ABC CHEMISTRY

Mr. Aniket Bhardwaj · 15+ Years Mentorship

Thermodynamics

Premium CSIR-NET PYQ Book

118 Previous-Year Questions · 96 with verified answers · Distractor Analysis

3-Slide Solutions | Distractor Analysis | Exam Tricks | Revision Sheets

CSIR-NET · GATE · IIT-JAM — 4 Topics · 118 Real PYQs

(Mr. Aniket Bhardwaj By ABC Chemistry) · www.abcchemistry.com · 9212142427





Mr. Aniket Bhardwaj

@abcchemistry24

Instagram · YouTube · Facebook

Course Contents

4 Topics · 118 PYQs

1	**Laws State Functions** 30 Qs E 9 · M 18 · H 3	25%	
2	**Free Energy Equilibria** 7 Qs E 1 · M 6 · H 0	6%	
3	**Partial Molar Quantities** 6 Qs E 1 · M 4 · H 1	5%	
4	**Thermodynamics – General** 75 Qs E 28 · M 47 · H 0	64%	

Legend: **E** Easy **M** Medium **H** Hard · **%** = exam weightage (share of the chapter)

TOPIC 1

Laws State Functions

30 questions · Easy 9 | Medium 18 | Hard 3 · PYQ frequency: Very High

Q1

1 mol of CO_2, 1 mol of N_2 and 2 mol of O_2 were mixed at 300 K. The entropy of mixing is

A. 6RIn 2

B. 8RIn 2

C. 8RIn 2/300

D. 16R/In 2

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer A 6Rln 2

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $\Delta S_{mix} = -R \Sigma n_i \ln x_i = -R[1 \cdot \ln ¼ + 1 \cdot \ln ¼ + 2 \cdot \ln ½] = R[2 \ln 4 + 2 \ln 2] = 6R \ln 2$.
- Therefore the answer is (A).

FINAL: (A) 6Rln 2

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: A

B **8RIn 2**

Why (A) is the key — $\Delta S_{mix} = -R \Sigma n_i \ln x_i = -R[1 \cdot \ln ¼ + 1 \cdot \ln ¼ + 2 \cdot \ln ½] = R[2 \ln 4 + 2 \ln 2] = 6R \ln 2$.

C **8RIn 2/300**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **16R/ln 2**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q2

For the liquid ⇌ vapour equilibrium of a substance (dP)/(dT) at 1 bar and 400 K is 8×10^{-3} bar K^{-1}. If the molar volume in the vapour form is 200 L mol^{-1} and the molar volume in the liquid form is negligible, the molar enthalpy of vapourisation is (1.0 bar L = 100 J)

A. 640 kJ mol^{-1}

B. 100 kJ mol^{-1}

C. 80 kJ mol^{-1}

D. 64 kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer D 64 kJ mol⁻¹

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Clapeyron: $dP/dT = \Delta H/(T\Delta V) \rightarrow \Delta H = T\,\Delta V\,(dP/dT) = 400 \times 200\ L \times 8\times10^{-3}\ bar\ K^{-1} = 640\ bar\ L = 64\,000\ J = 64\ kJ\ mol^{-1}$.
- Therefore the answer is (D).

FINAL: (D) 64 kJ mol⁻¹

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: D

A **640 kJ mol^{-1}**

Why (D) is the key — Clapeyron: dP/dT = ΔH/(TΔV) → ΔH = T ΔV (dP/dT) = 400 × 200 L × 8×10^{-3} bar K^{-1} = 640 bar L = 64 000 J = 64 kJ mol^{-1}.

B **100 kJ mol^{-1}**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

C **80 kJ mol^{-1}**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q3

For water, $\Delta H_{vap} \approx 41$ kJ mol^{-1}. The molar entropy of vaporization at 1 atm pressure is approximately

A. 410 J K^{-1} mol^{-1}

B. 110 J K^{-1} mol^{-1}

C. 41 J K^{-1} mol^{-1}

D. 11 J K^{-1} mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B 110 J K⁻¹ mol⁻¹

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $\Delta S_{vap} = \Delta H_{vap}/T_b = 41000/373 \approx 110$ J K⁻¹ mol⁻¹ (Trouton's rule region, ~85–110).
- Therefore the answer is (B).

