
Amount of heat required (Q_1) at constant pressure
$Q_1 = nC_p \Delta T$ ...(ii)
Dividing equation (ii) by (i), we get
$\therefore \frac{Q_1}{Q} = \frac{C_p}{C_v}$
$\Rightarrow Q_1 = (Q)\left(\frac{7}{5}\right)\left(\because \gamma = \frac{C_p}{C_v} = \frac{7}{5}\right)$

Question112

An HCl molecule has rotational, translational and vibrational motions. If

the rms velocity of HCl molecules in its gaseous phase is $\bar{v}$, m is its mass and k_B is Boltzmann constant, then its temperature will be:
[9 April 2019 I]

Options:

A. $\frac{m\bar{v}^2}{6k_B}$

B. $\frac{m\bar{v}^2}{3k_B}$

C. $\frac{m\bar{v}^2}{7k_B}$

D. $\frac{m\bar{v}^2}{5k_B}$

Answer: A

Solution:

Solution:

$\frac{1}{2}m\bar{v}^2 = 3k_BT$

or $T = \frac{m\bar{v}^2}{6k_B}$

Question113

The specific heats, C_p and C_v of a gas of diatomic molecules, A, are given (in units of $J\ mol^{-1}k^{-1}$) by 29 and 22, respectively. Another gas of diatomic molecules, B has the corresponding values 30 and 21. If they are treated as ideal gases, then:
[9 April 2019 II]

Options:

A. A is rigid but B has a vibrational mode.

B. A has a vibrational mode but B has none.

C. A has one vibrational mode and B has two.

D. Both A and B have a vibrational mode each.

Answer: B

Solution:

Solution:

$\gamma_A = \frac{C_P}{C_v} = \frac{29}{22} = 1.32 < 1.4$ (diatomic)

and $\gamma_B = \frac{30}{21} = \frac{10}{7} = 1.43 > 1.4$

Gas A has more than 5-degrees of freedom.

Question114

Two moles of an ideal monoatomic gas occupies a volume V at 27°C. The gas expands adiabatically to a volume 2 V. Calculate (1) the final temperature of the gas and (2) change in its internal energy. [2018]

Options:

A. (1) 189 K, (2) 2.7 kJ

B. (1) 195 K, (2) –2.7 kJ

C. (1) 189 K, (2) –2.7 kJ

D. (1) 195 K, (2) 2.7 kJ

Answer: C

Solution:

Solution:
In an adiabatic process
$TV^{\gamma-1} =$ Constant or, $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$
For monoatomic gas $\gamma = \frac{5}{3}$
$(300)V^{2/3} = T_2(2V)^{2/3} \Rightarrow T_2 = \frac{300}{(2)^{2/3}}$
$T_2 = 189K$ (final temperature)
Change in internal energy $\Delta U = n\frac{f}{2}R\Delta T$
$= 2\left(\frac{3}{2}\right)\left(\frac{25}{3}\right)(-111) = -2.7kJ$

Question115

Two moles of helium are mixed with n with moles of hydrogen. If $\frac{C_P}{C_V} = \frac{3}{2}$ for the mixture, then the value of n is [Online April 16, 2018]

Options:

A. 3/2

B. 2

C. 1

D. 3

Answer: B

Solution:

Solution:
Using formula,

$$\gamma_{mixture} = \left(\frac{C_p}{C_v}\right)_{mix} = \frac{\frac{n_1\gamma_1}{\gamma_1 - 1} + \frac{n_2\gamma_2}{\gamma_2 - 1}}{\frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}}$$

Putting the value of $n_1 = 2, n_2 = n, \left(\frac{C_p}{C_v}\right)_{mix} = \frac{3}{2}$

$\gamma_1 = \frac{5}{3}, \gamma_2 = \frac{7}{5}$ and solving we get, $n = 2$

Question116

The temperature of an open room of volume $30m^3$ increases from 17°C to 27°C due to sunshine. The atmospheric pressure in the room remains 1×10^5Pa. If n_i and n_f are the number of molecules in the room before and after heating, then $n_f - n_i$ will be :
[2017]

Options:

A. 2.5×10^{25}

B. -2.5×10^{25}

C. -1.61×10^{23}

D. 1.38×10^{23}

Answer: B

Solution:

