Edexcel A2 Physics: Thermodynamics – Calculation Practice

Praneel Physics

1. A gas in a cylinder has a volume of $0.5\,\text{m}^3$ and is at a pressure of $200\,\text{kPa}$. Calculate the work done on the gas when it is compressed to a volume of $0.3\,\text{m}^3$ at constant pressure. **(P)**

Working and Answer:
Work done $= P\Delta V = P(V_f - V_i) = 200 \times 10^3\,\text{Pa} \times (0.3 - 0.5)\,\text{m}^3 = -40,000\,\text{J}$. (Work done on the gas is $40\,\text{kJ}$)

2. A 2 kg block of ice at $0°C$ is heated until it melts completely. Calculate the amount of heat energy required. The latent heat of fusion of ice is $334,000\,\text{J/kg}$. **(P)**

Working and Answer:
$Q = mL = 2\,\text{kg} \times 334,000\,\text{J/kg} = 668,000\,\text{J}$.

3. A gas expands from a volume of $1.0\,\text{m}^3$ to $2.0\,\text{m}^3$ against a constant external pressure of $100\,\text{kPa}$. Calculate the work done by the gas. **(P)**

Working and Answer:
$W = P\Delta V = 100 \times 10^3\,\text{Pa} \times (2.0 - 1.0)\,\text{m}^3 = 100,000\,\text{J}$.

4. A metal rod of mass 0.5 kg is heated from $20°C$ to $80°C$. If the specific heat capacity of the metal is $500\,\mathrm{J/(kg \cdot K)}$, calculate the heat energy absorbed by the rod. **(P)**

Working and Answer:
$Q = mc\Delta T = 0.5\,\mathrm{kg} \times 500\,\mathrm{J/(kg \cdot K)} \times (80 - 20)\,\mathrm{K} = 15,000\,\mathrm{J}$.

5. A gas is compressed from a volume of $4.0\,\mathrm{m^3}$ to $2.0\,\mathrm{m^3}$ at a constant pressure of 150 kPa. Calculate the work done on the gas. **(P)**

Working and Answer:
$W = P\Delta V = 150 \times 10^3\,\mathrm{Pa} \times (2.0 - 4.0)\,\mathrm{m^3} =$ $-300,000\,\mathrm{J}$. (Work done on the gas is 300 kJ)

6. A gas undergoes an isothermal expansion from $2.0\,\mathrm{m}^3$ to $4.0\,\mathrm{m}^3$ at a temperature of $300\,\mathrm{K}$. If the initial pressure is $100\,\mathrm{kPa}$, calculate the work done by the gas. **(PP)**

Working and Answer:
$W = nRT \ln\left(\frac{V_f}{V_i}\right) = \frac{P_i V_i}{T} T \ln\left(\frac{V_f}{V_i}\right) = 100 \times 10^3 \times 2.0 \times \ln\left(\frac{4.0}{2.0}\right) = 138,600\,\mathrm{J}.$

7. A 1 kg block of water is heated from $20°C$ to $100°C$. Calculate the heat energy required. The specific heat capacity of water is $4,186\,\mathrm{J/(kg \cdot K)}$. **(PP)**

Working and Answer:
$Q = mc\Delta T = 1\,\mathrm{kg} \times 4186\,\mathrm{J/(kg \cdot K)} \times (100 - 20)\,\mathrm{K} = 334,880\,\mathrm{J}.$

8. A gas is heated at constant volume, causing its pressure to increase from $100\,\text{kPa}$ to $150\,\text{kPa}$. If the volume of the gas is $0.5\,\text{m}^3$, calculate the work done on the gas. **(PP)**

Working and Answer:
$W = P\Delta V = 0\,(\text{constant volume}) = 0\,\text{J}$.

9. A gas expands isothermally at $300\,\text{K}$ from a volume of $1.0\,\text{m}^3$ to $3.0\,\text{m}^3$. If the gas has a molar mass of $0.04\,\text{kg/mol}$ and the number of moles is 1, calculate the work done by the gas. **(PP)**

Working and Answer:
$W = nRT\ln\left(\frac{V_f}{V_i}\right) = 1 \times 8.31 \times 300 \ln\left(\frac{3.0}{1.0}\right) = 1,200\,\text{J}$.

10. A gas is compressed from $5.0\,\text{m}^3$ to $2.0\,\text{m}^3$ at a constant pressure of $200\,\text{kPa}$. Calculate the work done on the gas. **(PP)**

Working and Answer:
$W = P\Delta V = 200 \times 10^3\,\text{Pa} \times (2.0 - 5.0)\,\text{m}^3 =$
$-600,000\,\text{J}$. (Work done on the gas is $600\,\text{kJ}$)

11. A gas undergoes an adiabatic expansion from an initial pressure of $300\,\text{kPa}$ and volume of $0.1\,\text{m}^3$ to a final volume of $0.5\,\text{m}^3$. Calculate the final pressure of the gas assuming it behaves as an ideal gas with $\gamma = 1.4$. **(PPP)**

Working and Answer:
$P_1 V_1^\gamma = P_2 V_2^\gamma \Rightarrow P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma = 300 \times \left(\frac{0.1}{0.5}\right)^{1.4} = 300 \times 0.215 = 64.5\,\text{kPa}$.

12. A gas is heated from $20°C$ to $80°C$ at constant pressure of $100\,\text{kPa}$. Calculate the change in internal energy if the gas has a molar heat capacity of $C_p = 29\,\text{J}/(\text{mol}\cdot\text{K})$ and contains $2\,\text{mol}$. **(PPP)**

Working and Answer: $\Delta U = nC_v\Delta T = n(C_p - R)\Delta T = 2 \times (29 - 8.31) \times (80 - 20) =$ $2 \times 20.69 \times 60 = 2482.8\,\text{J}$.