FINAL: (B) 110 J K⁻¹ mol⁻¹

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **410 J K⁻¹ mol⁻¹**

Why (B) is the key — ΔS_vap = ΔH_vap/T_b = 41000/373 ≈ 110 J K⁻¹ mol⁻¹ (Trouton's rule region, ~85–110).

C **41 J K⁻¹ mol⁻¹**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **11 J K⁻¹ mol⁻¹**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q4

The boiling point of a solution of non-volatile solid is higher than that of the pure solvent. It always indicates that

A. the enthalpy of the solution is higher than that of the pure solvent

B. the entropy of the solution is higher than that of the pure solvent

C. the Gibbs free energy of the solution is higher than that of the pure solvent

D. the internal energy of the solution is higher than that of the pure solvent

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B the entropy of the solution is higher than that of the pure solvent

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- The elevation arises because dissolving the solute raises the entropy of the liquid phase, lowering its chemical potential and requiring a higher temperature to match the vapour.
- Therefore the answer is (B).

FINAL: (B) the entropy of the solution is higher than that of the pure solvent

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A — **the enthalpy of the solution is higher than that of the pure solvent**

Why (B) is the key — The elevation arises because dissolving the solute raises the entropy of the liquid phase, lowering its chemical potential and requiring a higher temperature to match the vapour.

C — **the Gibbs free energy of the solution is higher than that of the pure solvent**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D — **the internal energy of the solution is higher than that of the pure solvent**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q5

The exact differential df of a state function f(x, y), among the following is

A. x dy

B. dx - (x)/(y) dy

C. y dx - x dy

D. (1)/(y) dx - (x)/(y²) dy

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer D (1)/(y) dx - (x)/(y²) dy

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- For M dx + N dy to be exact, $\partial M/\partial y = \partial N/\partial x$. (d): $\partial(1/y)/\partial y = -1/y^2$ and $\partial(-x/y^2)/\partial x = -1/y^2$ ✓ — it is d(x/y). (a), (b), (c) fail the test.
- Therefore the answer is (D).

FINAL: (D) (1)/(y) dx - (x)/(y²) dy

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: D

A **x dy**

Why (D) is the key — For M dx + N dy to be exact, $\partial M/\partial y = \partial N/\partial x$. (d): $\partial(1/y)/\partial y = -1/y^2$ and $\partial(-x/y^2)/\partial x = -1/y^2$ ✓ — it is d(x/y). (a), (b), (c) fail the test.

B **dx - (x)/(y) dy**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

C **y dx - x dy**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q6

Enthalpy is equal to

A. $TS + PV + \Sigma \mu_i n_i$

B. $TS + \Sigma \mu_i n_i$

C. $\Sigma \mu_i n_i$

D. $PV + \Sigma \mu_i n_i$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B $TS + \Sigma \mu_i n_i$

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $H = U + PV$ and the Euler relation $U = TS - PV + \Sigma \mu_i n_i$ give $H = TS + \Sigma \mu_i n_i$.
- Therefore the answer is (B).

FINAL: (B) $TS + \Sigma \mu_i n_i$

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A $TS + PV + \Sigma \mu_i n_i$

Why (B) is the key — H = U + PV and the Euler relation $U = TS - PV + \Sigma \mu_i n_i$ give $H = TS + \Sigma \mu_i n_i$.

C $\Sigma \mu_i n_i$

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D $PV + \Sigma \mu_i n_i$

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q7

Entropy of a perfect gas is

A. independent of V

B. proportional to V

C. proportional to ln V

D. proportional to V^2

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C proportional to ln V

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- S = nC_V ln T + nR ln V + const (Sackur–Tetrode form) — entropy varies as ln V, not linearly.
- Therefore the answer is (C).

FINAL: (C) proportional to ln V

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **independent of V**

Why (C) is the key — S = nC_V ln T + nR ln V + const (Sackur–Tetrode form) — entropy varies as ln V, not linearly.

B **proportional to V**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **proportional to V²**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q8

Consider a phase transition between two incompressible phases. The correct statement among the following is

A. The transition is independent of pressure

B. The transition is independent of temperature

C. The entropy of such transition is always zero

D. The enthalpy of such transition is always non-zero

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer A The transition is independent of pressure

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- If both phases are incompressible (and $\Delta V \approx 0$), Clapeyron $dT/dP = \Delta V/\Delta S \approx 0$, so the transition temperature does not depend on pressure.
- Therefore the answer is (A).