Solution:
Given: Temperature $T_i = 17 + 273 = 290K$
Temperature $T_f = 27 + 273 = 300K$
Atmospheric pressure, $P_0 = 1 \times 10^5 Pa$
Volume of room, $V_0 = 30m^3$
Difference in number of molecules, $n_f - n_i = ?$
Using ideal gas equation, $PV = nRT\,(N_0)$,
$N_0 =$ Avogadro's number

$$\Rightarrow n = \frac{PV}{RT}(N_0)$$

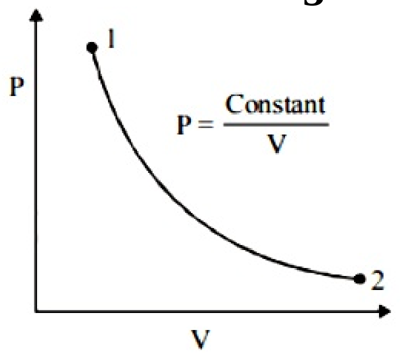
$$\therefore n_f - n_i = \frac{P_0V_0}{R}\left(\frac{1}{T_f} - \frac{1}{T_i}\right)N_0$$

$$= \frac{1 \times 10^5 \times 30}{8.314} \times 6.023 \times 10^{23}\left(\frac{1}{300} - \frac{1}{290}\right)$$

$$= -2.5 \times 10^{25}$$

Question117

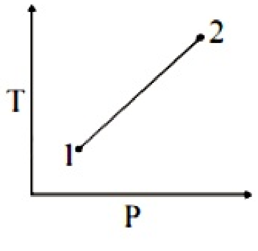
For the P-V diagram given for an ideal gas,



out of the following which one correctly represents the T-P diagram ? [Online April 9, 2017]

Options:

A.



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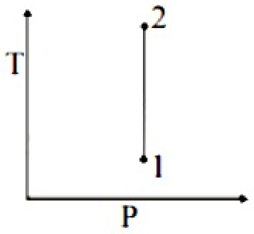

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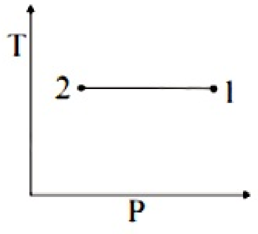

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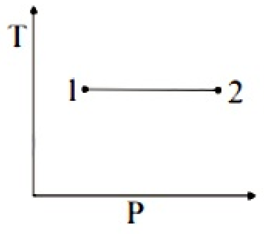


Answer: C

Solution:

Solution:
From P-V graph,
$P \propto \frac{1}{V}$, T = constant and Pressure is increasing from 2 to 1 so option (3) represents correct T-P graph.

Question118

N moles of a diatomic gas in a cylinder are at a temperature T. Heat is supplied to the cylinder such that the temperature remains constant but n moles of the diatomic gas get converted into monoatomic gas. What is the change in the total kinetic energy of the gas ? [Online April 9, 2017]

Options:

A. $\frac{1}{2}nRT$

B. 0

C. $\frac{3}{2}nRT$

D. $\frac{5}{2}nRT$

Answer: A

Solution:

Solution:
Energy associated with N moles of diatomic gas,
$U_i = N\frac{5}{2}RT$
Energy associated with n moles of monoatomic gas $= n\frac{3}{2}RT$
Total energy when n moles of diatomic gas converted into monoatomic $(U_f) = 2n\frac{3}{2}RT + (N - n)\frac{5}{2}RT$
$= \frac{1}{2}nRT + \frac{5}{2}N\,RT$
Now, change in total kinetic energy of the gas
$\Delta U = Q = \frac{1}{2}nRT$

Question119

C_p and C_v are specific heats at constant pressure and constant volume respectively. It is observed that
$C_p - C_v =$ a for hydrogen gas
$C_p - C_v =$ b for nitrogen gas
The correct relation between a and b is:
[2017]

Options:

A. a = 14b

B. a = 28b

C. $a = \frac{1}{14}b$

D. a = b

Answer: A

Solution:

Solution:
As we know, $C_p - C_v = R$ where C_p and C_v are molar specific heat capacities
or, $C_p - C_v = \frac{R}{M}$
For hydrogen $(M = 2) C_p - C_v = a = \frac{R}{2}$
For nitrogen $(M = 28) C_p - C_v = b = \frac{R}{28}$
$\therefore \frac{a}{b} = 14$ or, $a = 14b$

Question120

An ideal gas has molecules with 5 degrees of freedom. The ratio of specific heats at constant pressure (C_p) and at constant volume (C_v) is : [Online April 8, 2017]

Options:

A. 6

B. $\frac{7}{2}$

C. $\frac{5}{2}$

D. $\frac{7}{5}$

Answer: D

Solution:

