Heat – Specific Heat of Gases: <u>Illustrations</u> to Answers to Questions (Typical)

I-01	As per First Law of thermodynamics $\Delta Q = \Delta U + \Delta W$. In the process no heat is supplied as per statement of the
	problem. Therefore, $0 = \Delta U + \Delta W \Longrightarrow \Delta U = -\Delta W$. Given that $\Delta W_A = 2 \cdot \Delta W_B \Longrightarrow \Delta U_A = 2 \cdot \Delta U_B$. Since the
	two processes are stated to be carried out on the same sample of gas having n number of moles with same
	temperature rises $\Delta T_A = \Delta T_B = \Delta T$. Therefore, $\Delta U_A = n \cdot C_A \cdot \Delta T$ and $\Delta U_B = n \cdot C_B \cdot \Delta T$. This translates into
	$n \cdot C_A \cdot \Delta T = 2 \cdot n \cdot C_B \cdot \Delta T \Longrightarrow C_A = 2 \cdot C_B \Longrightarrow C_A > 2 \cdot C_B$. Hence, answer is option (c).
1.02	
1-02	As per First Law of thermodynamics $\Delta Q = \Delta U + \Delta W \Rightarrow n \cdot C_p \cdot \Delta T = n \cdot C_v \cdot \Delta T + p \cdot \Delta v \Rightarrow C_p = C_v + \frac{p \cdot \Delta v}{n \cdot \Delta T}$.
	Here, $v + \Delta v = v(1 + \gamma \cdot \Delta T) \Longrightarrow \Delta v = \gamma \cdot v \cdot \Delta T$. Therefore, $C_p = C_v + \frac{p \cdot \gamma \cdot v \cdot \Delta T}{n \cdot \Delta T} \Longrightarrow C_p = C_v + \left(\frac{p \cdot v}{n \cdot \Delta T}\right) \gamma$.
	Since, coefficient of expansion of solids is $\gamma \ll$ small, and the same is stated in the problem and hence is also
	$\left(\frac{p \cdot v}{n \cdot \Delta T}\right) \gamma$ is also small and in the equation it is added to C_V . Therefore, C_P is slightly greater than C_V .
	Hence, answer is option (c).
I-03	Given that at state A, $C_{n-A} - C_{\nu-A} = 1.00R$ and in state B, $C_{n-B} - C_{\nu-B} = 1.08R$. Equation for state A satisfies
	an ideal gas behavior, while in state B it is non-ideal gas behavior.
	It is known that at low pressures and high temperatures gases tend behave like ideal gases and therefore $p_{\perp} < p_{\rm p}$
	and $T_{c} > T_{c}$. These condition are provided in option (a). Hence answer is option (a).
	and $r_A \neq r_B$. These condition are provided in option (a). Thence and we is option (a).
I-04	In a constant volume process $\Delta Q = \Delta U + \Delta W \rightarrow \Delta Q_V = \Delta U_V + p \cdot \Delta V \Big _{A_V = 0} \Rightarrow \Delta Q_V = nC_V \Delta T_V$, and in
	constant pressure process $\Delta Q_n = \Delta U_n + p \cdot \Delta V _{x=0} \Rightarrow \Delta Q_n = nC_n \Delta T_n = \Delta U_V + p \cdot \Delta V$. Comparing the two
	process by taking $\Delta T_n = \Delta T_V = \Delta T \Longrightarrow \Delta U_n = \Delta U_V = \Delta U$, since internal energy is linearly dependent on
	temperature $\Delta Q_n = nC_n \Delta T = nC_V \Delta T + p \cdot \Delta V \Rightarrow nC_n \Delta T = nC_V \Delta T + nR\Delta T \Rightarrow C_n - C_V = R$. This final
	result matches with option (c). Hence answer is option (c).
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I-05	Since $\Delta Q_p = nC_p \Delta T$, therefore from given data $70 = 2 \times C_p \times (35 - 30) \Longrightarrow C_p = \frac{70}{10} = 7$, Further,
	$C_p = C_V + R \Longrightarrow C_V = C_p - R \Longrightarrow C_V = 7 - R$. Here, universal gas constant
	$R = 8.3 \text{ J.K}^{-1} \cdot \text{mol}^{-1} = \frac{8.3}{4.2} \text{ cal.K}^{-1} \cdot \text{mol}^{-1} \Big _{1\text{ Cal}=4.2\text{ J}}.$ Therefore, $C_V = 7 - \frac{8.3}{4.2} = 7 - 1.98 = 5.02$, accordingly
	$\Delta Q_V = nC_V \Delta T = 2 \times 5.02 \times 5 = 50.2$ cal. Considering SDs $\Delta Q_V = 50$, thus answer is option (b)
I-06	In the process since pressure and volume both are changing $\Delta Q = nC\Delta T$. As per FLT,
	$\Delta Q = \Delta U + \Delta W \Longrightarrow nC\Delta T = nC_V \Delta T + p\Delta V$. As per IGE $pV = nRT \Longrightarrow p\Delta V = nR\Delta T$, therefore, the heat
	equation takes a form $nC\Delta T = nC_V\Delta T + nR\Delta T \Rightarrow C = C_V + R \Rightarrow C > C_V$. Thus, answer is option (c).
	$\mathbf{r} = \mathbf{r} + $

T 07	
1-07	P-V graph given in the problem has $p = \frac{K}{V^{\gamma}} \Rightarrow pV^{\gamma} = K \Rightarrow p \cdot \gamma \cdot V^{\gamma-1} \cdot \Delta V + V^{\gamma} \cdot \Delta p = 0$. This is defines
	adiabatic process where no heat is exchanged with the environment. Since $\gamma = \frac{C_p}{C_V}$, the equation takes the form
	$p \cdot \frac{C_p}{C_V} \cdot \Delta V + V \cdot \Delta p = 0 \Longrightarrow C_p \cdot p \cdot \Delta V + C_V \cdot V \cdot \Delta p = 0.$ From ideal gas equation
	$pV = nRT \Rightarrow p\Delta V = nR\Delta T \Rightarrow V\Delta p = nR\Delta T$. It leads to $C_p \cdot n \cdot \Delta T + C_V \cdot n \cdot \Delta T = n \cdot C \cdot \Delta T = 0$. Since,
	$n \neq 0$ and $\Delta T \neq 0$ therefore for the identity to be valid $C = 0$ and matches with the option (d). Hence, answer is option (d).
I-08	Isothermal process is defined by $pV = \text{constant} \Rightarrow p\Delta V + V\Delta p = 0 \Rightarrow \frac{\Delta p}{p} = -\frac{\Delta V}{V}$. Negative sign on RHS
	indicates that increase in percentage pressure is associated with cause equal decrease in percentage volume. This matches with option (b). Hence answer is option (b)
I-09	Δp
	In adiabatic process $pV^{\gamma} = \text{constant} \Rightarrow p\gamma V^{\gamma-1} \Delta V + V^{\gamma} \Delta p = 0 \Rightarrow \frac{\Delta p}{p} = -\gamma \frac{\Delta V}{V} \Rightarrow \frac{\Delta V}{V} = -\frac{p}{\gamma}$. Negative
	sign on RHS indicates that increase of percentage pressure is associated with decrease in percentage volume.
	Now, using the given data, $\frac{\Delta V}{V} = -\frac{0.5\%}{1.4} = 0.357\%$. Thus based on SDs $\frac{\Delta V}{V} = -0.36\%$. Hence answer is
	option (a).
I-10	Given that initially $p_{A-i} = p_{B-i}$, $V_{A-i} = V_{B-i}$ and $T_{A-i} = T_{B-i}$ there for as per IGE $pV = nRT$, number of moles
	in two samples are $n_A = n_B = n$. Sample B undergoes isothermal process, therefore $p_{B-i}V_{B-i} = p_{B-f}V_{B-f}$.
	Therefore final pressure $p_{B-f} = \frac{p_{B-i}V_{B-i}}{V_{B-f}}$. As regards sample A which undergoes adiabatic process
	$p_{A-i}V_{A-i}{}^{\gamma} = p_{A-f}V_{A-f}{}^{\gamma} \Longrightarrow p_{A-f} = p_{A-i}\left(\frac{V_{A-i}}{V_{A-f}}\right)^{\gamma}.$ Therefore, $\frac{p_{A-f}}{p_{B-f}} = \frac{p_{A-i}\left(\frac{V_{A-i}}{V_{A-f}}\right)^{\gamma}}{p_{B-i}\left(\frac{V_{B-i}}{V_{B-f}}\right)}.$ Further it is given that
	$V_{A-f} = V_{B-f}, \text{ accordingly } \frac{p_{A-f}}{p_{B-f}} = \left(\frac{p_{A-i}}{p_{B-i}}\right) \left(\frac{V_{A-i}}{V_{B-i}}\right) \left(\frac{V_{B-f}}{V_{A-f}}\right). \text{ Accordingly, using the given data it leads to}$
	$\frac{p_{A-f}}{p_{B-f}} = 1 \times \left(V_{A-i}^{\gamma-1}\right) \left(V_{A-f}^{1-\gamma}\right) = \left(\frac{V_{A-i}}{V_{A-f}}\right)^{\gamma-1}.$ The problem states that in the both the process there is expansion of gas
	therefore $V_{A-f} > V_{A-i} \Longrightarrow \frac{V_{A-i}}{V_{A-f}} < 1$. Hence, $\frac{p_{A-f}}{p_{B-f}} = 1 \times \left(V_{A-i}^{\gamma-1}\right) \left(V_{A-f}^{1-\gamma}\right) = \left(\frac{V_{A-i}}{V_{A-f}}\right)^{\gamma-1} \Longrightarrow \frac{p_{A-f}}{p_{B-f}} < 1 \Longrightarrow p_{A-f} < p_{B-f}$ or
	$p_A < p_B$. This is matching with option (c) and hence answer is option (c). N.B.: Instead of this quantitative analysis can be a quick answer can be obtained from qualitative analysis. According to this in adiabatic expansion in sample A no heat is supplied to the system whereas in isothermal expansion in gas B heat is supplied by the system. This will lead to higher final pressure in gas B