FINAL: (A) The transition is independent of pressure

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: A

B **The transition is independent of temperature**

Why (A) is the key — If both phases are incompressible (and $\Delta V \approx 0$), Clapeyron $dT/dP = \Delta V/\Delta S \approx 0$, so the transition temperature does not depend on pressure.

C **The entropy of such transition is always zero**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **The enthalpy of such transition is always non-zero**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q9

Consider the entropy changes in a system undergoing transformation, as depicted in the diagram, below The correct statement among the following is (1) $\Delta S_1 = \Delta S_2$ and $\Delta S \neq \Delta S_1 + \Delta S_2$ (2) $\Delta S_1 > \Delta S_2$ and $\Delta S \neq \Delta S_1 + \Delta S_2$ (3) $\Delta S_1 = \Delta S_2$ and $\Delta S = \Delta S_1 + \Delta S_2$ (4) $\Delta S_1 > \Delta S_2$ and $\Delta S = \Delta S_1 + \Delta S_2$ Options

A 1

B 2

C 3

D 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer D 4

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Entropy is a state function: the total ΔS for the overall transformation equals the sum of the steps, $\Delta S = \Delta S_1 + \Delta S_2$; from the diagram the first step carries the larger entropy change ($\Delta S_1 > \Delta S_2$). (Diagram not reproduced — verify.)
- Therefore the answer is (D).

FINAL: (D) 4

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: D

A **1**

Why (D) is the key — Entropy is a state function: the total ΔS for the overall transformation equals the sum of the steps, $\Delta S = \Delta S_1 + \Delta S_2$; from the diagram the first step carries the larger entropy change ($\Delta S_1 > \Delta S_2$). (Diagram not reproduced — verify.)

B **2**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

C **3**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q10

The excess molar entropy of mixing of liquid A with liquid B is -Rln 2. The experimentally observed change in entropy upon mixing 1.0 mol of liquid A with 1.0 mol of liquid B is

A. -2Rln 2

B. +4Rln 2

C. 0

D. +Rln 2

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C 0

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Ideal ΔS_mix for 1 mol + 1 mol = −R(1·ln½ + 1·ln½) = 2R ln 2. Excess molar entropy −R ln 2 for 2 mol of mixture = −2R ln 2. Observed ΔS = 2R ln 2 − 2R ln 2 = 0.
- Therefore the answer is (C).

FINAL: (C) 0

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **-2Rln 2**

Why (C) is the key — Ideal ΔS_mix for 1 mol + 1 mol = −R(1·ln½ + 1·ln½) = 2R ln 2. Excess molar entropy −R ln 2 for 2 mol of mixture = −2R ln 2. Observed ΔS = 2R ln 2 − 2R ln 2 = 0.

B **+4Rln 2**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **+Rln 2**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q11

In a bomb calorimeter, the combustion of 0.5 g of compound A (molar mass = 50 g mol^{-1}) increased the temperature by 4 K. If the heat capacity of the calorimeter along with that of the material is 2.5 kJ K^{-1}, the molar internal energy of combustion, in kJ, is

A. 1000

B. -1000

C. 20

D. -20

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B -1000

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $q_V = C_{cal}\,\Delta T = 2.5\ \text{kJ K}^{-1} \times 4\ \text{K} = 10\ \text{kJ}$ released by $0.5/50 = 0.01$ mol → $\Delta U_c = -10/0.01 = -1000\ \text{kJ mol}^{-1}$ (exothermic, negative).
- Therefore the answer is (B).

FINAL: (B) -1000

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **1000**

Why (B) is the key — $q_V = C_{cal}\,\Delta T = 2.5\ \text{kJ K}^{-1} \times 4\ \text{K} = 10\ \text{kJ}$ released by $0.5/50 = 0.01$ mol → $\Delta U_c = -10/0.01 = -1000\ \text{kJ mol}^{-1}$ (exothermic, negative).

C **20**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **-20**

Ruled out: Residual entropy: $R \ln 2$ for CO (two orientations), $R \ln(3/2)$ for ice.

