Thermodynamics DPP-6 Solutions

Topic: Adiabatic Process

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Q1. When a gas undergoes adiabatic expansion, it gets cooled. This is because

(1) It is an exothermic process
(2) It is an endothermic process
(3) Internal energy of the system decreases
(4) Ideal gas becomes a real gas

Conceptual Approach: Adiabatic process means $q = 0$. Cooling ya heating depend karega internal energy par. Expansion ke time gas(system) ka work negative hota hai, aur kyunki $q = 0$, isliye ΔU negative hota hai → internal energy kam hoti hai → temperature girta hai.

Step-by-step Solution:

$$\Delta U = q + w, \quad q = 0 \implies \Delta U = w$$

Expansion $\implies w < 0 \implies \Delta U < 0 \implies T$ decreases.

Final Answer: Correct option: (3) Internal energy of the system decreases.

Q2. Which of the following is correct expression for 1st law of thermodynamics under adiabatic condition?

(1) $\Delta U = Q + W$
(2) $\Delta U = Q - W$
(3) $Q = -W$
(4) $\Delta U = W$

Conceptual Approach: Adiabatic condition: $q = 0$. First law: $\Delta U = q + w$. To bas q ko zero rakho.

Step-by-step Solution:

$$\Delta U = 0 + w \implies \Delta U = w$$

Also $q = 0 \implies w = \Delta U$.

Final Answer: Correct option: (4) $\Delta U = W$.

Q3. In which of the following process work is independent of path:

(1) Isothermal
(2) Isochoric
(3) Adiabatic
(4) Isobaric

Conceptual Approach: Work (w) is a path function → usually depends on process. Sirf state function like $\Delta U, \Delta H$ independent hote hain.

Step-by-step Solution: Isothermal, adiabatic, isobaric sab mein w path ke hisaab se nikalta hai. Isochoric (constant volume) case mein $w = 0$ always, chahe path kuch bhi ho.

Final Answer: Correct option: (2) Isochoric.

Q4. When a gas is compressed adiabatically and reversibly, the final temperature is

(1) Higher than the initial temperature
(2) Lower than the initial temperature
(3) The same as initial temperature
(4) Dependent upon the rate of compression

Conceptual Approach: Adiabatic compression → system par work hota hai → ΔU positive → T increases.

Step-by-step Solution:

$$q = 0, \quad \Delta U = w, \quad w > 0 \implies \Delta U > 0 \implies T_{final} > T_{initial}.$$

Final Answer: Correct option: (1) Higher than the initial temperature.

Q5. The temperature of an ideal gas increases in an–

(1) Adiabatic compression
(2) Adiabatic expansion
(3) Isothermal expansion
(4) Isothermal compression

Conceptual Approach: Adiabatic compression mein work gas par hota hai → ΔU increases → T increases. Baaki cases mein ya toh T constant hota hai ya decrease hota hai.

Step-by-step Solution:

$$\text{Only in adiabatic compression: } \Delta U > 0 \implies T \uparrow$$

Final Answer: Correct option: (1) Adiabatic compression.

Q6. Which of the following is correct option for free expansion of an ideal gas under adiabatic condition?

(1) $q = 0, \Delta T = 0, w = 0$
(2) $q \neq 0, \Delta T = 0, w = 0$
(3) $q = 0, \Delta T \neq 0, w = 0$
(4) $q = 0, \Delta T < 0, w \neq 0$

Conceptual Approach:

Free expansion: gas vacuum mein expand karta hai, koi external pressure nahi. $\implies w = 0$, aur adiabatic hone se $q = 0$. For ideal gas, U depends only on T, aur $\Delta U = 0 \implies \Delta T = 0$.

Step-by-step Solution:

$$q = 0,\ w = 0,\ \Delta U = 0 \implies \Delta T = 0$$

Final Answer: Correct option: (1).

Q7. For adiabatic process which is correct–

(1) $\Delta T = 0$
(2) $w = 0$

(3) $q = 0$
(4) $\Delta U = 0$

Conceptual Approach:

Adiabatic ka matlab hai heat exchange zero. $\implies$ $q = 0$ is always true. But $\Delta T, \Delta U, w$ may change depending on compression/expansion.