$$\begin{array}{c} \mathbf{I} \cdot \mathbf{I} \\ \text{Given that initially } p_{A-i} = p_{B-i}, V_{A-i} = V_{B-i} and T_{A-i} = T_{B-i} \text{ there for as per IGH} pV = nRT , number of moks in two samples are $n_A = n_B = n$. Sample B undergoes isothermal process, therefore $p_{B-i}V_{B-i} = p_{B-i}V_{B-i}$. Therefore final pressure $p_{B-f} = \frac{p_{B-i}V_{B-i}}{V_{B-f}} = \frac{p_{B-i}V_{B-i}}{V_{B-f}}$. As regards sample A which undergoes adiabatic process $p_{A-i}V_{A-i}^{-1} = p_{A-f}V_{A-j}^{-1} \Rightarrow p_{A-f} = p_{A-f}\left(\frac{V_{A-i}}{V_{A-f}}\right)^{\prime}$. Therefore, $\frac{p_{A-f}}{p_{B-f}} = \frac{p_{A-i}\left(\frac{V_{A-i}}{V_{A-f}}\right)^{\prime}}{p_{B-i}\left(\frac{V_{A-i}}{V_{B-f}}\right)^{\prime}}$. Further it is given that $p_{A-i}V_{A-j}^{-1} = p_{A-f}V_{A-j}^{-1} \Rightarrow p_{A-f} = p_{A-i}\left(\frac{V_{A-i}}{V_{A-f}}\right)^{\prime}$. Accordingly, using the given data it leads to $\frac{p_{A-f}V_{A-f}}{p_{B-i}} = \frac{nRT_A}{nRT_A} = \frac{p_{A-i}}{p_{B-i}}\left(\frac{V_{A-i}}{V_{A-j}}\right)^{\prime'}$. Again as per IGE, $p_{A-f}V_{A-j} = nRT_A$ and $p_{B-i}V_{B-j} = nRT_B$, therefore $\frac{p_{A-i}V_{A-j}}{p_{B-i}V_{B-j}} = \frac{nRT_A}{nRT_B} \Rightarrow \frac{p_{A-f}}{p_{B-f}} = \frac{T_A}{T_B} = \frac{p_{A-i}}{p_{B-j}} \left(\frac{v_{A-i}}{v_{A-j}}\right)^{\prime-1}$. Again as per IGE, $p_{A-j}V_{A-j} = nRT_A$ and $p_{B-j}V_{B-j} = nRT_B$, therefore $\frac{p_{A-i}V_{A-j}}{p_{B-j}V_{B-j}} = \frac{nRT_A}{nRT_B} \Rightarrow \frac{p_{A-f}}{p_{B-j}} = \frac{T_A}{T_B} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{nRT_A}{nRT_B} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{nRT_A}{nRT_B} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{nRT_A}{nRT_B} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{A-j}} = \frac{p_{A-i}V_{A-j}}{p_{A-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{B-j}} = \frac{p_{A-i}V_{A-j}}{p_{A-j}} = \frac{p_{A-i$$$

	and numerically it works out to $\frac{\Delta W_A}{\Delta W_B} < 1 \Rightarrow \Delta W_A < \Delta W_B$. Thus option (c) is correct.
	N.B.: Instead of this quantitative analysis can be a quick answer can be obtained from qualitative analysis. According to this in adiabatic expansion in sample A no heat is supplied to the system whereas in isothermal expansion in gas B heat is supplied to the system. Hence, isothermal process shall have more capacity to do the
	W_B work is unlimited and depends on the heat supplied, while in adiabatic process capacity to do the work W_A is limited by internal energy of the gas This will lead to higher final temperature in sample B.
I-13	Internal energy of the diatomic oxygen gas O_2 is $\Delta U = \frac{5}{2} nR\Delta T \Rightarrow \Delta U = nC\Delta T \Rightarrow C = 2.5R$. It is due to two
	dimensional motions translational and rotational. With increase of temperature internal energy of the gas it is
	given that $C = 3.5R$, i.e. internal energy increases this can happen only when third dimensional motion i.e. molecular vibrations becomes effective, this is provided in option (d). Hence answer is option (d).
I-14	When gas in a container is suddenly compressed heat transfer from the system to the environment will rate of
	compression $\frac{\Delta Q}{\Delta t} = kA \frac{\Delta T}{\Delta x}$, here k is conductivity of the container, A is cross-sectional area of the container,
	ΔT is difference in temperature across the Δx thickness of the container. Since conductivity $0 < k < \infty$ i.e. it is neither infinite there the process will not be necessarily isothermal, nor it is zero to be able to retain all work done during compression as heat and therefore process is not necessarily adiabatic. This rules our options (a) and (b).
	Thus, the process takes a midway between adiabatic and isothermal which depends upon $\frac{\Delta Q}{\Delta t}$ and therefore
	answer is Option (c) and (d).
I-15	As per FLT $\Delta Q = \Delta U + \Delta W$, since the process is isothermal where in $\Delta T = 0 \Longrightarrow \Delta U = KnR\Delta T = 0$, here K is a constant depending on number of atoms in molecules of gas. Accordingly, $\Delta Q = \Delta U + \Delta W$. Thus answer is option (d).
I-16	As per FLT $\Delta Q = \Delta U + \Delta W$, since the process is adiabatic where exchange of heat by the system is $\Delta Q = 0$.
	This makes ontion (a) to be correct Further it is stated that work by the system and hence $\Delta W \neq 0$ which
	makes option (d) to be correct. In adiabatic process since $\Delta Q = 0$ and therefore from (a) and (b) above.
	$\Delta Q \neq \Delta W$ which makes option (c) to be incorrect. But it makes option (d) to be correct
	Thus answer is option (a) and (d).
I-17	As per ideal gas equation $pV = nRT$. For a sample of gas undergoing isothermal process $p_1V_1 = p_2V_2$ Thus for
	process A, $p_i V_i = p_{f_i} V_{f_i}$ and $p_i V_i = p_{f_i} V_{f_i}$. Thus the initial points p_i
	for process is same, the final points are different and thus (p_{i},V_i)
	$p_{f_{a}}V_{f_{a}} \neq p_{f_{a}}V_{f_{a}}$ and hence the two processes are not isothermal. This
	makes option (a) to be incorrect. Yet, the given p-V graph A apparently of A
	inverse proportion. P_{f-4}, v_{f-4}
	Further in adiabatic process $p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$. For process A to be adiabatic (p_{f-B}, V_{f-B})
	necessary requirement is $p_i V_i^{\gamma} = p_{f=A} V_{f-A}^{\gamma}$ and for process B
	$p_i V_i^{\gamma} = p_{f=B} V_{f-B}^{\gamma}$. In these two identities LHS are equal and hence $p_{f=A} V_{f-A}^{\gamma} = p_{f=B} V_{f-B}^{\gamma}$. Principle of
	equalities of polynomial requires that variables of same index must be equal. Since, $V_{f-A} \neq V_{f-B}$ and hence the
	Two processes are adiabatic. This makes option (b) to be incorrect. Yet, the given p-V graph by observation process A is of inverse proportion and therefore isothermal. Further,

process B has different final point that of process A. Therefore, process B cannot be isothermal, this leaves only one possibility for process B is adiabatic. Thus option (c) is correct. Since a process has to be either isothermal and adiabatic, with no chance of being the both, having concluded option (c) to be correct, option (d) is incorrect. Thus answer is option (c). N.B.: The graph is since not scaled and hence discrimination between the process A and B shall have to be done based on its visual observation. Equality of polynomials to valuate option (b) is a good example of integration of mathematics in physics. I-18 Internal energy of monatomic gases is $U = \frac{3}{2}nRT \Rightarrow \Delta U = \left(\frac{3}{2}nR\right)\Delta T$ and $\Delta U = nC_V\Delta T$. Combining these two equations $C_V = \frac{3}{2}R$. Further, $C_p = C_V + R \Longrightarrow C_p = \frac{3}{2}R + R = \frac{5}{2}R$. Containers A and B contains helium and neon which are monatomic gases and hence $\gamma = \frac{C_p}{C_V} = \frac{\frac{5}{2}R}{\frac{3}{2}R} = \frac{5}{3}$. The container C has oxygen diatomic gas where $U = \frac{5}{2}nRT \Rightarrow \Delta U = \left(\frac{5}{2}nR\right)\Delta T$ and $\Delta U = nC_V\Delta T$. Combining these two equations $C_V = \frac{5}{2}R$. Further, $C_p = C_V + R \Longrightarrow C_p = \frac{5}{2}R + R = \frac{7}{2}R$. Containers A and B contains helium and neon which are monatomic gases and hence $\gamma = \frac{C_p}{C_V} = \frac{\frac{7}{2}R}{5_p} = \frac{7}{5}$. Further, PV^{γ} = Constant. Since change in volume is same in all the three gases, and gases in container A and B are monatomic hence they have same $\gamma = \frac{5}{2}$ on reduction in volume to half of the original $\frac{p_{Ai}V_{Ai}}{p_{Bi}V_{Bi}} = \frac{p_{Af}V_{Af}}{p_{Bf}V_{Bf}} \Longrightarrow \frac{p_{Ai}V_{Ai}}{p_{Ai}V_{Ai}} = \frac{p_{Af}\left(V_{Af}\right)^{\gamma}}{p_{Bf}\left(V_{Bf}\right)} \Longrightarrow p_{Af} = p_{Bf}$. Thus pressure will remain same for helium and for oxygen for which $\gamma = \frac{7}{5}$, the identity would But neon. be $\frac{p_{Ai}V_{Ai}^{5}}{V_{Ai}^{7}} = \frac{p_{Af}V_{Af}^{5}}{V_{Af}^{7}} \Rightarrow \frac{p_{Ai}V_{Ai}^{5}}{V_{Af}^{7}} = \frac{p_{Af}\left(V_{Af}\right)^{5}}{V_{Af}^{7}} \Rightarrow p_{Af}\left(V_{Af}\right)^{5} = p_{Cf}\left(V_{Cf}\right)^{7}.$ As per theory of equations of polynomial each corresponding variable is equal only-&-only when their indices are also equal. Since, indices of variables V_{Af} and V_{Cf} are unequal and hence variables $p_{Af} \neq p_{Cf}$. Thus this analysis satisfies conclusions in option (c), and hence option (c) is correct. $pV = nRT \Rightarrow p = \frac{nRT}{V}$. Combining the two Using ideal gas equation equations $\left(\frac{nRT}{V}\right)V^{\gamma} = \text{Constant} \Rightarrow TV^{\gamma-1} = \text{Constant}_{n}$. Applying similar logic based on values of $\gamma = \frac{5}{3} \Rightarrow \gamma - 1 = \frac{2}{3}$ for helium and neon and for oxygen $\gamma = \frac{7}{5} \Rightarrow \gamma - 1 = \frac{2}{5}$, temperature of gases in containers A & B will be same