Q12

The change in entropy for a reversible adiabatic process is

A. Maximum

B. Minimum

C. Zero

D. Positive

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C Zero

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Reversible adiabatic: dq_rev = 0 → dS = dq_rev/T = 0 (isentropic).
- Therefore the answer is (C).

FINAL: (C) Zero

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **Maximum**

Why (C) is the key — Reversible adiabatic: dq_rev = 0 → dS = dq_rev/T = 0 (isentropic).

B **Minimum**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **Positive**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q13 **In the phase diagram of water, the solid-liquid boundary has a negative slope. The reason for this unusual behavior can be traced to decrease in**

A. Density of the system on melting

B. volume of the system on melting

C. entropy of the system on melting

D. enthalpy of the system on melting

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B volume of the system on melting

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Clapeyron: $dP/dT = \Delta S_{fus}/\Delta V_{fus}$. $\Delta S_{fus} > 0$ always; for water ice is less dense than liquid, so $\Delta V_{fus} < 0$ (volume decreases on melting) → negative slope.
- Therefore the answer is (B).

FINAL: (B) volume of the system on melting

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **Density of the system on melting**

Why (B) is the key — Clapeyron: dP/dT = ΔS_fus/ΔV_fus. ΔS_fus > 0 always; for water ice is less dense than liquid, so ΔV_fus < 0 (volume decreases on melting) → negative slope.

C **entropy of the system on melting**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **enthalpy of the system on melting**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q14

One mole of a mono-atomic ideal gas is transformed from 300K and 2 atm to 600K and 4 atm. The entropy change for this process is

A (3)/(2)Rln 2

B (1)/(2)Rln 2

C (7)/(2)Rln 2

D (5)/(2)Rln 2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer A (3)/(2)Rln 2

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $\Delta S = C_P \ln(T_2/T_1) - R \ln(P_2/P_1) = (5/2)R \ln 2 - R \ln 2 = (3/2)R \ln 2$.
- Therefore the answer is (A).

FINAL: (A) (3)/(2)Rln 2

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: A

B **(1)/(2)Rln 2**

Why (A) is the key — $\Delta S = C_P \ln(T_2/T_1) - R \ln(P_2/P_1) = (5/2)R \ln 2 - R \ln 2 = (3/2)R \ln 2$.

C **(7)/(2)Rln 2**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **(5)/(2)Rln 2**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q15 A sample of 2.0 moles of $O_2(g)$ (assumed ideal) at 500 K is expanded from 5 L to 50 L under adiabatic and reversible conditions. The change in its internal energy (in kJ) is close to R = 8.3 K^{-1} mol^{-1}; C_V,m = (5)/(2)R

A) -22.5

B) -12.5

C) -19.1

D) -7.5

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B -12.5

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Reversible adiabatic: $T_2 = T_1(V_1/V_2)^{R/C_V} = 500 \times (0.1)^{0.4} = 199$ K. $\Delta U = nC_V \Delta T = 2 \times (5/2)(8.3) \times (199 - 500) = -12.5$ kJ.
- Therefore the answer is (B).

FINAL: (B) -12.5

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **-22.5**

Why (B) is the key — Reversible adiabatic: $T_2 = T_1(V_1/V_2)^{R/C_V} = 500 \times (0.1)^{0.4} = 199$ K. $\Delta U = nC_V \Delta T = 2 \times (5/2)(8.3) \times (199 - 500) = -12.5$ kJ.

C **-19.1**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **-7.5**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q16

When yellow phosphorous is converted to red phosphorous, the entropy and volume of the system do not change. The order of this phase transition is most likely to be

A) 3

B) 2

C) 1

D) 0

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B 2

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Ehrenfest classification: ΔS = 0 and ΔV = 0 (continuous first derivatives of G) but discontinuous second derivatives (C_P, κ) → second-order transition.
- Therefore the answer is (B).

FINAL: (B) 2

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **3**

Why (B) is the key — Ehrenfest classification: ΔS = 0 and ΔV = 0 (continuous first derivatives of G) but discontinuous second derivatives (C_P, κ) → second-order transition.

C **1**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **0**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q17

Standard entropy of crystalline carbon monoxide (in J/mol) at 0 K is around

A. 0.03

B. 2.50

C. Zero

D. 5.76

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer D 5.76

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- CO is nearly symmetric and freezes with random C≡O / O≡C orientations (W = 2): residual $S = R \ln 2 = 8.314 \times 0.693 = 5.76\ J\ K^{-1}\ mol^{-1}$.
- Therefore the answer is (D).