Solution:
The ratio of specific heats at constant pressure (C_p) and constant volume (C_v)
$\frac{C_p}{C_v} = \gamma = \left(1 + \frac{2}{f}\right)$
where f is degree of freedom
$\frac{C_p}{C_v} = \left(1 + \frac{2}{5}\right) = \frac{7}{5}$

Question121

An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure P and volume V is given by $PV^n =$ constant, then n is given by (Here C_P and C_V are molar specific heat at constant pressure and constant volume, respectively):
[2016]

Options:

A. $n = \frac{C_P - C}{C - C_V}$

B. $n = \frac{C - C_V}{C - C_P}$

C. $n = \frac{C_P}{C_V}$

D. $n = \frac{C - C_P}{C - C_V}$

Answer: D

Solution:

Solution:
For a polytropic process
$C = C_v + \frac{R}{1-n} \therefore C - C_v = \frac{R}{1-n}$
$\therefore 1 - n = \frac{R}{C - C_v} \therefore 1 - \frac{R}{C - C_V} = n$
$\therefore n = \frac{C - C_v - R}{C - C_v} = \frac{C - C_v - C_p + C_v}{C - C_v}$
$= \frac{C - C_p}{C - C_v} (\because C_p - C_{v = R})$

Question122

In an ideal gas at temperature T , the average force that a molecule applies on the walls of a closed container depends on T as Tq. A good estimate for q is:
[Online April 10,2015]

Options:

A. $\frac{1}{2}$

B. 2

C. 1

D. $\frac{1}{4}$

Answer: C

Solution:

Solution:

Pressure, $P = \frac{1}{3}\frac{mN}{V}V_{rms}^{2}$

or, $P = \frac{(mN)T}{V}$

If the gas mass and temperature are constant then

$P \propto (V_{rms})^2 \propto T$

So, force $\propto (V_{rms})^2 \propto T$

i.e., Value of $q = 1$

Question123

Using equipartition of energy, the specific heat (in $J\ kg^{-1}\ K^{-1}$) of aluminium at room temperature can be estimated to be (atomic weight of aluminium = 27)
[Online April 11, 2015]

Options:

A. 410

B. 25

C. 1850

D. 925

Answer: D

Solution:

Solution:

Using equipartition of energy, we have

$\frac{6}{2}KT = mCT$

$C = \frac{3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{23}}{27 \times 10^{-3}}$

$\therefore C = 925 J / kgK$

Question124

A gas molecule of mass M at the surface of the Earth has kinetic energy equivalent to 0°C. If it were to go up straight without colliding with any other molecules, how high it would rise? Assume that the height attained is much less than radius of the earth. (k_B. is Boltzmann constant).
[Online April 19, 2014]

Options:

A. 0

B. $\frac{273k_B}{2Mg}$

C. $\frac{546k_B}{3Mg}$

D. $\frac{819k_B}{2Mg}$

Answer: D

Solution:

Solution:
Kinetic energy of each molecule,
$K.E. = \frac{3}{2}K_BT$
In the given problem,
Temperature, $T = 0°C = 273K$
Height attained by the gas molecule, $h = ?$
$K.E. = \frac{3}{2}K_B(273) = \frac{819K_B}{2}$
$K.E = PE$
$\Rightarrow \frac{819K_B}{2} = Mgh$
or $h = \frac{819K_B}{2Mg}$

Question125

At room temperature a diatomic gas is found to have an r.m.s. speed of $1930ms^{-1}$. The gas is: [Online April 12, 2014]

Options:

A. H_2

B. Cl_2

C. O_2

D. F_2

Answer: A

Solution:

Solution:
$\because C = \sqrt{\frac{3RT}{M}}$
$(1930)^2 = \frac{3 \times 8.314 \times 300}{M}$

$M = \frac{3 \times 8.314 \times 300}{1930 \times 1930} \approx 2 \times 10^{-3} kg$
The gas is H_2.