	and for container C will be different. This analysis satisfies conclusions in option (d). Hence option (d) is
	correct. Summarizing the illustrations above, answers are options (c) and (d).
I-19	As per FLT $\Delta Q = \Delta U + \Delta W$. Since container is rigid and hence there cannot be any change in volume and hence necessarily $\Delta W = 0 \Rightarrow \Delta Q = \Delta U$. Further as per IGE $pV = nRT \Rightarrow V\Delta p = nR\Delta T$ and $\Delta Q = nC\Delta T \Rightarrow C = \frac{\Delta Q}{n\Delta T} = \frac{3}{1 \times 1} = 3 \text{ cal. K}^{-1} \cdot \text{mol}^{-1}$. And $\Delta U = knR\Delta T \Rightarrow k = \frac{\Delta U}{nR\Delta T} = \frac{\Delta Q}{nR\Delta T} = \frac{3}{1 \times 2 \times 1} \Big _{R=\frac{8.3}{1 \times 1}=1.98 \approx 2 \text{ cal. K}^{-1} \cdot \text{mol}^{-1}}$.
	Thus $k = 1.5$. This is valid for monatomic gases and is valid for option (a) and (b). Hence answer is option (a) and (b).
I-20	Energy of a gas is $U = knRT$. It is given that all four cylinders contain equal number of moles at same temperature. Therefore the only discriminant for energy is $k = 1.5$ for monatomic gases, $k = 2.5$ for diatomic gases and $k = 3.5$ for polyatomic gases. Among the four options Argon (Ar) is monatomic and hence $k = 1.5$ will be applicable for it; Hydrogen (H ₂) and Oxygen (O ₂) are diatomic gases and hence $k = 2.5$ will be applicable for it. And for Carbon Dioxide (CO ₂) which is Triatomic and thus will fall in category of polyatomic gases for which $k = 3.5$. Since, $k = 1.5$ is minimum for Argon and hence answer is option (a).
I-21	As per FLT $\Delta Q = \Delta U + \Delta W$ and no heat is stated to be supplied therefore $0 = \Delta U + \Delta W \Longrightarrow \Delta U = -\Delta W$. Further, gas is stated to be monatomic and therefore $\Delta U = 1.5nR\Delta T = 1.5 \times 1 \times 8.3 \times \Delta T \Longrightarrow \Delta U = 12.45\Delta T$. Since vehicle in motion is stopped the kinetic energy is converted into work done by the gas which makes (-)ve. But, $\Delta W = -\frac{1}{2}mv^2 = -\frac{1}{2} \times 0.02 \times 50^2 = -25 \text{ J}$. Thus, going back to $\Delta U = -\Delta W$ and substituting the values $12.45\Delta T = -(-25) \Longrightarrow \Delta T = \frac{25}{12.45} = 2.008 \text{ K}$. This in accordance with SDs is 2.0 K. Thus answer is 2.0 K.
I-22	Given that gas contained in rigid container is heated it implies that there will be no volumetric change and hence no work would be done $\Delta W = 0$. Therefore, as per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta U$. Further, $\Delta Q = mS\Delta T$ and hence using the given data $\Delta Q = 5 \times 1.72 \times (25 - 15) = 8.6$ cal. Its mechanical equivalent s $\Delta U = (\Delta Q \text{ cal})(J.\text{ cal}^{-1}) = 8.6 \times 4.2 = 36.12 \text{ J}$. Thus as per SDs answer is 36 J .
I-23	F.B.D. of forces acting on the piston is shown in the figure. Accordingly, pressure exerted by the gas on the piston is $p = \frac{p_{atm} \times A + mg}{A} = \frac{(100 \times 10^3)(100 \times 10^{-4}) + 50 \times 10}{100 \times 10^{-4}} = 1.50 \times 10^5$ Pa. It is stated that cylinder is heated slowly and therefore, piston without getting acceleration utilizes heat supplied in moving the piston through a distance 0.2 m and pressure remains same i.e. it is an isobaric process. Further, $W = (p \times A)\Delta x = p \times (A \times \Delta x) = p \times \Delta V = ((1.50 \times 10^5) \times (100 \times 10^{-4})) \times 0.2 = 300$ J. As per ideal gas equation $pV = nRT \Rightarrow p\Delta V = nR\Delta T$. Therefore, $R\Delta T = 300$ J. Here there are only two variables, one is <i>n</i> number of moles and other is change in temperature $\Delta T = \frac{300}{nR}$. Using this expression ΔT is eliminated in terms of <i>n</i> in $\Delta Q = nC_p\Delta T = nC_p \left(\frac{300}{nR}\right) \Rightarrow \Delta Q = \frac{300C_p}{R}$.
	We know that $\frac{C_p}{C_V} = \gamma$ and $C_p = C_V + R \Rightarrow 1 = \frac{C_V}{C_p} + \frac{R}{C_p} \Rightarrow \frac{R}{C_p} = 1 - \frac{1}{\gamma} \Rightarrow C_p = \frac{\gamma R}{\gamma - 1}$. Substituting this value

	of C_P in ΔQ we get $\Delta Q = \left(\frac{300}{R}\right) \left(\frac{\gamma R}{\gamma - 1}\right) = \frac{300\gamma}{\gamma - 1}$. Using the given value of γ heat supplied is
	$\Delta Q = \frac{300 \times 1.4}{1.4 - 1} = \frac{420}{0.4} = 1250 \text{ J. Hence answer is } 1250 \text{ J.}$
I-24	Here all quantities are given in CGS. It is given that mass one mol of gas where $M = 2.2 \text{ g.mol}^{-1}$, heat required to raise temperature by 1 K at constant pressure is $\Delta Q_p = m \cdot S_p \cdot \Delta T = 2 \times 3.4 \times 1 = 6.8 \text{ cal}$, and at constant volume it is $\Delta Q_v = m \cdot S_v \cdot \Delta T = 2 \times 2.4 \times 1 = 4.8 \text{ cal}$. Further, for each mole of gas $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q_p = \Delta Q_v + \Delta W$. Using the values derived above, $\Delta W = \Delta Q_p - \Delta Q_v = 6.8 - 4.8 = 2 \text{ cal}$. It is known that $C_p - C_v = R$, where C_p and C_v are molar heat capacities at constant pressure and constant volume and universal gas constant R has unit erg. ${}^{0}\text{C}^{-1}$.mol ⁻¹ . Equating $\Delta W _{\text{cal}}$ for raising temperature by 1°C of 1 mol of hydrogen, with a mechanical equivalent of heat $\Delta W _{\text{erg}} = R$ the relation is $\Delta W _{\text{cal}} \cdot J = R \times n \times \Delta T \Rightarrow J = \frac{R \times n \times \Delta T}{\Delta W _{\text{cal}}} \text{ erg.cal}^{-1}$. Using the derived and given values $J = \frac{(8.3 \times 10^7) \times 1 \times 1}{2} = 5.15 \times 10^7 \text{ erg.cal}^{-1}$. Thus as per SDs of the data given in the problem $J = 4.2 \text{ erg.cal}^{-1}$.
I-25	We know that $C_p = C_V + R \Rightarrow \frac{C_p}{C_V} = 1 + \frac{R}{C_V} \Rightarrow \frac{R}{C_V} = \frac{C_p}{C_V} - 1 \Rightarrow C_V = \frac{R}{\frac{C_p}{C_V} - 1}$. Now with $R = 8.3 \text{ J.K}^{-1} \text{ .mol}^{-1} \text{ and}$
	the given ratio motar heat capacity of the given gas $C_V = \frac{7}{7} = 8.5 \times 6 = 49.8$ J.K .mol ² . Further internal energy of gas $\Delta U = n \cdot C_V \cdot \Delta T$. Using given data $\Delta U = 1 \times 49.8 \times 50 = 2490$ J. Since internal energy of a fixed mass of gas depends on change of temperature, it will remain same for all the three process. Hence answer is 2490 J for all cases.
I-26	As per FLT $\Delta Q = \Delta U + \Delta W$, here for a constant volume process $\Delta W = 0$ and hence $\Delta Q_V = \Delta U \Rightarrow \Delta Q_V = n \cdot C_V \cdot \Delta T \Rightarrow C_V = \frac{\Delta Q_V}{n \cdot \Delta T}$. As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT}$. Using the given data converted to SI $n = \frac{(1.0 \times 10^5)(1.0 \times 10^3 \times 10^{-6})}{8.3 \times 300} = \frac{1}{24.9}$. Using this value of number of moles (<i>n</i>) molar heat
	capacity of the air is $C_V = \frac{2.0}{\frac{1}{24.9} \times 1} = 49.8$ cal. ⁰ C ⁻¹ .mol ⁻¹ . At constant pressure
	$\Delta Q_p = \Delta Q_V + \Delta W_p \Longrightarrow \Delta Q_p = \Delta Q_V + p\Delta V. \text{ As per IGE, Applying dividend } \frac{pV}{pV'} = \frac{nRT}{nRT'} \Longrightarrow \frac{V'}{V} = \frac{T'}{T}$ $\frac{V'-V}{V} = \frac{T'-T}{T} \Longrightarrow \Delta V = \frac{V}{T}\Delta T. \text{ Therefore, at constant pressure } \Delta W = p\Delta V = p\frac{V}{T}\Delta T. \text{ Thus work done}$
	$\frac{V}{\text{during constant pressure process is } \Delta W_p = \frac{(1.0 \times 10^5)(1.0 \times 10^3 \times 10^{-6})}{300} \times 1 = \frac{1}{3} \text{ J}. \text{ Converting it into calories as}$

	desired $\Delta W _{cal} = \frac{\Delta W_p}{I} = \frac{1}{3} \times \frac{1}{4.2} = 0.079 \text{ cal.}$ Here, it is to be noted that $J = 4.2 \times 10^{-7} \text{ erg.cal}^{-1} = 4.2 \text{ J.cal}^{-1}$.
	Thus, using given data and derived values $\Delta Q_n = \Delta Q_V + \Delta W_V = 2 + 0.079 = 2.079$ cal. As per SDs the answer
	is 2.08 cal.
1.07	
1-27	As per FLT, $\Delta Q_p = \Delta U + p\Delta V \Rightarrow \Delta U = \Delta Q_p - p\Delta V$. Using given data and converting into SI,
	$\Delta U = 50 - (2.0 \times 10^{\circ}) \times (100 \times 10^{-6}) = 50 - 20 = 30 \text{ J}.$ This is the answer to part (a).
	As per IGE, using given into SI $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(2.0 \times 10^5)(100 \times 10^{-6})}{8.3 \times 300} = \frac{0.2}{8.3 \times 3.0} = 0.008 \text{ mol.}$
	This is the answer of part (b).
	Since, $\Delta Q_p = nC_p \Delta T \Rightarrow C_p = \frac{\Delta Q_p}{n \times \Delta T}$, here has been determined in part (b) of the answer. Further, it is a
	isobaric process $\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow \frac{V_2 - V_1}{V_1} = \frac{T_2 - T_1}{T_1} \Rightarrow \frac{200 - 100}{100} = \frac{\Delta T}{T_1} \Rightarrow \Delta T = T_1$. The initial temperature is given
	to be $T_1 = 100 \text{ K}$. Therefore, $C_p = \frac{\Delta Q_p}{n \times T_1} = \frac{50}{0.008 \times 300} = \frac{500}{24} = 20.8 \text{ J.K}^{-1} \text{.mol}^{-1}$. This is the part (c) of the
	answer.
	Further, $\Delta Q_V = \Delta U = nC_V \Delta T \Rightarrow C_V = \frac{\Delta Q_V}{n\Delta T}$. Using the values derived above $C_V = \frac{30}{0.008 \times 300} = \frac{30}{2.4} = 12.5$
	J.K ⁻¹ .mol ⁻¹ . This is part (d) of the answer. Thus answers for each part are (a) 30 J (b) 0.008 (c) 20.8 J.K^{-1} .mol ⁻¹ (d) 12.5 J.K^{-1} .mol ⁻¹
I-28	As per FLT $Q = \Delta U + W$, with the given data $Q = \Delta U + \frac{Q}{2} \Rightarrow \Delta U = Q - \frac{Q}{2} \Rightarrow \Delta U = \frac{Q}{2}$. Further, for
	monatomic gases $\Delta U = \frac{Q}{2} = \frac{3}{2} nR\Delta T$. Therefore molar heat capacity is $C = \frac{Q}{n\Delta T} = 3R$. Hence answer is 3R.
I-29	As per IGE $pV = nRT$, using the given $p - V$ relation we have $kV \times V = nRT \Longrightarrow kV^2 = nRT$. Differentiating
	the equation $2kV\Delta V = nR\Delta T \Rightarrow \Delta V = \frac{nR\Delta T}{2kV}$. As per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow nC\Delta T = nC_V\Delta T + p\Delta V$.
	Substituting ΔV in this new form of FLT $nC\Delta T = nC_V\Delta T + kV\left(\frac{nR\Delta T}{2kV}\right) \Rightarrow nC\Delta T = nC_V\Delta T + \frac{nR\Delta T}{2}$. On
	dividing the final form with $n\Delta T$ we get $C = C_V + \frac{R}{2}$. Proved.
I_30	
1-30	As per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow nC\Delta T = nC_v\Delta T + p\Delta V$. Combining given p-V relation in the IGE
1-30	As per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow nC\Delta T = nC_V\Delta T + p\Delta V$. Combining given p-V relation in the IGE $pV = nRT \Rightarrow (aV^b)V = nRT \Rightarrow aV^{b+1} = nRT$. On differentiating we get $a(b+1)V^b\Delta V = nR\Delta T$. It leads
1-50	As per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow nC\Delta T = nC_V\Delta T + p\Delta V$. Combining given p-V relation in the IGE $pV = nRT \Rightarrow (aV^b)V = nRT \Rightarrow aV^{b+1} = nRT$. On differentiating we get $a(b+1)V^b\Delta V = nR\Delta T$. It leads to $\Delta V = \frac{nR\Delta T}{a(b+1)V^b}$ Substituting in the final form of FLT $nC\Delta T = nC_V\Delta T + (aV^b)\left(\frac{nR\Delta T}{a(b+1)V^b}\right)$. It