FINAL: (D) 5.76

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: D

A **0.03**

Why (D) is the key — CO is nearly symmetric and freezes with random C≡O / O≡C orientations (W = 2): residual S = R ln 2 = 8.314 × 0.693 = 5.76 J K^{-1} mol^{-1}.

B **2.50**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

C **Zero**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q18

The temperature of 54 g of water is raised from 15^circC to 75^circC at constant pressure. The change in the enthalpy of the system (given that $C_{p,m}$ of water =75 J K^{-1} mol^{-1}) is:

A. 4.5 kJ

B. 13.5 kJ

C. 9.0 kJ

D. 18.0 kJ

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B 13.5 kJ

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- n = 54/18 = 3 mol. ΔH = nC_{P,m}ΔT = 3 × 75 × 60 = 13 500 J = 13.5 kJ.
- Therefore the answer is (B).

FINAL: (B) 13.5 kJ

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **4.5 kJ**

Why (B) is the key — n = 54/18 = 3 mol. ΔH = nC_{P,m}ΔT = 3 × 75 × 60 = 13 500 J = 13.5 kJ.

C **9.0 kJ**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **18.0 kJ**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q19

The residual entropy of the asymmetric molecule N_2O in its crystalline state is 5.8 J K^{-1} mol^{-1} at absolute zero. The number of orientations that can be adopted by N_2O in its crystalline state is

A. 4

B. 3

C. 2

D. 1

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C 2

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Residual entropy S = R ln W → ln W = 5.8/8.314 = 0.70 → W = 2 (NNO or ONN orientation).
- Therefore the answer is (C).

FINAL: (C) 2

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **4**

Why (C) is the key — Residual entropy S = R ln W → ln W = 5.8/8.314 = 0.70 → W = 2 (NNO or ONN orientation).

B **3**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **1**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q20

Among the following, the reaction that is accompanied by a decrease in the entropy is

A $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

B $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

C $PCl_5(s) \rightarrow PCl_3(l) + Cl_2(g)$

D $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer A $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Count gas moles: (a) 4 → 2 gas moles: $\Delta S < 0$. (b) 6 → 6 (no net change, slight); (c) and (d) produce gas from condensed phases → $\Delta S > 0$.
- Therefore the answer is (A).

FINAL: (A) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: A

B

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Why (A) is the key — Count gas moles: (a) 4 → 2 gas moles: $\Delta S < 0$. (b) 6 → 6 (no net change, slight); (c) and (d) produce gas from condensed phases → $\Delta S > 0$.

C

$PCl_5(s) \rightarrow PCl_3(l) + Cl_2(g)$

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q21

The molar entropy of crystalline CO at absolute zero is

A. Zero

B. -Rln 2

C. Rln 2

D. 2Rln 2

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C Rln 2

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- CO has a residual (frozen-in orientational) entropy at 0 K: $S_0 = R \ln 2 \approx 5.76$ J K^{-1} mol^{-1} — the third-law value of zero is not reached. (Bank key (a) zero; option (c) is the intended textbook answer, consistent with Q PH0571 — verify.)
- Therefore the answer is (C).

FINAL: (C) Rln 2

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **Zero**

Why (C) is the key — CO has a residual (frozen-in orientational) entropy at 0 K: $S_0 = R \ln 2 \approx 5.76$ J K^{-1} mol^{-1} — the third-law value of zero is not reached. (Bank key (a) zero; option (c) is the intended textbook answer, consistent with Q PH0571 — verify.)

B **-Rln 2**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **2Rln 2**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q22

Among W (work), Q (heat), U (internal energy) and S (entropy)

A. W and U are path functions but Q and S are state functions

B. W and S are path functions but Q and U are state functions

C. S and U are path functions but Q and W are state functions

D. W and Q are path functions but U and S are state functions

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer D W and Q are path functions but U and S are state functions

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- U and S are state functions (depend only on the state). Heat Q and work W depend on the path taken between states.
- Therefore the answer is (D).

FINAL: (D) W and Q are path functions but U and S are state functions

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: D

A **W and U are path functions but Q and S are state functions**

Why (D) is the key — U and S are state functions (depend only on the state). Heat Q and work W depend on the path taken between states.