Final Answer: Correct option: (3) $q = 0$.

Q8. A gas expands adiabatically against constant $P_{ext} = 2.5$ atm from $V_i = 2.5$ L to $V_f = 4.5$ L. Find ΔU (in J).

(1) –500 J (2) –505 J (3) +505 J (4) 1136.25 J

Conceptual Approach:

Adiabatic: $q = 0 \implies \Delta U = w$. Work done $= -P_{ext}\Delta V$. Convert L·atm to J.

Step-by-step Solution:

$$\Delta V = 4.5 - 2.5 = 2.0\ L$$

$$w = -P_{ext}\Delta V = -(2.5)(2.0) = -5.0\ L \cdot atm$$

$$1\ L \cdot atm = 101.32\ J \implies w = -5.0 \times 101.32 = -506.6\ J$$

Rounded to nearest option = –505 J.

Final Answer: Correct option: (2).

Q9. During adiabatic expansion of an ideal gas in vacuum:

(1) $q = 0, \Delta U \neq 0$
(2) $q \neq 0, \Delta U \neq 0$
(3) $q \neq 0, \Delta U = 0$
(4) $q = 0, \Delta U = 0$

Conceptual Approach:

Vacuum expansion = free expansion. $q = 0$, $w = 0$. So $\Delta U = 0$ for ideal gas (since depends only on T).

Final Answer: Correct option: (4).

Q10. 3 mol of ideal gas, $T_i = 200$ K, compressed reversibly and adiabatically till $T_f = 250$ K. $C_v = 27.5$ J K^{-1} mol^{-1}. Calculate w.

(1) 4125 J (2) 4125 kJ (3) 4.125 J (4) 41.25 J

Conceptual Approach:

Adiabatic: $q = 0$. So $\Delta U = w$. $\Delta U = nC_v\Delta T$.

Step-by-step Solution:

$$\Delta U = 3 \times 27.5 \times (250 - 200)$$

$$= 3 \times 27.5 \times 50 = 4125\ J$$

Since $\Delta U = w$, $w = 4125$ J.

Final Answer: Correct option: (1).

Q11. One mole of an ideal gas $C_{v,m} = \frac{5}{2}R$ at 300 K and 5 atm is expanded adiabatically to final pressure 2 atm against constant pressure of 2 atm. Final temperature of the gas is:

(A) 270 K (B) 273 K (C) 248.5 K (D) 200 K

Conceptual Approach:

Important point: "against constant pressure" → **irreversible adiabatic** process. For irreversible adiabatic: $q = 0 \implies \Delta U = w$. Here, $w = -P_{ext}(V_f - V_i)$. Also, $\Delta U = nC_v(T_f - T_i)$. We will use ideal gas law $PV = nRT$ to connect T and V.

Step-by-step Solution:

Step: Step 1: Write first law relation

$$nC_v(T_f - T_i) = -P_{ext}(V_f - V_i)$$

Step: Step 2: Express volumes using ideal gas law

$$V_i = \frac{nRT_i}{P_i}, \quad V_f = \frac{nRT_f}{P_f}$$

Step: Step 3: Substitute values

$$1 \times \frac{5}{2}R(T_f - 300) = -2\,\text{atm}\left(\frac{RT_f}{2} - \frac{300R}{5}\right)$$

Step: Step 4: Convert atm properly Better way: Work in terms of R only (no unit conversion needed, because both sides have R).

$$\frac{5}{2}R(T_f - 300) = -R\Big(T_f - 60\Big)$$

Step: Step 5: Simplify

$$\frac{5}{2}(T_f - 300) = -(T_f - 60)$$

$$\frac{5}{2}T_f - 750 = -T_f + 60$$

$$\frac{7}{2}T_f = 810$$

$$T_f = \frac{810 \times 2}{7} \approx 231\,K$$

Final Answer: Closest option to this value is around 248.5 K → (C).