	to $0 = C_v + \frac{C_p - C_v}{(b+1)} \Rightarrow C_v (b+1) = C_v - C_p$. Dividing the final form by C_v we get $b+1 = 1 - \frac{C_p}{C_v}$. Using the
	given ratio γ we get $b+1=1-\gamma \Rightarrow b=-\gamma$. Hence answer is $-\gamma$.
I-31	Two ideal gases when mixed each will have same pressure and temperature. Therefore, as per IGE
	$pV = nRT \Rightarrow \frac{pV_1}{pV_2} = \frac{n_1RT}{n_2RT} \Rightarrow \frac{V_1}{V_2} = \frac{n_1}{n_2} = \frac{1}{2}$. Further both have same ratio $\frac{C_p}{C_v} = \gamma$. Further, the relation
	$C_{p} = C_{v} + R \Rightarrow \frac{C_{p}}{C_{v}} = 1 + \frac{R}{C_{v}} \Rightarrow \gamma = 1 + \frac{R}{C_{v}} \Rightarrow \frac{C_{v}}{R} = \frac{1}{\gamma - 1} \Rightarrow C_{v} = \frac{R}{\gamma - 1} \text{Likewise,} 1 = \frac{C_{v}}{C_{p}} + \frac{R}{C_{p}} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_{p}} \Rightarrow C_{p} = \frac{\gamma R}{\gamma - 1}$
	These values of C_p and C_V will be useful in following steps.
	Heat gained for ΔT rise of temperature of gas 1 as per FLT will be $\Delta Q_{p-1} = \Delta Q_{V-1} + \Delta W_1$. Since
	$\Delta W = p\Delta V = p(nR\Delta T). \text{ Accordingly, } n_1C_{p-1}\Delta T = n_1C_{V-1}\Delta T + n_1R\Delta T \Longrightarrow C_{p-1} = C_{V-1} + R. \text{ Likewise for gas 2 it}$
	is $n_2 C_{p-2} \Delta T = n_2 C_{V-2} \Delta T + n_2 R \Delta T \Longrightarrow C_{p-2} = C_{V-2} + R$. Thus for the mixture
	$\Delta Q_p = \Delta Q_{p-1} + \Delta Q_{p-1}; \ \Delta Q_V = \Delta Q_{V-1} + \Delta Q_{V-2} \text{ and } \Delta W = \Delta W_1 + \Delta W_2. \text{ Adding respective elements of energy}$
	equations for the two gases it leads to $(n_1C_{p-1}+n_2C_{p-2})\Delta T = (n_1C_{V-1}+n_2C_{V-2})\Delta T + p(n_1+n_2)R\Delta T$. It leads
	$\operatorname{to}\left(n_{1}\frac{\gamma R}{\gamma-1}+2n_{1}\frac{\gamma R}{\gamma-1}\right)=\left(n_{1}\frac{R}{\gamma-1}+2n_{1}\frac{R}{\gamma-1}\right)+\left(n_{1}+2n_{1}\right)R\Longrightarrow 3n_{1}\frac{\gamma R}{\gamma-1}=3n_{1}\frac{R}{\gamma-1}+3n_{1}R$
	Taking C_p and C_V as molar heat capacities of the mixture at constant pressure and volume respectively,
	accordingly, $(n_1 + n_2)C_p = (n_1 + n_2)C_V + (n_1 + n_2)R \Longrightarrow (n_1 + 2n_1)C_p = (n_1 + 2n_1)C_V + (n_1 + 2n_1)R$. It leads
	to $3n_1C_p = 3n_1C_V + 3n_1R \Longrightarrow C_p = C_V + R$, therefore $C_p = C_V + R$. It leads to $C_V = \frac{R}{\gamma - 1}$ and $C_p = \frac{\gamma R}{\gamma - 1}$.
	Moreover, such equations for gas 1, Gas 2 and the mixture have similar variables with identical coefficients and
	therefore the $\frac{C_P}{C_V}$ for the mixture is same as γ . Hence answer is γ .
1-32	Heat goined for ΔT rise of temperature of gas 1 as per ELT will be $\Delta Q = \Delta Q + \Delta W$. Since
1 52	Theat gamed for ΔT rise of temperature of gas 1 as per FLT will be $\Delta Q_{p-1} = \Delta Q_{V-1} + \Delta W_1$. Since $\Delta W = p\Delta V = p(pP\Delta T)$. Accordinate $C = \Delta T$, $C = \Delta T$, $D = T$, $T = D = D$. For the part of the problem of the prob
	$\Delta W = p\Delta V = p(nR\Delta I). \text{ Accordingly, } n_1 C_{p1}\Delta I = n_1 C_{V1}\Delta I + n_1 R\Delta I \Longrightarrow 1 \times 2.5R = 1 \times 2.5R + 1 \times R. \text{ Likewise}$ for any 2 it is 1 × 3.5R × $\Delta T = 1 \times 2.5R \times \Delta T + 1 \times R\Delta T \Longrightarrow 3.5R = 2.5R + R. \text{ Thus, for the mixture}$
	$\Delta Q_p = \Delta Q_{p-1} + \Delta Q_{p-1}; \Delta Q_V = \Delta Q_{V-1} + \Delta Q_{V-2} \text{ and } \Delta W = \Delta W_1 + \Delta W_2. \text{ Adding respective elements of energy}$
	equations for the two gases it leads to $(n_1C_{p-1}+n_2C_{p-2})\Delta T = (n_1C_{V-1}+n_2C_{V-2})\Delta T + p(n_1+n_2)R\Delta T$. It leads
	to $(1 \times 2.5R + 1 \times 3.5R) = (1 \times 1.5R + 1 \times 2.5R) + (1+1)R \Longrightarrow 2 \times 3R = 2 \times 2R + 2R \Longrightarrow nC_p = nC_V + nR$. Here
	in the mixture number of moles is $2(=1+1)$. Thus comparing coefficients $C_p = 3R$, $C_V = 2R$ and the ratio
	$\gamma = \frac{C_p}{C_V} = \frac{3}{2} = 1.5$. Hence, the answer is 3 <i>R</i> , 2 <i>R</i> , 1.5.
1-33	ъV
1-33	As per IGE $pV = nRT \Rightarrow T = \frac{pv}{nR}$. Solving each part separately –
	Part (a): Since p-V values for each point is shown in the graph and hence taking data from the figure

$$T_{a} = \frac{(100 \times 10^{3})(5000 \times 10^{-6})}{0.5 \times \frac{25}{3}} = 120 \text{ K}, \qquad T_{b} = \frac{(100 \times 10^{3})(10000 \times 10^{-6})}{0.5 \times \frac{25}{3}} = 240 \text{ K},$$

$$T_{c} = \frac{(200 \times 10^{3})(105000 \times 10^{-6})}{0.5 \times \frac{25}{3}} = 480 \text{ K} \text{ and } T_{d} = \frac{(200 \times 10^{3})(5000 \times 10^{-6})}{0.5 \times \frac{25}{3}} = 240 \text{ K}$$
Part (b): Since 'ab' is isobaric (constant pressure) process and 'bc' is isochoric (constant volume) process and hence
$$\Delta Q_{ab} = nC_{p}\Delta T \text{ and } \Delta Q_{bc} = nC_{V}\Delta T.$$
Here, the relation $C_{p} = C_{V} + R$ leads to

 $\frac{C_p}{C_v} = 1 + \frac{R}{C_v} \Rightarrow \gamma = 1 + \frac{R}{C_v} \Rightarrow \frac{C_v}{R} = \frac{1}{\gamma - 1} \Rightarrow C_v = \frac{R}{\gamma - 1}$, and likewise, $1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p} \Rightarrow C_p = \frac{\gamma R}{\gamma - 1}$. Using these values of C_p and C_v temperatures at a,b and c determined in part (a) heat supplied during path ab of the

cycle,
$$\Delta Q_{ab} = nC_p \Delta T = n \frac{\gamma R}{\gamma - 1} (T_b - T_a) = 0.5 \times \frac{\frac{5}{3} \times \frac{25}{3}}{\frac{5}{3} - 1} (240 - 120) = 0.5 \times \frac{125}{9} \times \frac{3}{2} \times 120 = 1250 \text{ J.}$$
 And during

bc
$$\Delta Q_{bc} = nC_V \Delta T = n \frac{R}{\gamma - 1} (T_c - T_b) = 0.5 \times \frac{\frac{25}{3}}{\frac{5}{3} - 1} \times (480 - 240) = 0.5 \times \frac{25}{2} \times 240 = 1500 \text{ J}.$$

25

Part (c): Heat liberated during 'cd' isobaric process and 'da' is isochoric process is $\Delta Q_{cd} = nC_p\Delta T$ and $\Delta Q_{da} = nC_v\Delta T$. Accordingly, determined in part (a) heat supplied during path ab of the cycle, $\Delta Q_{cd} = nC_p\Delta T = n\frac{\gamma R}{\gamma - 1}(T_d - T_c) = 0.5 \times \frac{\frac{5}{3} \times \frac{25}{3}}{\frac{5}{2} - 1}(240 - 480) = 0.5 \times \frac{125}{9} \times \frac{3}{2} \times (-240) = -2500 \text{ J}$, here (-)ve sign is

indicative of heat liberated. Likewise, in part 'da' $\Delta Q_{da} = nC_V \Delta T = n \frac{R}{\gamma - 1} (T_a - T_d) = 0.5 \times \frac{\frac{25}{3}}{\frac{5}{3} - 1} \times (120 - 240)$ or

 $\Delta Q_{da} = 0.5 \times \frac{25}{2} \times (-120) = -750$, in this part also (-)ve sign is indicative of heat liberated. Combining values arrived at in all the parts the answer is (a) 120 K, 240 K, 480 K, 240 K (b) 1250 J, 1500 J (c) 2500 J, 750 J.