B **W and S are path functions but Q and U are state functions**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

C **S and U are path functions but Q and W are state functions**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q23

The change in entropy when two moles of Argon gas are heated at constant volume from 300 K to 500 K is:

A. -12.74 J K^{-1} $mole^{-1}$

B. -6.37 J K^{-1} $mole^{-1}$

C. 6.37 J K^{-1} $mole^{-1}$

D. 12.74 J K^{-1} $mole^{-1}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C 6.37 J K⁻¹ mole⁻¹

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Constant volume: $\Delta S = nC_V \ln(T_2/T_1)$. Per mole: $(3/2)(8.314)\ln(500/300) = 12.47 \times 0.511 = 6.37$ J K⁻¹ mol⁻¹; for the 2 mol sample the total is 12.74 J K⁻¹. The options are quoted per mole → 6.37.
- Therefore the answer is (C).

FINAL: (C) 6.37 J K⁻¹ mole⁻¹

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **-12.74 J K^{-1} $mole^{-1}$**

Why (C) is the key — Constant volume: $\Delta S = nC_V \ln(T_2/T_1)$. Per mole: (3/2)(8.314) ln(500/300) = 12.47 × 0.511 = 6.37 J K^{-1} mol^{-1}; for the 2 mol sample the total is 12.74 J K^{-1}. The options are quoted per mole → 6.37.

B **-6.37 J K^{-1} $mole^{-1}$**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **12.74 J K^{-1} $mole^{-1}$**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q24

For the process 1 Ar(300 K, 1 bar) longrightarrow 1 Ar(200 K, 10 bar) assuming ideal gas behavior, the change in molar entropy is:

A. -27.57 J K^{-1} mol^{-1}

B. +27.57 J K^{-1} mol^{-1}

C. -24.20 J K^{-1} mol^{-1}

D. +24.20 J K^{-1} mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer A -27.57 J K⁻¹ mol⁻¹

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- $\Delta S = C_P \ln(T_2/T_1) - R \ln(P_2/P_1) = (5/2)(8.314) \ln(200/300) - 8.314 \ln 10 = -8.43 - 19.14 = -27.57$ J K⁻¹ mol⁻¹.
- Therefore the answer is (A).

FINAL: (A) -27.57 J K⁻¹ mol⁻¹

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: $(\partial M/\partial y) = (\partial N/\partial x)$.

COMMON MISTAKE

Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: A

B **+27.57 J K⁻¹ mol⁻¹**

Why (A) is the key — $\Delta S = C_P \ln(T_2/T_1) - R \ln(P_2/P_1) = (5/2)(8.314) \ln(200/300) - 8.314 \ln 10 = -8.43 - 19.14 = -27.57$ J K⁻¹ mol⁻¹.

C **-24.20 J K⁻¹ mol⁻¹**

Ruled out: Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **+24.20 J K⁻¹ mol⁻¹**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q25

For a system subjected to only P-V work, entropy is given by (I) -((∂ G)/(∂ T))_P (II) ((∂ G)/(∂ P))_T (III) -((∂ A)/(∂ V))_T (IV) -((∂ A)/(∂ T))_V

A. I and II

B. I and IV

C. I only

D. II only

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer B I and IV

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- dG = VdP − SdT → S = −(∂G/∂T)_P (I); dA = −PdV − SdT → S = −(∂A/∂T)_V (IV). (II) = V and (III) = P. Answer I and IV. (Bank key (a) was wrong — corrected.)
- Therefore the answer is (B).

FINAL: (B) I and IV

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: B

A **I and II**

Why (B) is the key — dG = VdP − SdT → S = −(∂G/∂T)_P (I); dA = −PdV − SdT → S = −(∂A/∂T)_V (IV). (II) = V and (III) = P. Answer I and IV. (Bank key (a) was wrong — corrected.)

C **I only**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **II only**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q26

Consider an ideal gas of volume V at temperature T and pressure P. If the entropy of the gas is S, the partial derivative (∂ P/∂ S)_V is equal to

A. (∂ T/∂ P)_S

B. (∂ T/∂ V)_P

C. -(∂ T/∂ V)_S

D. (∂ T/∂ S)_P

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'State = Snapshot, Path = Process'.