Question126

Modern vacuum pumps can evacuate a vessel down to a pressure of 4.0×10^{-15} atm. at room temperature (300 K). Taking $R = 8.0 J K^{-1} mole^{-1}$, 1 atm = 10^5 Pa and $N_{Avogadro} = 6 \times 10^{23} mole^{-1}$, the mean distance between molecules of gas in an evacuated vessel will be of the order of:
[Online April 9, 2014]

Options:

A. 0.2 μm

B. 0.2 mm

C. 0.2 cm

D. 0.2 nm

Answer: B

Solution:

Solution:

Question127

There are two identical chambers, completely thermally insulated from surroundings. Both chambers have a partition wall dividing the chambers in two compartments.
Compartment 1 is filled with an ideal gas and Compartment 3 is filled with a real gas. Compartments 2 and 4 are vacuum. A small hole (orifice) is made in the partition walls and the gases are allowed to expand in vacuum.
Statement-1: No change in the temperature of the gas takes place when ideal gas expands in vacuum. However, the temperature of real gas goes down (cooling) when it expands in vacuum.
Statement-2: The internal energy of an ideal gas is only kinetic. The internal energy of a real gas is kinetic as well as potential.
[Online April 9, 2013]

Options:

A. Statement-1 is false and Statement-2 is true.

B. Statement-1 and Statement-2 both are true. Statement-2 is the correct explanation of

Statement-1.

C. Statement-1 is true and Statement-2 is false.

D. Statement-1 and Statement-2 both are true. Statement-2 is not correct explanation of Statement-1.

Answer: A

Solution:

Solution:
In ideal gases the molecules are considered as point particles and for point particles, there is no internal excitation, no vibration and no rotation. For an ideal gas the internal energy can only be translational kinetic energy and for real gas both kinetic as well as potential energy.

Question128

In the isothermal expansion of 10g of gas from volume V to 2V the work done by the gas is 575J. What is the root mean square speed of the molecules of the gas at that temperature? [Online April 25, 2013]

Options:

A. 398m/s

B. 520m/s

C. 499m/s

D. 532m/s

Answer: C

Solution:

Solution:

$$\text{mean freee time } (r) = \frac{\text{mean free path}}{\text{average speed}} = \frac{\lambda}{V_{av}}$$

$$= \left(\frac{KT}{\sqrt{2}\pi d^2 \rho}\right) \times \sqrt{\frac{\pi m}{8RT}}$$

$$= \frac{K\sqrt{\pi m}\sqrt{T}}{\sqrt{2}\pi d^2 p\sqrt{8}R}.$$

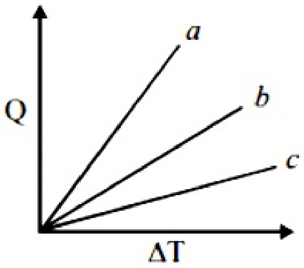
$\frac{K\sqrt{\pi m}}{\sqrt{2}\pi d^2 p\sqrt{8}R}$ = consider as const.

hence $z \propto \sqrt{T}$

Question129

Figure shows the variation in temperature (DT) with the amount of heat supplied (Q) in an isobaric process corresponding to a monoatomic (M), diatomic (D) and a polyatomic (P) gas. The initial state of all the gases

are the same and the scales for the two axes coincide. Ignoring vibrational degrees of freedom, the lines a, b and c respectively correspond to :



[Online April 9, 2013]

Options:

A. P, M and D

B. M, D and P

C. P, D and M

D. D, M and P

Answer: B

Solution:

Solution:
On giving same amount of heat at constant pressure, there is no change in temperature for mono, dia and polyatomic.
$(\Delta Q)_P = \mu C_p \Delta T \quad \left(\mu = \frac{\text{No. of molecules}}{\text{Avogedro's no.}}\right)$
or $\Delta T \propto \frac{1}{\text{no. of molecules}}$

Question130

A perfect gas at 27°C is heated at constant pressure so as to double its volume. The final temperature of the gas will be, close to
[Online May 7, 2012]

Options:

A. 327°C

B. 200°C

C. 54°C

D. 300°C

Answer: A

Solution:

Solution:
Given, $V_1 = V$

$V_2 = 2V$
$T_1 = 27° + 273 = 300K$
$T_2 = ?$
From charle's law
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ ($\because$ Pressure is constant)
or, $\frac{V}{300} = \frac{2V}{T_2}$
$\therefore T_2 = 600K = 600 - 273 = 327°C$

Question131

A given ideal gas with $\gamma = \frac{C_p}{C_v} = 1.5$ at a temperature T. If the gas is compressed adiabatically to one-fourth of its initial volume, the final temperature will be
[Online May 12, 2012]

Options:

A. $2\sqrt{2}T$

B. $4T$

C. $2T$

D. $8T$

Answer: C

Solution:

Solution:
$T V^{\gamma-1} =$ constant
$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
$\Rightarrow T(V)^{1/2} = T_2\left(\frac{V}{4}\right)^{1/2}$
$[\because \gamma = 1.5, T_1 = T, V_1 = V$ and $V_2 = \frac{V}{4}]$
$\therefore T_2 = \left(\frac{4V}{V}\right)^{1/2} T = 2T$

Question132

A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats γ. It is moving with speed v and it's suddenly brought to rest. Assuming no heat is lost to the surroundings, its temperature increases by:
[2011]

Options:

A. $\frac{(\gamma-1)}{2\gamma R} M v^2 K$

B. $\frac{\gamma M^2 v}{2R} K$

C. $\frac{(\gamma - 1)}{2R} M v^2 K$

D. $\frac{(\gamma - 1)}{2(\gamma + 1)R} M v^2 K$

Answer: C

Solution:

Solution:
As, work done is zero.
So, loss in kinetic energy = heat gain by the gas

$\frac{1}{2}mv^2 = nC_v\Delta T = n\frac{R}{\gamma - 1}\Delta T$

$\frac{1}{2}mv^2 = \frac{m}{M}\frac{R}{\gamma - 1}\Delta T$

$\therefore \Delta T = \frac{M v^2(\gamma - 1)}{2R} K$

Question133

Three perfect gases at absolute temperatures T_1, T_2 and T_3 are mixed. The masses of molecules are m_1, m_2 and m_3 and the number of molecules are n_1, n_2 and n_3 respectively. Assuming no loss of energy, the final temperature of the mixture is : [2011]

Options:

A. $\frac{n_1T_1 + n_2T_2 + n_3T_3}{n_1 + n_2 + n_3}$

B. $\frac{n_1T_1^2 + n_2T_2^2 + n_3T_3^2}{n_1T_1 + n_2T_2 + n_3T_3}$

C. $\frac{n_1^2T_1^2 + n_2^2T_2^2 + n_3^2T_3^2}{n_1T_1 + n_2T_2 + n_3T_3}$

D. $\frac{(T_1 + T_2 + T_3)}{3}$

Answer: A

Solution:

Solution:

Number of moles of first gas $= \frac{n_1}{N_A}$

Number of moles of second gas $= \frac{n_2}{N_A}$

Number of moles of third gas $= \frac{n_3}{N_A}$

If there is no loss of energy then

$P_1V_1 + P_2V_2 + P_3V_3 = PV$

$\frac{n_1}{N_A}RT_1 + \frac{n_2}{N_A}RT_2 + \frac{n_3}{N_A}RT_3$

$= \frac{n_1 + n_2 + n_3}{N_A}RT_{mix}$

$T_{mix} = \frac{n_1T_1 + n_2T_2 + n_3T_3}{n_1 + n_2 + n_3}$

Question134

One kg of a diatomic gas is at a pressure of $8 \times 10^4 N / m^2$. The density of the gas is $4kg / m^3$. What is the energy of the gas due to its thermal motion? [2009]

Options:

A. $5 \times 10^4 J$

B. $6 \times 10^4 J$

C. $7 \times 10^4 J$

D. $3 \times 10^4 J$

Answer: A

Solution:

Solution:
Given, mass $= 1kg$ Density $= 4kgm^{-3}$
Volume $= \frac{mass}{density} = \frac{1}{4}m^3$
Internal energy of the diatomic gas
$= \frac{5}{2}PV = \frac{5}{2} \times 8 \times 10^4 \times \frac{1}{4} = 5 \times 10^4 J$

Question135

The speed of sound in oxygen (O_2) at a certain temperature is $460ms^{-1}$. The speed of sound in helium (He) at the same temperature will be (assume both gases to be ideal) [2008]

Options:

A. $1421ms^{-1}$

B. $500ms^{-1}$

C. $650ms^{-1}$

D. $330ms^{-1}$

Answer: A

Solution:

Solution:

The speed of sound in a gas is given by $v = \sqrt{\frac{\gamma RT}{M}}$

$\therefore v \propto \sqrt{\frac{\gamma}{M}}$ [As R and T is constant]

$\therefore \frac{v_{O_2}}{v_{He}} = \sqrt{\frac{\gamma_{O_2}}{M_{O_2}} \times \frac{M_{He}}{\gamma_{He}}}$

$= \sqrt{\frac{1.4}{32} \times \frac{4}{1.67}} = 0.3237$

$\therefore v_{He} = \frac{v_{O_2}}{0.3237} = \frac{460}{0.3237} = 1421 m / s$

Question136

If C_P and C_V denote the specific heats of nitrogen per unit mass at constant pressure and constant volume respectively, then [2007]