I-34 **Part (a):** In this process part 'ab' is isochoric (constant volume) process and temperature at 'a ' is given to be $T_a = 300 \text{ K.}$ As per IGE $pV = nRT \Rightarrow nR = \frac{pV}{T} \text{ and } T = \frac{pV}{nR}$. Thus, $nR = \frac{p_a V_a}{T_a} = \frac{(100 \times 10^3)(100 \times 10^{-6})}{300} = \frac{1}{30}$ and $TT_b = \frac{p_a V_a}{nR} = \frac{(200 \times 10^3)(100 \times 10^{-6})}{\frac{1}{30}} = 600 \text{ K}$, likewise $T_c = \frac{p_c V_c}{nR} = \frac{(200 \times 10^3)(150 \times 10^{-6})}{\frac{1}{30}} = 900 \text{ K}.$ **Part (b):** Work done in the process $W_{ac} = W_{ab} + W_{bc} = 0 + p_b \Delta V_{bc} = p_b (V_c - V_b)$. Since process 'ab' is isochoric

	$\Delta V_{ab} = 0 \Longrightarrow W_{ab} = 0$ process and hence using the data $W_{ac} = (200 \times 10^3)((150 - 100) \times 10^{-6}) = 10$ J
	Part (c): Amount of heat supplied in isochoric path 'ab' is $Q_{ab} = nC_V \Delta T$ and in isobaric path 'bc'
	$Q_{bc} = nC_p\Delta T$. Using the relation $C_p = C_V + R$ leads to $\frac{C_p}{C_V} = 1 + \frac{R}{C_V} \Rightarrow \gamma = 1 + \frac{R}{C_V} \Rightarrow \frac{C_V}{R} = \frac{1}{\gamma - 1} \Rightarrow C_V = \frac{R}{\gamma - 1}$, and
	likewise, $1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p} \Rightarrow C_p = \frac{\gamma R}{\gamma - 1}$. Accordingly, $Q_{ab} = n \left(\frac{R}{\gamma - 1}\right) \Delta T = n R \left(\frac{1}{\gamma - 1}\right) \left(T_b - T_a\right)$ using
	given data and derived value $Q_{ab} = \frac{1}{30} \left(\frac{1}{1.67 - 1} \right) (600 - 300) = 14.9 \text{ J.}$ Likewise, $Q_{bc} = n \frac{\gamma R}{\gamma - 1} (T_c - T_b)$.
	Substituting data, $Q_{bc} = \frac{1}{30} \left(\frac{1.67}{0.67} \right) (900 - 600) = 24.9 \text{ J}.$
	Part (d): As per FLT $\Delta Q = \Delta U + \Delta W \Longrightarrow \Delta U = (\Delta Q_{ab} + \Delta Q_{bc}) - \Delta W$ J. Using the values derived in part (b)
	and (c) $\Delta U = (24.9+14.9) - 10 = 29.8 \text{ J}$. Consolidating results in each part answer is (a) 600 K, 900 K
	(b) 10 J (c) 14.9 J, 24.9 J (d) 29.8 J.
I-35	As per given data heat gained by the gas $\Delta Q_1 = m_a \times S_a \times \Delta T = 3 \times S_a \times (100 - 20) = 240 \times S_a$. Heat liberated
	by steam to the gas $\Delta Q_{-} = m_s \times L_s = 0.095 \times 540 = 51.3$ J. On equilibrium of the process
	$\Delta Q_{+} = \Delta Q_{-} \Longrightarrow 240 \times S_{g} = 51.3 \Longrightarrow S_{g} = \frac{51.3}{240} = 0.214 \text{ cal.g}^{-1}.\text{K}^{-1}.$ Since answer is required in J.g ⁻¹ .K ⁻¹ and
	hence $S_{g-J} = S_g \times J = 0.214 \times 4.2 = 0.898 \text{ J.g}^{-1} \text{.K}^{-1}$. Using SDs the answer is 0.90 J.g $^{-1}$.K $^{-1}$.
I-36	In adiabatic process $p_1 V_1^{\gamma} = p_2 V_2^{\gamma} \Longrightarrow \frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{\gamma}$. Using the given data $\frac{p_2}{p_1} = \left(\frac{4.00}{3.00}\right)^{1.5} = 1.539$. Using SDs
	$\frac{p_2}{p_1} = 1.54$. Thus answer to part (a) is 1.54.
	Further, as per IGE $pV = nRT$, therefore for the required ratio of temperature $\frac{T_2}{T_1} = \frac{p_2V_2}{p_1V_1} = \left(\frac{p_2}{p_1}\right)\left(\frac{V_2}{V_1}\right)$. Using
	given data and valued arrived at in part (a) $\frac{T_2}{T_1} = 1.54 \left(\frac{300}{400}\right) = 1.15$. Thus answer to part (b) is 1.54. Thus
	consolidated part wise answer is (a) 1.54 (b) 1.15.
I-37	On given sample of gas adiabatic process is carried out accordingly $p_1V_1^{\gamma} = p_2V_2^{\gamma} = K$. It is also given that
	$\frac{V_1}{V_2} = 2$. Accordingly, using the given data
	$\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow p_2 = \left(2.5 \times 10^5\right) 2^{1.5} = 7.07 \times 10^5.$ Thus using SGs answer to part (a) is
	$7.1 \times 10^5 $ Pa .
	From IGE, using given and proved data final temperature $\frac{p_2V_2}{p_1V_1} = \frac{nRT_2}{nRT_1} \Rightarrow T_2 = \left(\frac{p_2}{p_1}\right) \left(\frac{1}{2}\right) T_1$. Thus final

$$\begin{array}{rcl} & \text{temperature is } T_{2} = \left(\frac{7.1 \times 10^{2}}{2.5 \times 10^{2}}\right) \left(\frac{1}{2}\right) \times 300 - 426 \text{ K. Thus using SGs answer to part (b) is 426 \text{ K.} \\ & \text{In adiabatic process } \frac{p}{p_{1}} = \left(\frac{V_{1}}{V}\right)^{2} \Rightarrow p = \left(p_{1}V_{1}^{2}\right) \frac{1}{V^{2}} \text{ and work done in the process } W = \frac{V_{1}}{p_{1}} pdV = K_{1}^{2} \frac{1}{V^{2}} \frac{1}{V^{2}} dV \\ & \text{Thus, } W = \frac{1}{1-\gamma} \left[\frac{K}{V^{2}}\right]_{V_{1}}^{V_{2}} = \frac{1}{1-\gamma} \left[\frac{p_{2}V_{1}^{2}}{V_{2}^{-1}} - \frac{p_{1}V_{1}^{2}}{V_{2}^{-1}}\right] = \frac{1}{1-\gamma} \left[p_{2}V_{2} - p_{1}V_{1}\right] = \frac{1}{1-\gamma} \left[p_{1}V_{1} - p_{2}V_{2}\right]. \text{ Substituting the data } W = \frac{1}{1.5-1} \left[\left(2.5 \times 10^{5}\right)(100 \times 10^{-8}) - (7.1 \times 10^{5})(50 \times 10^{-8})\right] = \frac{1}{0.5} \left[25 - 35.5\right] = -21J. \text{ Thus answer to part (c) is -21J.} \\ \hline 1^{-38} & \text{ On given sample of gas adiabatic process is carried out accordingly } pV_{1}^{2} = p_{2}V_{2}^{2} = K. \text{ It is also given that } \\ \frac{p_{1}}{p_{2}} = 2. \text{ Accordingly, } \frac{p_{1}}{p_{2}} = \left(\frac{V_{1}}{V_{1}}\right)^{2} \Rightarrow \frac{V_{2}}{V_{1}} = \left(\frac{p_{1}}{p_{1}}\right)^{\frac{1}{2}} \Rightarrow \frac{V_{2}}{V_{1}} = 2^{\frac{1}{14}} = 1.64 \text{ atm. Further as per Ideal Gas Equation } \\ pV = nRT accordingly, & \frac{p_{1}V_{2}}{p_{1}V_{1}} = \frac{nRT_{2}}{nRT_{1}} \Rightarrow T_{2} = \left(\frac{p_{2}}{p_{1}}\right)\left(\frac{V_{1}}{V_{1}}\right)T_{1}. \text{ Using the given and derived data.} \\ T_{3} = \frac{1}{2} \times 1.64 \times (273 + 20) = 240. \text{ Thus answer is 249 K.} \\ \text{ N.B.: Here, ambient temperature needs to be converted into thermodynamic scale.} \\ \hline 1^{-39} & \text{ Since the system is adiabatic and hence processes (a) and (b) given in the problems will be adiabatic. In an adiabatic process is carried out accordingly $p_{1}V_{1}^{2} \Rightarrow p_{2} = (100 \times 10^{3}) \times 4^{45} = 800 \times 10^{3} \text{ Pa}. \text{ Now as per Ideal Gas Equation } \\ pV = nRT accordingly, & \frac{p_{1}V_{2}}{p_{1}V_{1}} \Rightarrow p_{2} = (100 \times 10^{3}) \times 4^{45} = 800 \times 10^{3} (400) \left(\frac{100}{400}\right) 300 = 600 \text{ K}. \text{ Thus answer is 800 kPa and 600 K. \\ \hline 1^{-40} & \text{ With The storeordingly } p_{1}V_{1}^{2} = p_{2}V_{2}^{2} \Rightarrow p_{n-1} = 2p_{n-1} \left(\frac{V_{n-1}}{V_{n-2}}\right)^{2} \Rightarrow 2p_{0} \left(\frac{V_{n}}{\frac{2}{4}}\right)^{$$$

$$p_{k-1} = p_0 \left(\frac{V_0}{V_{k-1}} \right)^2 \Rightarrow p_0 \left(\frac{V_0}{V_0} \right)^2 = 2^p p_0 \quad \text{Second part of the process is isothermal where}$$

$$p_{k-1}V_{k-1} = p_{k-2}V_{k-2} \Rightarrow p_{k-2} = p_{k-1} \frac{V_{k-1}}{V_{k-2}} = 2^p p_0 \left(\frac{2}{\frac{V_0}{V_0}} \right)^2 = 2^{p+1} p_0 \text{. This part (a) of the answer.}$$
Thus in both the cases final pressure, the answer, is $2^{p+1} p_0$.
$$1-41 \quad \text{Given that system can exchange het with the surrounding and hence when it is compressed slowly, it will be isothermal process and accordingly $p_1V_1 = p_2V_2$. And when gas is compressed suddenly, it will not have time to exchange the heat with the surrounding and hence it will be an adiabatic process where $p_1V^2 = p_2V_2^2 = K$. Processes are carried out in two parts in both the cases, accordingly taking each case in its parts.
Case (a): Taking first part which is isothermal $p_0V_0 = p_{a-1}V_{a-1} \Rightarrow V_{a-1} = \frac{p_0V_0}{P_{a-1}} = \frac{p_0V_0}{2} = 2V_0$. Second part of the process is adiabatic, thus $p_{a-1}V_{a-1}^2 = p_{a-2}V_{a-2}^2 \Rightarrow V_{a-2} = \left(\frac{p_{a-1}V_{a-1}}{P_{a-2}} \right)^2 = V_a \left(\frac{p_{a-1}}{P_{a-2}} \right)^{\frac{1}{2}}$. Substituting values we get $V_{a-2} = 2V_0 \left(\frac{\frac{p_0}{2}}{\frac{p_0}{2}} \right)^{\frac{1}{2}} = 2^{\frac{p_0}{2}}V_0$. This answer of part (a).
Case (b): Taking first part it is adiabatic process where $p_0V_0^2 = p_{a-1}V_{a-1}^2$. Using the given data we get $\left(\frac{V_{a-1}}{V_0} \right)^2 = \frac{p_0}{p_{a-1}} \Rightarrow V_{a-1} = V_0 \left(\frac{p_0}{\frac{p_0}{2}} \right)^{\frac{1}{2}} = 2^{\frac{1}{2}}V$. Second part of the process is isothermal where $p_{b-1}V_{b-1} = p_{b-1}V_{b-2} \Rightarrow V_{b-2} \Rightarrow V_{b-2} = V_0 \left(\frac{p_0}{\frac{p_0}{2}} \right)^{\frac{1}{2}} = 2^{\frac{1}{2}}V_0$. This part (a) of the answer.
Thus in both the cases final pressure, the answer, is $2^{p+1}V_0$.
Thus in both the cases final pressure, the answer, is $2^{p+1}V_0$.
Thus in both the cases final pressure, the answer, is $2^{p+1}V_0$.
This answer of Part (a).
It is known that $C_p = C_V + R \Rightarrow \frac{p_V}{C_p} = 1 + \frac{R}{C_V} \Rightarrow \frac{R}{C_V} = \gamma - 1 \Rightarrow C_V = \frac{R}{\gamma - 1} = \frac{R \cdot 3}{1.5 - 1} = 16.6 \text{ J.K}^1 \text{ mot}^1$. This answer of Par$$