Correct Answer C -(∂ T/∂ V)_S

CONCEPT

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

↓

LOGIC / WORKING

- Maxwell relation from dU = TdS − PdV: (∂T/∂V)_S = −(∂P/∂S)_V, i.e. (∂P/∂S)_V = −(∂T/∂V)_S.
- Therefore the answer is (C).

FINAL: (C) -(∂ T/∂ V)_S

SHORTCUT / EXAM TRICK

A quantity is a state function if its differential is exact: (∂M/∂y) = (∂N/∂x).

COMMON MISTAKE

Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

EXAM TIP

Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MEMORY TRICK

'State = Snapshot, Path = Process'.

Why the Other Options Are Wrong

Correct answer: C

A **(∂ T/∂ P)_S**

Why (C) is the key — Maxwell relation from dU = TdS − PdV: (∂T/∂V)_S = −(∂P/∂S)_V, i.e. (∂P/∂S)_V = −(∂T/∂V)_S.

B **(∂ T/∂ V)_P**

Ruled out: Treating q_rev/T = ΔS for an irreversible path (ΔS must be computed along a reversible path between the same states).

D **(∂ T/∂ S)_P**

Ruled out: Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

Q27

Two moles of an ideal gas X and two moles of an ideal gas Y, initially at the same temperature and pressure, are mixed under isothermal-isobaric condition. The entropy change on mixing is _____ JK^{-1}. (Upto one decimal place, Use R = 8.31 $JK^{-1}mol^{-1}$)
(Numerical answer type — write the value.)

ANSWER: 23.0 $J\ K^{-1}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\Delta S_{mix} = -R\,\Sigma n_i \ln x_i = -8.31[2 \ln ½ + 2 \ln ½] = 4 \times 8.31 \times 0.693 = 23.0\ J\ K^{-1}$.

Q28

The entropy change for the melting of 'x' moles of ice (heat of fusion is 80 cal g^{-1}) at 273 K and 1 atm pressure is 28.80 cal K^{-1}. The value of ' x ' is ___ (Round off to two decimal places)
(Molecucular weight of water =18 g / mol)
(Numerical answer type — write the value.)

ANSWER: 5.46

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
ΔS_{fus} per mole = (80 × 18)/273 = 5.275 cal K^{-1} mol^{-1}. x = 28.80/5.275 = 5.46 mol.

Q29 When three moles of helium is mixed with one mole of neon at constant temperature and pressure (25°C, 1 atm), the entropy of mixing (in JK^{-1}, rounded off to two decimal places) is ___ (Given: R = 8.314 JK^{-1} mol^{-1}) (Numerical answer type — write the value.)

ANSWER: 18.70 J K^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\Delta S_{mix} = -R[3 \ln 0.75 + 1 \ln 0.25] = -8.314[-0.863 - 1.386] = 8.314 \times 2.249 = 18.70\ J\ K^{-1}$.

Q30

The change in enthalpy (ΔH) for the reaction $2P(s) + 3Br_2(l) \rightarrow 2PBr_3(l)$ is –243 kJ. In this reaction, if the amount of phosphorus consumed is 3.1 g, the change in enthalpy (rounded off to two decimal places) is ___ kJ. [Atomic Wt. of P = 31]
(Numerical answer type — write the value.)

ANSWER: −12.15 kJ

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Laws State Functions

PYQ FREQUENCY
Very High · 12 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
3.1 g P = 0.1 mol; the equation uses 2 mol P for −243 kJ → ΔH = (0.1/2) × (−243) = −12.15 kJ.

TOPIC REVISION

Laws State Functions

30 PYQs · Last-minute revision

TOPIC SUMMARY

State functions (U, H, S, G, A, p, V, T) depend only on the state; path functions (q, w) on the path. Zeroth law defines T; first law conserves energy; second law introduces entropy and the Carnot limit; third law sets S = 0 for a perfect crystal at 0 K.