Options:

A. $C_P - C_V = 28R$

B. $C_P - C_V = R / 28$

C. $C_P - C_V = R / 14$

D. $C_P - C_V = R$

Answer: B

Solution:

Solution:
According to Mayer's relationship
$C_P - C_V = R$, as per the question $(C_P - C_V)M = R$
$\Rightarrow C_P - C_V = R / 28$
Here $M = 28 =$ mass of 1 unit of N_2

Question137

A gaseous mixture consists of 16 g of helium and 16 g of oxygen. The ratio $\frac{C_p}{C_v}$ of the mixture is [2005]

Options:

A. 1.62

B. 1.59

C. 1.54

D. 1.4

Answer: A

Solution:

Solution:
For mixture of gas specific heat at constant volume

$$C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$

No. of moles of helium,

$$n_1 = \frac{m_{He}}{M_{He}} = \frac{16}{4} = 4$$

Number of moles of oxygen,

$$n_2 = \frac{16}{32} = \frac{1}{2}$$

$$\therefore C_v = \frac{4 \times \frac{3}{2}R + \frac{1}{2} \times \frac{5}{2}R}{\left(4 + \frac{1}{2}\right)} = \frac{6R + \frac{5}{4}R}{\frac{9}{2}}$$

$= \frac{29R \times 2}{9 \times 4} = \frac{29R}{18}$ and

Specific heat at constant pressure

$$C_p = \frac{n_1 C_{p_1} + n_2 C_{p_2}}{(n_1 + n_2)} = \frac{4 \times \frac{5R}{2} + \frac{1}{2} \times \frac{7R}{2}}{\left(4 + \frac{1}{2}\right)}$$

$$= \frac{10R + \frac{7}{4}R}{\frac{9}{2}} = \frac{47R}{18}$$

$$\therefore \frac{C_p}{C_v} = \frac{47R}{18} \times \frac{18}{29R} = 1.62$$

Question138

One mole of ideal monatomic gas ($\gamma = 5 / 3$) is mixed with one mole of diatomic gas ($\gamma = 7 / 5$). What is gamma for the mixture? γ Denotes the ratio of specific heat at constant pressure, to that at constant volume [2004]

Options:

A. 35/23

B. 23/15

C. 3/2

D. 4/3

Answer: C

Solution:

Solution:
$\gamma_1 = \frac{5}{3}\gamma_2 = \frac{7}{5}$
$n_1 = 1, n_2 = 1$
$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$
$\Rightarrow \frac{1 + 1}{\gamma - 1} = \frac{1}{\frac{5}{3} - 1} + \frac{1}{\frac{7}{5} - 1} = \frac{3}{2} + \frac{5}{2} = 4$
$\therefore \frac{2}{\gamma - 1} = 4 \Rightarrow \gamma = \frac{3}{2}$

Question139

During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_P / C_V for the gas is [2003]

Options:

A. $\frac{4}{3}$

B. 2

C. $\frac{5}{3}$

D. $\frac{3}{2}$

Answer: D

Solution:

Solution:
$P \propto T^3 \Rightarrow PT^{-3} = $ constant .....(i)
But for an adiabatic process, the pressure temperature relationship is given by
$P^{1-\gamma}T^{\gamma} = $ constant
$\Rightarrow PT^{\frac{\gamma}{1-\gamma}} = $ constt......(ii)
From (i) and (ii) $\frac{\gamma}{1-\gamma} = -3 \Rightarrow \gamma = -3 + 3\gamma \Rightarrow \gamma = \frac{3}{2}$

Question140

Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will [2002]

Options:

A. increase

B. decrease

C. remain same

D. decrease for some, while increase for others

Answer: C

Solution:

The centre of mass of gas molecules also moves with lorry with uniform speed. As there is no relative motion of gas molecule. So, kinetic energy and hence temperature remain same.

Question141

At what temperature is the r.m.s velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C?
[2002]

Options:

A. 80 K

B. –73 K

C. 3 K

D. 20 K

Answer: D

Solution:

RMS velocity of a gas molecule is given by

$V_{rms} = \sqrt{\frac{3RT}{M}}$

Let T be the temperature at which the velocity of hydrogen molecule is equal to the velocity of oxygen molecule.

$\therefore \sqrt{\frac{3RT}{2}} = \sqrt{\frac{3R \times (273 + 47)}{32}}$

$\Rightarrow T = 20K$