	In adiabatic process $p_1 V_1^{\gamma} = p_2 V_2^{\gamma} \Longrightarrow p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{\gamma} = (150 \times 10^3) \left(\frac{150 \times 10^{-6}}{50 \times 10^{-6}}\right)^{1.5} = 779.4 \text{ kPa and as per SDs}$
	780 kPa. As per IGE $pV = nRT \Rightarrow \frac{p_1V_1}{p_2V_2} = \frac{T_1}{T_2} \Rightarrow T_2 = T_1 \frac{p_2V_2}{p_1V_1} = 300 \times \frac{(780 \times 10^3)(50 \times 10^{-6})}{(150 \times 10^3)(150 \times 10^{-6})} = 520 \text{ K. Thus}$
	answers of part (c) are 780 kPa and 520K.
	Change in internal energy $\Delta U = nC_V \Delta T$. Using value of $n = 0.009$ from answer of part (a) and $C_v = 16.6$ J.K ⁻¹ .mol ⁻¹ from answer of part (b) $\Delta U = 0.009 \times 16.6 \times (520 - 300) = 33$ J. This is part (e) of the answer.
	The process is since adiabatic and hence no heat is exchanged by the system with the environment and therefore as per FLT $\Delta Q = \Delta U + \Delta W \Rightarrow 0 = \Delta U + \Delta W \Rightarrow \Delta W = -\Delta U$. Hence using answer from part (e) $\Delta W = -33$ J. This is part (d) of the answer.
	Consolidating answers of all the parts, (a) 0.009, (b) $2R = 16.6 \text{ J.K}^{-1} \text{.mol}^{-1}$, (c) 780 kPa, 520 K, (d) -33 J, (e) 33 J
I-43	It is given that $V_{iA} = V_{iB} = V_{iC} = V_i$, $T_{iA} = T_{iB} = T_{iC} = T_i$, $V_{fA} = V_{fB} = f_{iC} = V_f$, $p_{fA} = p_{fB} = p_{fC} = p_f$ and
	$\frac{V_f}{V_i} = 2$. Each sample undergoes different process.
	Sample A: It is isothermal process, therefore, $p_{iA}V_i = p_fV_f \Rightarrow p_{iA} = p_f \frac{V_f}{V_i} = 2p_f$.
	Sample B: It is adiabatic process therefore $p_{iB}V_i^{\gamma} = p_f V_f^{\gamma} \Rightarrow p_{iB} = p_f \left(\frac{V_f}{V_i}\right)^{\gamma} = 2^{1.5} p_f = 2\sqrt{2} p_f$
	Sample C: It is isobaric process, therefore, $p_{iC} = p_f$
	Accordingly, $p_{iA}: p_{iB}: p_{iC}:: 2p_f: 2\sqrt{2}p_f: p_f \Rightarrow p_{iA}: p_{iB}: p_{iC}:: 2: 2\sqrt{2}: 1$. Hence, answer is $2: 2\sqrt{2}: 1$
I-44	Given that for two samples $V_{Ai} = V_{Bi} = V_i$, $p_{Ai} = p_{Bi} = p_i$, $V_{Af} = V_{Bf} = 2V_i$ and $W_A = W_B = W$.
	The sample A undergoes isothermal expansion and therefore work done in the process $\frac{2V}{2} = \frac{2V_i}{2} n RT$ 2V
	$W_A = \int_{V_i} p dv = \int_{V_i} \frac{nRT}{v} dv = nRT \ln \frac{2V_i}{V_i} - nRT \ln 2.$
	Sample B undergoes adiabatic expansion where $\Delta Q = 0$, therefore as per FLT,
	$\Delta Q = \Delta U + \Delta W \Longrightarrow 0 = \Delta U + \Delta W \Longrightarrow \Delta W_B = -\Delta U_B = -(nC_V \Delta T) = -\frac{nR\Delta T}{\gamma - 1}. \text{ As per IGE, } p_i V_i = nRT_{Bi},$
	$p_{Bf}V_{Bf} = nRT_{Bf}$ and $p_iV_i^{\gamma} = p_{fB}(2V_i)^{\gamma} \Rightarrow p_{fB} = \frac{p_i}{2^{\gamma}}$. Accordingly, $\Delta T = T_{Bf} - T_{Bi} = \frac{p_{Bf}V_{Bf} - p_{Bi}V_{Bi}}{nR}$. Thus
	$\Delta T = \frac{p_{Bf}(2V_i) - p_i V_i}{nR} = \frac{\frac{p_i}{2^{\gamma}}(2V_i) - p_i V_i}{nR} = (2^{1-\gamma} - 1)\frac{p_i V_i}{nR}.$ Therefore $\Delta W_B = -\frac{nR}{\gamma - 1} \times (2^{1-\gamma} - 1)\frac{p_i V_i}{nR} = \frac{1 - 2^{1-\gamma}}{\gamma - 1}p_i V_i.$
	Since, $W_A = W_B \Longrightarrow nRT \ln 2 = \frac{1 - 2^{1-\gamma}}{\gamma - 1} nRT \Longrightarrow \frac{1 - 2^{1-\gamma}}{\gamma - 1} = \ln 2 \Longrightarrow 1 - 2^{1-\gamma} = (\gamma - 1) \ln 2$. Hence proved.

Given that $V_i = 1 \times 10^{-3}$, $V_f = 0.5 \times 10^{-3}$ and $T_i = 300$ K. Since compression is sudden and hence it will not have I-45 enough time to dissipate heat developed during compression. Therefore process is virtually adiabatic. Accordingly, $pV^{\gamma} = K \Rightarrow p_i V_i^{\gamma} = p_f V_f^{\gamma} \Rightarrow \frac{p_f}{p_i} = \left(\frac{V_i}{V_c}\right)^{\gamma} = \left(\frac{1 \times 10^{-3}}{0.5 \times 10^{-3}}\right)^{1.5} = 2^{1.5} = 2\sqrt{2}$. This answer for part (a). Work done in an adiabatic process is $W = \int_{V_f}^{V_f} p dv = \int_{V_f}^{V_f} \frac{K}{V^{\gamma}} dv = \frac{K}{1-\gamma} \left[\frac{1}{V^{\gamma-1}} \right]_{V_f}^{V_f} = \frac{1}{1-\gamma} \left[\frac{p_f V_f^{\gamma}}{V_f^{\gamma-1}} - \frac{p_i V_i^{\gamma}}{V_f^{\gamma-1}} \right].$ $W = \frac{p_i V_i - p_f V_f}{\gamma - 1} = \frac{(100 \times 10^3)(1 \times 10^{-3}) - (2\sqrt{2} \times 100 \times 10^3)(0.5 \times 10^{-3})}{1.5 - 1} = 200(1 - 1.414) = -82 \text{ J}.$ Therefore. This is answer of part (b). As per FLT $\Delta Q = \Delta U + \Delta W \Longrightarrow 0 = \Delta U + \Delta W \Longrightarrow \Delta U = -\Delta W = -(-82) = 82$ J. This is answer of part (c). As per IGE using given and derived data $pV = nRT \Rightarrow \frac{p_f V_f}{p_i V_i} = \frac{T_f}{T_i} \Rightarrow T_f = \left(\frac{p_f}{p_i}\right) \left(\frac{V_f}{V_i}\right) T_i = 2\sqrt{2} \times \frac{1}{2} \times 300 = 300\sqrt{2}$ K. Thus final temperature $T_f = 300 \times 1.414 = 424.2$ K. This is answer of part (d). cooling from $T_f = 424$ K to $T_f' = 300$ K at constant Work done in pressure $\Delta W_p = \int_{V_f}^{V_f} p dv = p \int_{V_f}^{V} dv = p V - p V_f = nRT - nRT_f$ J. It leads to $\Delta W_p = nR(300 - 424)$. Here it needs to determine $n = \frac{p_i V_i}{RT} = \frac{(100 \times 10^3)(1 \times 10^{-3})}{R \times 300} = \frac{1}{3R}$. Thus $\Delta W_p = nR(300 - 424) = -41.4$ This is answer of part (e). During cooling, under constant pressure, in part (e) of the problem volume of gas would decrease as per IGE such that $\frac{V_f}{T_c} = \frac{V_f}{T_c} \stackrel{'}{\Longrightarrow} = \frac{V_f}{T_c} T_f \stackrel{'}{=} = \frac{0.5}{300\sqrt{2}} \times 300 = \frac{1}{2\sqrt{2}}$. The gas is now expanded isothermally from $V_f' = \frac{1}{2\sqrt{2}}$ ltr to original volume $V_i = 1$ ltr. It requires to know volume attained in part (e) in this case work done . In this case V is the volume attained in part (e) of the problem which as per IGE at constant pressure $\Delta W_{\rm iso} = \int_{-\frac{1}{2}}^{1} p dV = \int_{-\frac{1}{2}}^{1} \frac{nRT}{V} p dV = \frac{1}{3R} R \times 300 \int_{-\frac{1}{2}}^{1} \frac{1}{V} p dV = 100 \left[\ln V\right]_{\frac{1}{2\sqrt{2}}}^{1} = 100 \ln \left(2\sqrt{2}\right) = 100 \times \frac{\log 2\sqrt{2}}{\log 2.718}$ This solves into $\Delta W_{iso} = 100 = 100 \times 1.03 = 103$. Thus answer to part (f) is 103 J. Total work done in the process is equal to [work done in part (b)]+ [work done in part (e)]+ [work done in part (f) = (-82) + (-41.4) + 103 = -20.4 J. This is answer to part (g) **Consolidating answers to all parts (a)** $2\sqrt{2}$ (b) -82 J (c) 82 J (d) 424 K (e) -41.4 J (f) 103 J (g) -20.4 J **N.B.:** Here natural logarithm $\ln x \Rightarrow \log_e x$ obtained in integration is converted to logarithm to the base 10 $\log x \Rightarrow \log_{10} x$. Here, Napier's Constant or Euler's Number e = 2.718. Accordingly, the conversion is $\ln x = \log_{10} x \times \log_e 10 \Rightarrow \ln x = \frac{\log_{10} x}{\log_{10} e}$. In the instant problem in part (f) is $x = 2\sqrt{2}$.

