CBSE Test Paper 05

Chapter 12 Thermodynamics

1. Two cylinders A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. What is the change in internal energy of the gas? **1**
   a. 10 J
   b. 50 J
   c. 100 J
   d. 0.0 J
2. An ideal gas is taken through a Carnot cycle. The isothermal expansion occurs at 250 $^\circ$C, and the isothermal compression takes place at 50.0°C. Assuming that the gas absorbs 1 200 J of energy from the hot reservoir during the isothermal expansion, find the energy expelled to the cold reservoir in each cycle **1**
   a. 752 J
   b. 711 J
   c. 721 J
   d. 741 J
3. A steam engine has a boiler that operates at 500 K. The energy from the burning fuel changes water to steam, and this steam then drives a piston. The cold reservoir's temperature is that of the outside air, approximately 300 K. What is the maximum thermal efficiency of this steam engine? **1**
   a. 40 percent
   b. 30 percent
   c. 25 percent
   d. 45 percent
4. A water heater is operated by solar power. If the solar collector has an area of 6.00 m^2 and the power delivered by sunlight is 550 W/ m^2, how long does it take to increase the temperature of 1.00 m^3 of water from 20.0°C to 60.0°C? **1**
   a. 51.7 ks
   b. 50.7 ks

   c. 48.7 ks
   d. 52.7 ks
5. If C_p and C_v are molar specific heat capacities of an ideal gas at constant pressure and volume respectively and R is the universal gas constant, relation between the three is **1**
   a. $C_p - C_v = 2R$
   b. $C_p + C_v = R$
   c. $C_p + C_v = 2R$
   d. $C_p - C_v = R$

6. Find the values of two molar specific heats of nitrogen. Given, $\gamma = 1.41$ and R =8.31 J $mol^{-1}K^{-1}$. **1**

7. The internal energy of compressed gas is less than that of the rarefied gas at the same temperature. Why? **1**

8. Explain What is meant by isothermal and adiabatic operations. **1**

9. Calculate the work done for adiabatic expansion of a gas. **2**

10. Why does the density of solid | liquid decreases with rise in temperature? **2**

11. How does Carnot cycle operates? **2**

12. Two bodies at different temperatures T_1 and T_2 are brought in contact. Under what condition, they settle to mean temperature? (after they attain equilibrium) **3**

13. 1 g of water at 100°C is converted into steam of the same temperature. If the volume of steam is 1551 cm^3, find out the change in internal energy of the water. Latent heat of steam = 2256×10^3 J/kg. Consider atm pressure. **3**

14. State and explain First Law of Thermodynamics. **3**

15. Calculate the work done during the isothermal Process. **5**

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Answer

1. d. 0.0

   Explanation: Internal energy depends on temperature and temperature remains constant because system is thermally insulated. so that change in internal energy will be zero.

2. d. 741 J

   Explanation: $\eta = \frac{T_H - T_L}{T_H} = \frac{50}{523}$
   $\eta = \frac{W}{Q_H}$
   $\frac{50}{523} = \frac{W}{1200}$
   W = 459 J

   $W = Q_H - Q_L$

   $Q_L = Q_H - W = 1200 - 459 = 741$ J

3. a. 40 percent

   Explanation: $\eta = \frac{T_H - T_L}{T_H} = \frac{200}{500} = 0.4 = 40\%$

4. b. 50.7 ks

   Explanation: $Q = ms\Delta T$
   $P = \frac{W}{t} = \frac{ms\Delta T}{t}$
   $t = \frac{ms\Delta T}{P} = \frac{1000 \times 4186 \times 40}{550 \times 6}$ = 50700 sec = 50.7 K sec

5. d. $C_p - C_v = R$

   Explanation: This is Meyer's Equation
   At constant volume as there is no work done on the gas(ΔV=0) all the heat supplied goes for the increase of internal energy. Hence temperature of body increases with less supply of heat. Whereas at constant pressure heat supplied accounts for both internal energy and work done on the gas.
   if we increase temp. of 1 mole of gas by 1K or 1C then
   $P\Delta V = nR\Delta T$

n = 1 mole

$\Delta T = 1^\circ C$

$P\Delta V = R$

$W = P\Delta V$

$C_P > C_V$

$C_P - C_V = W$

$C_P - C_V = R$

This is also called Meyer's formula.