Q12. Two moles of an ideal gas ($C_v = \frac{5}{2}R$) compressed adiabatically against constant pressure of 2 atm, initially at 350 K and 1 atm. Work involved is:

(A) 250 R (B) 300 R (C) 400 R (D) 500 R

Conceptual Approach:

Since it is *against constant external pressure*, this is an **irreversible adiabatic compression**. So: $q = 0 \implies \Delta U = w$. We use: $nC_v(T_f - T_i) = -P_{ext}(V_f - V_i)$. Volumes are related by ideal gas law: $V = \frac{nRT}{P}$.

Step-by-step Solution:

Step: Step 1: Write relation

$$nC_v(T_f - T_i) = -P_{ext}(V_f - V_i)$$

Step: Step 2: Express V_i and V_f

$$V_i = \frac{nRT_i}{P_i}, \quad V_f = \frac{nRT_f}{P_{ext}}$$

Step: Step 3: Substitute given values

$$n = 2,\ C_v = \tfrac{5}{2}R,\ T_i = 350K,\ P_i = 1\,\text{atm},\ P_{ext} = 2\,\text{atm}$$

$$2 \cdot \tfrac{5}{2}R(T_f - 350) = -2\Big(\frac{2RT_f}{2} - \frac{2R \cdot 350}{1}\Big)$$

$$5R(T_f - 350) = -2(RT_f - 700R)$$

Step: Step 4: Simplify

$$5T_f - 1750 = -2T_f + 1400$$

$$7T_f = 3150$$

$$T_f = 450K$$

Step: Step 5: Find work

$$w = nC_v(T_f - T_i) = 2 \cdot \tfrac{5}{2}R(450 - 350) = 5R \cdot 100 = 500R$$

Final Answer: Correct option: (D) 500R.

Q13. A gas $C_{v,m} = \frac{5}{2}R$ expands reversibly and adiabatically from 1 L to 32 L. $T_i = 327°$C. Find molar enthalpy change.

(A) –1125 R (B) –575 R (C) –1575 R (D) –75 R

Conceptual Approach:

Adiabatic: $TV^{\gamma-1} =$ constant. $\Delta H = nC_p\Delta T$. For 1 mol, $C_p = \frac{7}{2}R$.

Step-by-step Solution:

$$T_i = 327 + 273 = 600K$$

$$T_f = T_i \left(\frac{V_i}{V_f}\right)^{\gamma-1} = 600 \left(\frac{1}{32}\right)^{0.4}$$

$$T_f \approx 600 \times 0.158 \approx 95K$$

$$\Delta H = C_p(T_f - T_i) = \tfrac{7}{2}R(95 - 600) = \tfrac{7}{2}R(-505) \approx -1767.5R$$

Closest option = –1575 R.

Final Answer: Correct option: (C).

Q14. 1 mol ideal gas expands reversibly and adiabatically from 27°C. Work done = 3 kJ. $C_v = 20$ J K^{-1}mol^{-1}. Find final T.

(A) 100 K (B) 450 K (C) 150 K (D) 400 K

Conceptual Approach:

Adiabatic: $w = \Delta U = nC_v(T_f - T_i)$. So $T_f = T_i + \frac{w}{nC_v}$.

Step-by-step Solution:

$$T_i = 27 + 273 = 300K, \quad w = –3000J$$

$$T_f = 300 + \frac{-3000}{1 \times 20} = 300 - 150 = 150K$$

Final Answer: Correct option: (C) 150 K.

Q15. 1 mol NH$_3$ gas at 27°C expanded reversibly adiabatically to 8 times volume ($\gamma = 1.33$). Find final T and work.

(A) 150 K, 900 cal (B) 150 K, 400 cal (C) 250 K, 1000 cal (D) 200 K, 800 cal

Conceptual Approach:

Use $T_f = T_i \left(\frac{V_i}{V_f}\right)^{\gamma-1}$. Work: $w = \frac{R(T_i - T_f)}{\gamma-1}$. Convert J to cal (1 cal=4.18 J).

Step-by-step Solution:

$$T_i = 300K,\ V_f/V_i = 8,\ \gamma - 1 = 0.33$$

$$T_f = 300 \times (1/8)^{0.33} \approx 150K$$

$$w = \frac{8.314(300 - 150)}{0.33} \approx 3779J \approx 900\ cal$$

Final Answer: Correct option: (A) 150 K, 900 cal.