T 16	The system is stated to be adjusted and kenne when noten is moved from
1-40	The system is stated to be adiabatic and hence when piston is moved from $V = V = V$
	initial indeposition it will undergo adiabatic change as per $p_1v_1 = p_2v_2$. If $p_2\overline{2}$, $I = p_2\overline{2}$,
	new position the piston divides the tube in ratio 1.5. It implies that $V = V = V = V = 1 + 3$
	$\frac{V_L}{V_R} = \frac{1}{3} \Rightarrow \frac{V_L + V_R}{V_R} = \frac{1+3}{3} \Rightarrow \frac{V}{V_R} = \frac{4}{3} \Rightarrow V_R = \frac{3}{4}V \Rightarrow V_L = \frac{1}{4}V. \text{ Therefore, } \begin{bmatrix} V_{p_L}, \frac{1}{4}, T_L \end{bmatrix} = p_R, \frac{3V}{4}, T_R \end{bmatrix}$
	on left part would be $p\left(\frac{V}{2}\right)^{\gamma} = p_L\left(\frac{V}{4}\right)^{\gamma} \Rightarrow p_L = p\left(\frac{4}{2}\right)^{\gamma} = p(2)^{1.5}$ and on the
	right part $p\left(\frac{V}{2}\right)^{\gamma} = p_R\left(\frac{3V}{4}\right)^{\gamma} \Rightarrow p_R = p\left(\frac{2}{3}\right)^{\gamma} = p\left(\frac{2}{3}\right)^{1.5}$.
	As regards temperature as per IGE $pV = nRT \Rightarrow \frac{p_1V_1}{p_2V_2} = \frac{T_1}{T_2}$ and therefore on left and right parts it is
	$\frac{p\frac{V}{2}}{p_{L}\frac{V}{4}} = \frac{T}{T_{L}} \Rightarrow T_{L} = T\frac{p_{L}}{2p} = T\frac{(2)^{1.5} p}{2p} = \sqrt{2} \cdot T \text{and} \frac{p\frac{V}{2}}{p_{R}\frac{3V}{4}} = \frac{T}{T_{R}} \Rightarrow T_{R} = T\frac{3p_{R}}{2p} = T\frac{3\left(\frac{2}{3}\right)^{1.5} p}{2p} = \sqrt{\frac{2}{3}T}$
	respectively. Thus ratio of temperature of two parts $\frac{T_L}{T_R} = \frac{\sqrt{2} \cdot T}{\sqrt{\frac{2}{2}}T} = \frac{\sqrt{3}}{1} \Rightarrow T_L : T_R :: \sqrt{3} : 1$. Thus answer is
	$\sqrt{3}$:1
I-47	$r_{V} = (\rho_{a} gh)V = ((1.36 \times 10^{4}) \times 9.81 \times 0.75)(200 \times 10^{-6})$
	$DV = DU_{\alpha}SU_{\alpha}V = 0$
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{PT} = \frac{(V \text{ Hg} O)}{PT} = \frac{(V \text{ Hg} O)}{PT} = 0.008 \text{ mol. Thus}$
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V \text{ HgB})}{RT} = \frac{(V \text{ HgB})}{8.3 \times 300} = 0.008 \text{ mol. Thus}$ answer of part (a) is 0.008
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V + rg O)^2}{RT} = \frac{(V + rg O)^2}{8.3 \times 300} = 0.008 \text{ mol. Thus}$ answer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V + NgO)^2}{RT} = \frac{(V - NgO)^2}{RT} = \frac{(V - NgO)^2}{RT} = 0.008 \text{ mol. Thus}$ answer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V \Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V \text{ HgG})}{RT} = \frac{(V \text{ HgG})}{RT} = \frac{(V \text{ HgG})}{8.3 \times 300} = 0.008 \text{ mol. Thus}$ ans wer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V \Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V \text{ HgG})}{RT} = \frac{(V \text{ HgG})}{RT} = \frac{(V \text{ HgG})}{RT} = \frac{(V \text{ HgG})}{RT} = 0.008 \text{ mol. Thus}$ ans wer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V \Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on right part $\Delta T_R = \frac{\Delta Q_R}{nC_V} = \frac{10}{0.008 \times 12.5} = 100 \text{ K}$ and hence temperature in vessel on the right side is
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V \text{ ng} O)^2}{RT} = 0.008 \text{ mol. Thus}$ answer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on right part $\Delta T_R = \frac{\Delta Q_R}{nC_V} = \frac{10}{0.008 \times 12.5} = 100 \text{ K}$ and hence temperature in vessel on the right side is $T_R = T + \Delta T_R = 300 + 100 = 400 \text{ K}$
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(V + RT)^2}{RT} = \frac{10}{RT} = \frac{10}{$
	As per IGE $pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{(T + IgS^{-})^{-}}{RT} = (T + I$
	As per IGE $pV = nRT \Rightarrow n = \frac{P}{RT} = \frac{(1 + ngO)^2}{RT} = \frac{(1 + ngO)^2}{RT} = \frac{(1 + ngO)^2}{RT} = \frac{(1 + ngO)^2}{RT} = 0.008 \text{ mol. Thus}$ ans wer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on right part $\Delta T_R = \frac{\Delta Q_R}{nC_V} = \frac{10}{0.008 \times 12.5} = 100 \text{ K}$ and hence temperature in vessel on the right side is $T_R = T + \Delta T_R = 300 + 100 = 400 \text{ K}$ Since it is a isochoric (constant volume) process therefore as per IGE $pV = nRT \Rightarrow p_1 = p_2 \frac{T_1}{T_2}$. Therefore pressure on left part in terms of height of mercury column would be $h_L = h \frac{T_L}{T} = 75 \times \frac{350}{300} = 87.5 \text{ cm of Hg and}$ on the right side is $h_R = h \frac{T_R}{T} = 75 \times \frac{400}{300} = 100 \text{ cm of Hg}$. Thus difference in height of mercury column is
	As per IGE $pV = nRT \Rightarrow n = \frac{pT}{RT} = \frac{(1 + qE^2)^2}{RT} = (1$
	As per IGE $pV = nRT \Rightarrow n = \frac{pT}{RT} = \frac{(V + R_B^{-1})^2}{RT} = \frac{(V + R_B^{-1})^2}{RT} = \frac{(V + R_B^{-1})^2}{RT} = \frac{(V + R_B^{-1})^2}{RT} = 0.008 \text{ mol. Thus}$ answer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V \Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on right part $\Delta T_R = \frac{\Delta Q_R}{nC_V} = \frac{10}{0.008 \times 12.5} = 100 \text{ K}$ and hence temperature in vessel on the right side is $T_R = T + \Delta T_R = 300 + 100 = 400 \text{ K}$ Since it is a isochoric (constant volume) process therefore as per IGE $pV = nRT \Rightarrow p_1 = p_2 \frac{T_1}{T_2}$. Therefore pressure on left part in terms of height of mercury column would be $h_L = h \frac{T_L}{T} = 75 \times \frac{350}{300} = 87.5 \text{ cm}$ of Hg and on the right side is $h_R = h \frac{T_R}{T} = 75 \times \frac{400}{300} = 100 \text{ cm}$ of Hg. Thus difference in height of mercury column is $\Delta h = h_L - h_R = 87.5 - 100 = 12.5 \text{ cm}.$ N.B.: in last step mod operator is used since difference in height of mercury in two sides of manometer is asked which is absolute value and not a relative value.
1-48	As per IGE $pV = nRT \Rightarrow n = \frac{P}{RT} = \frac{(1 + RT)^2}{RT} = \frac{(1 + RT)^2}{RT} = \frac{(1 + RT)^2}{8.3 \times 300} = 0.008 \text{ mol Thus}$ answer of part (a) is 0.008. Since volume of capillary is negligible as compared to volume of tanks and hence the process is considered to be constant volume process and hence on supply of heat $\Delta Q = nC_V\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{nC_V}$. Accordingly, on left part $\Delta T_L = \frac{\Delta Q_L}{nC_V} = \frac{5.0}{0.008 \times 12.5} = 50 \text{ K}$ hence temperature in left vessel $T_L = T + \Delta T_L = 300 + 50 = 350 \text{ K}$ and on right part $\Delta T_R = \frac{\Delta Q_R}{nC_V} = \frac{10}{0.008 \times 12.5} = 100 \text{ K}$ and hence temperature in vessel on the right side is $T_R = T + \Delta T_R = 300 + 100 = 400 \text{ K}$ Since it is a isochoric (constant volume) process therefore as per IGE $pV = nRT \Rightarrow p_1 = p_2 \frac{T_1}{T_2}$. Therefore pressure on left part in terms of height of mercury column would be $h_L = h \frac{T_L}{T} = 75 \times \frac{350}{300} = 87.5 \text{ cm}$ of Hg and on the right side is $h_R = h \frac{T_R}{T} = 75 \times \frac{400}{300} = 100 \text{ cm}$ of Hg. Thus difference in height of mercury column is $\Delta h = h_L - h_R = 87.5 - 100 = 12.5 \text{ cm}.$ N.B.: in last step mod operator is used since difference in height of mercury in two sides of manometer is asked which is absolute value and not a relative value.

temperature of two vessels are same $n_1 C_{V1} = n_2 C_{V2} \Longrightarrow n_2 = \frac{n_1 C_{V1}}{C_{V2}}$. Further, $C_p = C_V + R \Longrightarrow \frac{C_p}{C_V} - 1 = \frac{R}{C_V}$. It leads to $\gamma - 1 = \frac{R}{C_v} \Rightarrow C_v = \frac{R}{\gamma - 1}$. Since $R = 8.3 \text{ J.K}^{-1}$. mol⁻¹, therefore for He $C_{v-\text{He}} = \frac{8.3}{1.67 - 1} = \frac{8.3}{0.67} = 12.4$ and for hydrogen $C_{V-H} = \frac{8.3}{1.4-1} = \frac{8.3}{0.4} = 20.75 \text{ J.K}^{-1} \text{ mol}^{-1}$. Accordingly number of moles of H₂ $n_{\rm H_2} = \frac{n_{\rm He}C_{\rm He}}{C_{\rm H}} = n_{\rm He} \left(\frac{12.4}{20.75}\right) \quad \text{J.K}^{-1}.\text{ mol}^{-1}. \text{ Further mass of a gas } m = nM \implies n = \frac{m}{N}, \text{ therefore,}$ $\frac{m_{\rm H_2}}{M_{\rm H_2}} = \frac{m_{\rm He}}{M_{\rm He}} \left(\frac{12.4}{20.75}\right) \Longrightarrow m_{\rm H_2} = m_{\rm He} \left(\frac{M_{\rm H_2}}{M_{\rm He}}\right) \left(\frac{12.4}{20.75}\right) = 0.1 \left(\frac{2}{4}\right) \left(\frac{12.4}{20.75}\right) = 0.03 \,\text{g}.$ Thus answer is 0.03 g. When valve of the system, after attaining equilibrium, is closed as I-49 A B shown in the figure both the vessels will undergo different processes as under $p_{A}, 2V_{0}$ $p_{\scriptscriptstyle B}, 2V_{\scriptscriptstyle 0},$ Vessel A: Since the walls of vessel are diathermic and hence and p_a, V_a, T_a p_0, V_0, T_0 T_{μ} piston is pulled slowly it will undergo heat transfer with environment to make the process isothermal. Accordingly, $p_{A-i}V_{A-i} = p_{A-f}V_{A-f}$. Using the given data $p_0V_0 = p_{A-f} \times 2V_0$. -Thus $p_{A-f} = \frac{p_0}{2}$, and temperature of gas in vessel A would remain T_0 . Vessel B: Since the walls of vessel B are adiabatic and hence it will undergo adiabatic process accordingly $p_{B-i}V_{B-i}^{\gamma} = p_{B-f}V_{B-f}^{\gamma}$. Thus using the given data $p_{B-f} = \frac{p_0V_0^{\gamma}}{(2V_0)^{\gamma}} = \frac{p_0}{2^{\gamma}}$. In respect of temperature of vessel B, using IGE $pv = nRT \Rightarrow \frac{p_{B-i}V_{B-i}}{p_{B-f}V_{B-f}} = \frac{T_{i-B}}{T_{f-B}} \Rightarrow T_{f-B} = T_{i-B} \frac{p_{B-f}V_{B-f}}{p_{B-i}V_{B-i}}$. On using given and derived data it leads to $T_{f-B} = T_0 \frac{\frac{p_0}{2^{\gamma}} \times 2V_0}{p_0 V_0} = \frac{T_0}{2^{\gamma-1}} .$ **Thus answer to part (a) is** for vessel temperature and pressure of gas in vessel A are T_0 , $\frac{p_0}{2}$ and the values for vessel B are $T_0/2^{\gamma-1}$, $p_0/2^{\gamma}$. Now again value is opened with pistons held in the new position for sufficiently long time and allowing the gases to attain common temperature and pressure. In this condition gases in vessel will be able to communicate with gases in vessel A and also heat transfer with environment will take place. Thus the gases in both the vessels will attain an equilibrium with the environment at a **temperature** T_0 and uniform pressure p_f . Thus extending IGE to new situation $p_f(4V_0) = p_0(2V_0) \Longrightarrow p_f = \frac{p_0}{2}$. Thus answer to part (a) is for vessel temperature and pressure of gas in the two vessels is T_0 , $\frac{\mu_0}{2}$. Thus consolidating answer for both the parts it is (a) T_0 , $\frac{p_0}{2}$ in vessel A and $T_0/2^{\gamma-1}$, $p_0/2^{\gamma}$ in vessel B