6. Given, γ = 1.41 and $R = 8.31 Jmol^{-1}K^{-1}$.

   We know, $C_V = \frac{R}{(\gamma - 1)} = \frac{8.31}{(1.41-1)}$ = 20.3 J $mol^{-1}K^{-1}$

   $\because \quad \frac{C_p}{C_V} = \gamma \Rightarrow C_p = C_V \cdot \gamma$

   $= 20.3 \times 1.41$

   = 28.623 $Jmol^{-1}K^{-1}$.

7. The internal energy of a compressed gas is less than that of rarefied gas at the same temperature because in compressed gas, the mutual attraction between the molecules increases as the molecules comes close. Therefore, potential energy is added to internal energy and since potential energy is negative, total internal energy decreases.

8. Adiabatic Process - Pressure, volume and temperature of the system changes but there is no exchange of heat.

   Isothermal Process - Pressure, volume changes temperature remains Constant.

9. Consider an ideal gas (say μ mole), which is undergoing an adiabatic expansion. Let the gas expands by an infinitesimally small volume dV, at a constant pressure p, then the infinitesimally small work done given by dW = pdV

   The net work done from an initial volume V_1 to final volume V_2 of the gas is given by,

   $W = \int_{V_1}^{V_2} pdV$

   Now we know that for an adiabatic process,

   $p = \frac{K}{V^\gamma} = KV^{-\gamma}$

   $\therefore W = \int_{V_1}^{V_2} \left(KV^{-\gamma}\right) dV = K\left[\frac{V^{-\gamma+1}}{-\gamma+1}\right]_{V_1}^{V_2}$

$$= \frac{KV_2^{-\gamma+1} - KV_1^{-\gamma+1}}{(1-\gamma)}$$ .....(i)

Now using the basic formula for an adiabatic process,

$K = p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$, K being a constant, we get from equation (i)

$$W = \frac{p_2 V_2^{\gamma} \cdot V_2^{-\gamma+1} - p_1 V_1^{\gamma} \cdot V_2^{-\gamma+1}}{(1-\gamma)}$$

$$= \frac{1}{(1-\gamma)}(p_2 V_2 - p_1 V_1)$$

Now for an ideal gas, $p_1 V_1 = \mu R T_1$ and $p_2 V_2 = \mu R T_2$. So, we have

$$W = \frac{1}{(1-\gamma)}[\mu R T_2 - \mu R T_1]$$

$$= \frac{\mu R}{(\gamma-1)}[T_1 - T_2]$$

10. Let P = Density of solid | liquid at temperature T

    P^1 = Density of solid | liquid at Temperature $\mathrm{T} + \Delta\mathrm{T}$

    Since Density $= \frac{Mass}{Volume}$

    So, $P = \frac{M}{V}$ ...(i)

    $P^1 = \frac{M}{v^1}$ ...(ii)

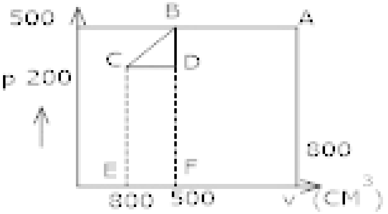
    V^1 = Volume of solid at temperature $\mathrm{T} + \Delta\mathrm{T}$

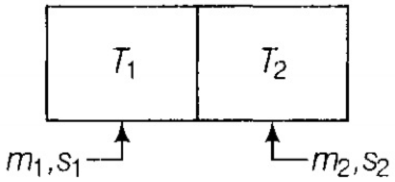
    V = Volume of solid at temperature T

    Since on increasing the temperature, solids | liquids expand that is their volumes increases, so by equation (i) & (ii) Density is inversely proportional to volumes, so if volume increases on increasing the temperature, Density will decrease.

11. A Carnot cycle operates as follows:-
    i. It receives thermal energy isothermally from some hot reservoir maintained at a constant high temperature T_H.
    ii. It rejects thermal energy isothermally to a constant low–temperature reservoir (T_2).
    iii. The change in temperature is reversible adiabatic process.

    Such a cycle, which consist of two isothermal processes bounded by two adiabatic processes, is called Carnot cycle.



12. 

Let m_1 *and* m_2 are masses of bodies with specific heats s_1 *and* s_2, then if their temperature after they are in thermal equilibrium is T.
Then, if $T_1 > T > T_2$ and assuming no heat loss.