13. A gas expands adiabatically from an initial volume of $0.1\,\text{m}^3$ to $0.5\,\text{m}^3$ and does $200\,\text{J}$ of work. Calculate the change in internal energy of the gas. **(PPP)**

Working and Answer: $\Delta U = W + Q = W + 0\,(\text{adiabatic}) = 200\,\text{J}$.

14. A gas is compressed from $4.0\,\mathrm{m}^3$ to $2.0\,\mathrm{m}^3$ at a constant pressure of $150\,\mathrm{kPa}$. Calculate the change in internal energy if the gas has a molar heat capacity of $C_v = 20\,\mathrm{J/(mol \cdot K)}$ and contains $3\,\mathrm{mol}$. **(PPP)**

Working and Answer:
$$\Delta U = nC_v\Delta T = nC_v\left(\frac{P\Delta V}{R}\right) = 3 \times 20 \times \left(\frac{150 \times 10^3 \times (2-4)}{8.31}\right) = -1,080\,\mathrm{J}.$$

15. A gas expands isothermally at $400\,\mathrm{K}$ from a volume of $1.0\,\mathrm{m}^3$ to $2.0\,\mathrm{m}^3$. If the gas has a molar mass of $0.04\,\mathrm{kg/mol}$ and the number of moles is 2, calculate the work done by the gas. **(PPPP)**

Working and Answer:
$$W = nRT\ln\left(\frac{V_f}{V_i}\right) = 2 \times 8.31 \times 400 \ln\left(\frac{2.0}{1.0}\right) = 2 \times 8.31 \times 400 \times 0.693 = 4,600\,\mathrm{J}.$$

16. A gas is heated at constant volume, causing its pressure to increase from 100 kPa to 200 kPa. If the volume of the gas is $0.5\,\mathrm{m}^3$, calculate the change in internal energy. **(PPPP)**

> *Working and Answer:*
> $\Delta U = nC_v\Delta T = \frac{PV}{R}C_v\Delta T = \frac{(200-100)\times 10^3 \times 0.5}{R}C_v = 25,000\,\mathrm{J}.$

17. A gas expands adiabatically from an initial pressure of 400 kPa and volume of $0.1\,\mathrm{m}^3$ to a final volume of $0.4\,\mathrm{m}^3$. Calculate the final pressure of the gas assuming it behaves as an ideal gas with $\gamma = 1.4$. **(PPPP)**

> *Working and Answer:*
> $P_1V_1^\gamma = P_2V_2^\gamma \Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = 400 \times \left(\frac{0.1}{0.4}\right)^{1.4} = 400 \times 0.396 = 158.4\,\mathrm{kPa}.$

18. A gas is heated from $25°C$ to $75°C$ at constant pressure of 150 kPa. Calculate the change in internal energy if the gas has a molar heat capacity of $C_p = 29\,\mathrm{J/(mol \cdot K)}$ and contains 4 mol. **(PPPP)**

Working and Answer:
$\Delta U = nC_v\Delta T = n(C_p - R)\Delta T = 4 \times (29 - 8.31) \times (75 - 25) =$
$4 \times 20.69 \times 50 = 4,138\,\mathrm{J}.$

19. A gas expands isothermally at 350 K from a volume of $1.0\,\mathrm{m}^3$ to $3.0\,\mathrm{m}^3$. If the gas has a molar mass of 0.04 kg/mol and the number of moles is 1, calculate the work done by the gas. **(PPPPP)**

Working and Answer:
$W = nRT\ln\left(\frac{V_f}{V_i}\right) = 1 \times 8.31 \times 350\ln\left(\frac{3.0}{1.0}\right) = 1,200\,\mathrm{J}.$

20. A gas is compressed from $5.0\,\text{m}^3$ to $2.0\,\text{m}^3$ at a constant pressure of $200\,\text{kPa}$. Calculate the change in internal energy if the gas has a molar heat capacity of $C_v = 20\,\text{J}/(\text{mol}\cdot\text{K})$ and contains $3\,\text{mol}$. **(PPPPP)**

Working and Answer:

$$\Delta U = nC_v\Delta T = nC_v\left(\frac{P\Delta V}{R}\right) = 3\times 20\times\left(\frac{200\times 10^3\times(2-5)}{8.31}\right) = -1,080\,\text{J}.$$

21. A gas expands adiabatically from an initial pressure of $500\,\text{kPa}$ and volume of $0.1\,\text{m}^3$ to a final volume of $0.5\,\text{m}^3$. Calculate the final pressure of the gas assuming it behaves as an ideal gas with $\gamma = 1.4$. **(PPPPP)**

Working and Answer:

$$P_1V_1^\gamma = P_2V_2^\gamma \Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = 500\times\left(\frac{0.1}{0.5}\right)^{1.4} = 500\times 0.215 = 107.5\,\text{kPa}.$$

22. A gas is heated from $20°C$ to $80°C$ at constant pressure of $100\,\text{kPa}$. Calculate the change in internal energy if the gas has a molar heat capacity of $C_p = 29\,\text{J}/(\text{mol}\cdot\text{K})$ and contains $2\,\text{mol}$. **(PPPPP)**

Working and Answer:
$\Delta U = nC_v\Delta T = n(C_p - R)\Delta T = 2 \times (29 - 8.31) \times (80 - 20) =$
$2 \times 20.69 \times 60 = 2482.8\,\text{J}$.