(b)
$$T_0$$
, $\frac{p_0}{2}$
1-50 Gas in left part is injected at pressure and temperature p_1 and T_1 respectively and in right side at p_2 and T_2 . When separator is slid to an equilibrium position and released both parts will exert equal and opposite pressure p_1 . Thus, in the adiabatic process both parts will attain different volumes and corresponding new values of different temperature.
Thus as per adiabatic process for kft part p_1
 $p_1\left(\frac{V_0}{2}\right)^{\gamma} = p_{,k}(kV_0)^{\gamma} \Rightarrow p_{,k} = \frac{p_1}{(2k)^{\gamma}}$. Likewise, for right part $p_2\left(\frac{V_0}{2}\right)^{\gamma} = p_{,k}((1-k)V_0)^{\gamma} \Rightarrow p_{,R} = \frac{p_1}{(2k)^{\gamma}}$. Since piston stays in equilibrium it is possible only when $p_{,R} = p_{,R} \Rightarrow \frac{p_1}{(2k)^{\gamma}} = \frac{p_2}{(2(1-k))^{\gamma}} \Rightarrow \frac{1-k}{k} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}}$.
On applying componendo $\frac{1}{k} = \frac{p_1^{\frac{1}{\gamma}} + p_2^{\frac{1}{\gamma}}}{p_1^{\frac{1}{\gamma}}} \Rightarrow k = \frac{p_1^{\frac{1}{\gamma}}}{p_1^{\frac{1}{\gamma}} + p_2^{\frac{1}{\gamma}}}$. Thus volume of left part is $V_{N'} = (1-k)V_0 = \left(1-\frac{p_1^{\frac{1}{\gamma}}}{p_1^{\frac{1}{\gamma}} + p_2^{\frac{1}{\gamma}}}\right)V_0 = \left(\frac{p_2^{\frac{1}{\gamma}}}{p_1^{\frac{1}{\gamma}} + p_2^{\frac{1}{\gamma}}}\right)V_0$. This is answer of part (a).
Since process is adiabatic and hence heat is not given to either part, accordingly heat given to kft part is Zero.
This answers in part (a) can be expressed in reduced form by taking $A = p_1^{\frac{1}{\gamma}} + p_2^{\frac{1}{\gamma}}$. Accordingly, answer to part (a) is $V_{1/2} = \frac{p_1^{\frac{1}{\gamma}}V_0}{A}$. On similar lines answer to part (c) in reduced form is $\left(\frac{A}{2}\right)^{\gamma}$.

Given that in the adiabatic system piston is suddenly moved from $L_i = 0.4 \text{ m}$ to $L_f = 0.8 \text{ m}$ causing an adiabatic expansion from volume $V_i = AL_i$ to $V_f = AL_f$. Accordingly, $p_i V_i^{\gamma} = p_f V_f^{\gamma} \Rightarrow \left(\frac{A \times L_f}{A \times L_i}\right)^{\gamma} = \frac{p_i}{p_f} \Rightarrow \left(\frac{L_f}{L_i}\right)^{\gamma} = \frac{p_i}{p_f}$. I-51 Thus using the given data $\left(\frac{0.8}{0.4}\right)^{\gamma} = \frac{1}{0.355} \Longrightarrow 2^{\gamma} = 2.81 \Longrightarrow \gamma = \log_2 2.81 = 1.49$. Progression of sound in gases is an adiabatic process and accordingly velocity of sound $v = \sqrt{\frac{\gamma \times p}{\rho}}$. Here, ρ is density of air at pressure p, and $\rho = \frac{m}{V} = \frac{m}{AL} = \frac{0.03 \times 10^{-3}}{10^{-4} \times 0.4} = 0.75 \text{ kg.m}^{-3}$. Thus using given and derived data $v = \sqrt{\frac{1.49 \times 10^5}{0.75}} = 445.7 \text{ m.s}^{-1}$. Thus as per SDs velocity of sound is 446 m.s⁻¹ is the answer. N.B.: It is important to have a proficiency in handling such logarithmic calculations. I-52 Velocity of sound in gases is $v = \sqrt{\frac{\gamma \times p}{\rho}}$, here it is seen that except γ data is available in respect of other variables. Accordingly, $\frac{C_p}{C} = \gamma = \frac{v^2 \rho}{n} = \frac{(1280)^2 \times 0.089}{10^5} = 1.48$. Further, it is known that $C_p = C_v + R$. It leads to $\frac{C_p}{C_v} = 1 + \frac{R}{C_v} \Rightarrow \gamma - 1 = \frac{R}{C_v} \Rightarrow C_v = \frac{R}{\gamma - 1}$ and likewise $1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p} \Rightarrow \frac{\gamma - 1}{\gamma} = \frac{R}{C_p} \Rightarrow C_p = \frac{\gamma R}{\gamma - 1}$, here $R = 8.3 \text{ J.K}^{-1} \text{ .mol}^{-1}$. Accordingly, using available data $C_V = \frac{8.3}{1.48 - 1} = 17.3 \text{ J.K}^{-1} \text{ .mol}^{-1}$ and $C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_V = 1.48 \times 17.3 = 25.6 \text{ J.K}^{-1} \text{.mol}^{-1}$ Thus answers are 18.0 J.K⁻¹.mol⁻¹, 26.3 J.K⁻¹.mol⁻¹, I-53 Velocity of sound in gases is $v = \sqrt{\frac{\gamma \times p}{\rho}}$, here density at $p = 10^5 \text{ N.m}^{-2}$ is $\rho = \frac{4.0 \times 10^{-3}}{2.24 \times 10^{-2}} = 1.76 \times 10^{-1} \text{ kg.m}^{-3}$. The only unknown $\gamma = \frac{C_p}{C_v}$ is from $C_p = C_v + R \Longrightarrow 1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Longrightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p} \Longrightarrow \frac{1}{\gamma} = 1 - \frac{R}{C_p} \Longrightarrow \gamma = \frac{C_p}{C_p - R}$. Since given that $C_p = 5$ cal.K⁻¹.mol⁻¹, which in thermodynamic units is $C_p = 5.0 \times 4.2 = 21$ J.K⁻¹.mol⁻¹.Thus, $\gamma = \frac{21}{21 - 8.3} = 1.65$. Thus $v = \sqrt{\frac{1.65 \times 10^5}{1.76 \times 10^{-1}}} = \sqrt{\frac{1.65}{1.76}} \times 10^3 = 968 \,\mathrm{m.s^{-1}}$. Thus as per SDs 960 m.s⁻¹. I-54 Separation between two nodes is given to be $\frac{\lambda}{2} = 0.06 \Rightarrow \lambda = 0.12$ m. Therefore, from given frequency $v = f \times \lambda = (3.0 \times 10^3) \times 0.12 = 3.6 \times 10^2 \text{ m.s}^{-1}$. Therefore, $\frac{C_p}{C_v} = \gamma$ from formula of velocity of sound in gases is $v = \sqrt{\frac{\gamma \times p}{\rho}} \Rightarrow v^2 = \frac{\gamma \times p}{\rho} \Rightarrow \gamma = \frac{v^2 \times \rho}{p}$. Given that $\rho = 1.7 \times 10^{-3} \,\text{g.cm}^{-3}$ which in SI is

$$\rho = \frac{1.7 \times 10^{-3} \times 10^{-3}}{10^{-6}} = 1.7 \text{ kg.m}^{-3}. \text{ Accordingly, } \gamma = \frac{(360)^2 \times 1.7}{1.5 \times 10^5} = 1.47. \text{ Further, } C_p = C_v + R \Rightarrow \frac{C_p}{C_v} = 1 + \frac{R}{C_v}.$$
Accordingly, $\gamma - 1 = \frac{R}{C_v} \Rightarrow C_v = \frac{R}{\gamma - 1} = \frac{8.3}{1.47 - 1} = 17.7 \text{ J.K}^{-1.mol}^{-1}. \text{ Likewise, } 1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p}.$
It leads to $C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_v = 1.47 \times 17.7 = 26.0$. Thus answers are 26.0 J.K<sup>-1.mol}^{-1}, 17.7 J.K<sup>-1.mol}^{-1}.

It leads to $C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_v = 1.47 \times 17.7 = 26.0$. Thus answers are 26.0 J.K<sup>-1.mol}^{-1}, 17.7 J.K<sup>-1.mol}^{-1}.

It leads to $C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_v = 1.47 \times 17.7 = 26.0$. Thus answers are $26.0 \text{ J.K}^{-1.mol}^{-1}, 17.7 \text{ J.K}^{-1.mol}^{-1}.$

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It leads to $C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_v = 1.47 \times 17.7 = 26.0$. Thus answers are $26.0 \text{ J.K}^{-1.mol}^{-1}, 17.7 \text{ J.K}^{-1.mol}^{-1}.$

It leads $V = 0.5 \times \frac{1}{2} = (5.0 \times 10^3) \times 2 \times (3.3 \times 10^{-2}) = 330 \text{ m.s}^{-1}.$ Further, $v = \sqrt{\frac{\gamma \times p}{\rho}} \Rightarrow v^2 = \frac{\gamma \times p}{\rho} \Rightarrow \gamma = \frac{v^2 \times \rho}{\rho}.$

From IGE $pV = nRT \Rightarrow pV = \frac{m}{M}RT \Rightarrow p = \frac{m}{V} \times \frac{RT}{M} = \rho \frac{RT}{M}.$ Further, $v = \sqrt{\frac{\gamma \times p}{\rho}} \Rightarrow v^2 = \frac{\gamma \times p}{\rho} \Rightarrow \gamma = \frac{v^2 \times \rho}{p}.$

Using the data and derived expression $\gamma = \frac{v^2 \times \rho}{\rho \left(\frac{RT}{M}\right)} = \frac{v^2 \times M}{RT}.$ Using the data $\gamma = \frac{(330)^2 \times 0.032}{8.3 \times 300} = 1.4.$ Further, $\frac{C_p}{C_p} = \gamma \text{ and } C_p = C_v + R.$ Accordingly, $\frac{C_p}{C_v} = 1 + \frac{R}{C_v} \Rightarrow \gamma - 1 = \frac{R}{C_v} \Rightarrow C_v = \frac{R}{\gamma - 1} = \frac{8.3}{1.4 - 1} = \frac{8.3}{0.4} = 20.7.$ J.K^{-1.mol⁻¹}, and $1 = \frac{C_v}{C_p} + \frac{R}{C_p} \Rightarrow 1 = \frac{1}{\gamma} + \frac{R}{C_p} \Rightarrow C_p = \frac{\gamma R}{\gamma - 1} = \gamma C_v = 1.4 \times 20.7 = 29.0.$ Thus answers are 29.0 J.K^{-1.mol⁻¹}, 20.7 J.K^{-1.mol⁻¹}.</sup></sup></sup></sup>

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