NCERT TEXTUAL EXERCISE (SOLVED)

1. A geyser heats water flowing at the rate of 3.0 litre/min from 27°C to 77°C. If the geyser operates on a gas burner, what is the rate of combustion of fuel, if its heat of combustion is 4×10^4 J/g?

Sol. Given, volume of water heated = 3 litre/min. Mass of water heated, m = 3000 g/min

Rise in temperature, $\Delta T = 77 - 27 = 50°C$, Specific heat of water, $c = 4.2$ $Jg^{-1}°C^{-1}$

Amount of heat used, $\Delta Q = mc\,\Delta T = 3000 \times 4.2 \times 50 = 63 \times 10^4$ J/min

Heat of combustion = 4×10^4 J/g; Rate of combustion of fuel =

$$\frac{63\times10^4}{4\times10^4} = 15.75 \text{ g/min}$$

2. What amount of heat must be supplied to 2×10^{-2} kg of nitrogen at room temperature to raise its temperature by 45°C at constant pressure? Given molecular mass of nitrogen is 28 and $R = 8.3$ J $mol^{-1}K^{-1}$.

Sol. Given, m = mass of gas = 2×10^{-2} kg = 20 g; Rise in temperature $\Delta T = 45°C$

Molecular mass, $M = 28$

Heat required,

$$\Delta Q = nC_p\Delta T = \left(\frac{m}{M}\right)C_p\Delta T = \left(\frac{20}{28}\right)\left(\frac{7}{2}R\right)(45) = \frac{20}{28}\left(\frac{7}{2}\times 8.3\right)45 = 933.75\ J$$

3. Explain, why

(a) Two bodies at different temperatures T_1 and T_2, if brought in thermal contact do not necessarily settle to the mean temperature, $\frac{T_1 + T_2}{2}$.

(b) The coolant in a chemical or nuclear plant (i.e., the liquid used to prevent different parts of a plant from getting too hot) should have high specific heat.

(c) Air pressure in a car tyre increases during driving.

(d) The climate of a harbour town has more temperature (i.e., without extremes of heat and cold) than that of a town in a desert at the same latitude.

Sol. (a) In thermal contact, heat from the body at higher temperature transfers to the body at lower temperature, till temperature of both becomes equal. Final temperature can be the mean temperature, $\left(\frac{T_1 + T_2}{2}\right)$, only when thermal capacities of two bodies are equal.

(b) Because heat absorbed $\propto$ specific heat of substance.

(c) Temperature of air inside the tyre increases due to motion during driving. Air pressure, therefore, increase inside the tyre (by Charle's law, $P \propto T$).

(d) In a harbour town, the relative humidity is more than in a desert town. Due to high specific heat of water, the variations in the temperature of humid air are less. Hence, the climate of a harbour town is more without extreme of hot and cold.

4. A cylinder with a movable piston contains 3 moles of H_2 at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase, if the gas is compressed to half of its original volume? (Given $\gamma = 1.4$)

Sol. The process is adiabatic, as no heat is exchanged

$$\therefore P_2V_2^{\gamma} = P_1V_1^{\gamma} \qquad \therefore \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma}$$

Given $V_2 = \dfrac{V_1}{2}$

$$\therefore \frac{P_2}{P_1} = \left(\frac{V_1}{V_1/2}\right)^{1.4} = 2.64$$

5. In changing state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state A to B via a process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case (take 1 cal = 4.2 J)?

Sol. For change in adiabatic, $\Delta Q = 0$, $\Delta W = -22.3$ J

Now $\Delta U = \Delta Q - \Delta W = 0 - (-22.3) = 22.3$ J

Second time, $\Delta Q = 9.35$ cal $= 9.35 \times 4.2 = 39.3$ J

$\Delta W = \Delta Q - \Delta U = 39.3 - 22.3 = 17$ J

6. An electric heater supplies heat to a system at a rate of 100 *W*. If system performs work at a rate of 75 joules per second, at what rate is the internal energy increasing?

Sol. Given, $\dfrac{\Delta Q}{\Delta t} = 100\ W = 100$ J/s

Useful work done, $\dfrac{\Delta W}{\Delta t} = 75\ \text{Js}^{-1}$

Now, $\dfrac{\Delta U}{\Delta t} = \dfrac{\Delta Q - \Delta W}{\Delta t} = 100 - 75 = 25$ J/s.

7. Two cylinders A and B of equal capacity are connected to each other via stopcock. The cylinder A contains an ideal gas at standard temperature and pressure, while the cylinder B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Answer the following:

(a) What is the final pressure of the gas A and B?

(b) What is the change in internal energy of the gas?

(c) What is the change in temperature of the gas?

(d) Do the intermediate state of the system (before setting to the final equilibrium state) lie on its *P-V-T* surface?

Sol. (a) If the stopcock opens suddenly, volume of gas would become double at 1 atmospheric pressure, therefore, pressure would become half (i.e., 1/2 atmosphere).

(b) As no work is done on the system by the gas, there will be no change in internal energy.

(c) Gas does not do any work on expanding, thereby, no change in temperature of gas would occur.

(d) No, the process of the expansion is rapid and cannot be controlled. The intermediate state would be a non-equilibrium state, which do not follow gas equation. In due course, gas will come back to the equilibrium state.

8. A refrigerator is to remove heat from the eatable kept inside it at 10°C. Calculate the coefficient of performence, if room temperature is 36°C.

Sol. Given T_1 = 36°C = 36 + 273 = 309 K; T_2 = 10°C = 10 + 273 = 283 K

$$\text{Coefficient of performance} = \frac{T_2}{T_1 - T_2} = \frac{283}{309 - 283} = 10.9$$

9. A steam engine delivers 5.4×10^8 J of work per minute and absorbs 3.6×10^9 J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Sol. Useful work done per min (Output) = 5.4×10^8 J; Heat absorbed per min (Input) = 3.6×10^9 J

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{5.4 \times 10^8}{3.6 \times 10^9} = 0.15 = 15\%$$

Heat energy wasted/min. = Heat absorbed/min – useful work done/minute

$= 3.6 \times 10^9 - 5.4 \times 10^8 = 3.06 \times 10^9$ J