Heat lost by hot body = heat gained by cold body
$m_1 s_1 (T_1 - T) = m_2 s_2 (T - T_2)$
$\Rightarrow \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2} = T$[equilibrium temperature]
So for, bodies to settle down to mean temperature,
$m_1 = m_2$ and $s_1 = s_2$ means bodies have same specific heat and have equal masses.
Then,
$T = \frac{T_1 + T_2}{2}$[mean temperature]

13. Given, mass of water, $m = 1g = 1 \times 10^{-3} kg$
Hence, pressure is $p = 1.013 \times 10^5 N/m^2$
Volume of water, $V_s = 1551 cm^3 = 1551 \times 10^{-6} m^3$
Volume of water, $V_W = \frac{\text{mass}}{\text{density}} = \frac{1 \times 10^{-5}}{10^3} = 2 \times 10^{-6} \text{m}^3$

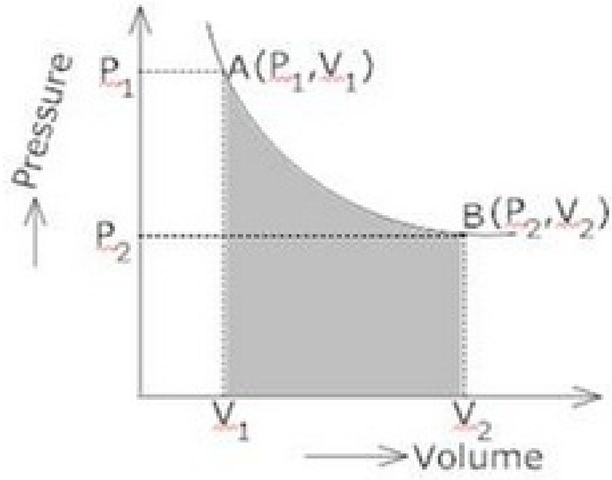
Latent heat of steam L = 2256×10^3
First law of thermodynamics gives
$\Delta Q = \Delta U + p \Delta V$
$\Rightarrow mL = \Delta U + p(V_s - V_w)$
Change in internal energy is
$\Delta U = mL - p(V_s - V_w)$
$= 1 \times 10^{-3} \times 2256 \times 10^3 - 1.013 \times 10^5 \times \left(1551 \times 10^{-6} - 10^{-6}\right)$
$= 2256 - 0.1013 \times 1550 \cong 2099\text{J}$

14. According to First Law of Thermodynamics, if an amount of heat ΔQ is supplied to a thermodynamic system, a part of it may increase the internal energy of the system by ΔU and the remaining part is used up as the external work done ΔW by the system. Thus, we have $\Delta Q = \Delta U + \Delta W$
First Law of Thermodynamics follows the conservation law of energy and establishes

an exact relation between heat transferred and mechanical work done. It provides a valuable concept of internal energy. It is applicable to every process in nature and to all the three states of matter i.e., solid, liquid and gases. Moreover, change in internal energy of a system may be due to any cause like change in translational or rotational or vibrational kinetic energy or molecular potential energy etc.

15. Let an ideal gas is allowed to expand isothermally. Let the gas expands from initial state A (P_1, V_1) to final state B (P_2, V_2)

The work done by the gas in expanding from state A to state B is



$W = +\int_{V_1}^{V_2} PdV$ ...(1)

from gas equation, PV = nRT

or $P = \frac{nRT}{V}$ ...(2)

from (1) and (2)

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

For isothermal expansion T is constant.

$$W = nRT\int_{V_1}^{V_2} \frac{dV}{V} \left(\because \int \frac{dV}{V} = Log_e V\right)$$

W = nRT [loge V] $\Big|_{V_1}^{V_2}$

W = nRT [$\log_e V_2$ - $\log_e V_1$] $\left(\because Logm - Logn = Log\frac{m}{n}\right)$

W = nRT $\log_e \frac{V_2}{V_1}$

W = 2.303 nRT $\log_{10} \frac{V_2}{V_1}$ (log e = 2.303 Log 10)

If M = Molecular Mass of gas

for 1 gram of ideal gas,

W = 2.303 $\frac{RT}{M} Log10 \frac{V_2}{V_1}$

$\frac{R}{M}$ = r = gas constant for 1 gram mass of an ideal gas,

W = 2.303 r T $\log_{10} \frac{V_2}{V_1}$

by Boyal's law, $P_1 V_1 = P_2 V_2 \Rightarrow \frac{V_2}{V_1} = \frac{P_1}{P_2}$

So W = 2.303 r T $\log_{10} \frac{P_1}{P_2}$