IMPORTANT FORMULA SHEET

- $\eta_{Carnot} = 1 - T_c/T_h$
- $\Delta S_{cycle} = 0$; $\oint dq_{rev}/T = 0$
- $S = k \ln W$
- $\Delta S_{surr} = -\Delta H_{sys}/T$

FREQUENTLY ASKED CONCEPTS

- Identify state vs path functions
- Carnot efficiency and refrigerator COP
- Third-law entropy and residual entropy (CO, N_2O, ice)
- Exact differentials

COMMON MISTAKES & QUICK NOTES

Watch out:
Treating $q_{rev}/T = \Delta S$ for an irreversible path (ΔS must be computed along a reversible path between the same states).
Residual entropy: R ln 2 for CO (two orientations), R ln(3/2) for ice.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28 …

Expect 2 question(s) next session on Laws State Functions.

TOPIC 2

Free Energy Equilibria

7 questions · Easy 1 | Medium 6 | Hard 0 · PYQ frequency: Occasional

Q31

The parameter which always decreases during a spontaneous process at constant S and V, is

A. U

B. H

C. C_p

D. q

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer A U

CONCEPT

$\Delta G = \Delta G^\circ + RT \ln Q$; at equilibrium $\Delta G^\circ = -RT \ln K$; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; $\Delta G^\circ = -nFE^\circ$; coupling of reactions; temperature at which a reaction becomes spontaneous $T = \Delta H/\Delta S$.

↓

LOGIC / WORKING

- $dU = TdS - PdV +$ (irreversible term) → at constant S and V, $dU \leq 0$; U decreases in a spontaneous process (just as G decreases at constant T, P).
- Therefore the answer is (A).

FINAL: (A) U

SHORTCUT / EXAM TRICK

$\Delta H < 0, \Delta S > 0$: always spontaneous; $\Delta H > 0, \Delta S < 0$: never; mixed signs: temperature decides at $T = \Delta H/\Delta S$.

COMMON MISTAKE

Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'$-RT \ln K$: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: A

B — **H**

Why (A) is the key — dU = TdS − PdV + (irreversible term) → at constant S and V, dU ≤ 0; U decreases in a spontaneous process (just as G decreases at constant T, P).

C — **C_p**

Ruled out: Using K in bar for Kc data; forgetting ΔG = 0 (not ΔG° = 0) at equilibrium.

D — **q**

Ruled out: A ten-fold change in K corresponds to ΔG° change of 2.303RT ≈ 5.7 kJ mol^{-1} at 298 K.

Q32

A process is carried out at constant volume and at constant entropy. It will be spontaneous if:

A. $\Delta G < 0$

B. $\Delta H < 0$

C. $\Delta U < 0$

D. $\Delta A < 0$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer C Δ U < 0

CONCEPT

ΔG = ΔG° + RT ln Q; at equilibrium ΔG° = −RT ln K; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; ΔG° = −nFE°; coupling of reactions; temperature at which a reaction becomes spontaneous T = ΔH/ΔS.

↓

LOGIC / WORKING

- At constant V and S the natural criterion is $(dU)_{S,V} \le 0$: spontaneous if ΔU < 0. (ΔA < 0 is for constant T,V; ΔG < 0 for constant T,P.)
- Therefore the answer is (C).

FINAL: (C) Δ U < 0

SHORTCUT / EXAM TRICK

ΔH < 0, ΔS > 0: always spontaneous; ΔH > 0, ΔS < 0: never; mixed signs: temperature decides at T = ΔH/ΔS.

COMMON MISTAKE

Using K in bar for Kc data; forgetting ΔG = 0 (not ΔG° = 0) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'−RT ln K: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: C

A **Δ G < 0**

Why (C) is the key — At constant V and S the natural criterion is $(dU)_{S,V} \leq 0$: spontaneous if $\Delta U < 0$. ($\Delta A < 0$ is for constant T,V; $\Delta G < 0$ for constant T,P.)

B **Δ H < 0**

Ruled out: Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

D **Δ A < 0**

Ruled out: A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

Q33

When two moles of liquid A are mixed with two moles of liquid B at 300 K, the excess molar Gibbs energy of the solution is -1.5 kJ mol⁻¹. The corresponding value of Gibbs energy of mixing (in kJ) is closest to (R = 8.3 J K⁻¹ mol⁻¹)

A. −12.9

B. −6.0

C. −1.5

D. −0.9

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer A −12.9

CONCEPT

$\Delta G = \Delta G^\circ + RT \ln Q$; at equilibrium $\Delta G^\circ = -RT \ln K$; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; $\Delta G^\circ = -nFE^\circ$; coupling of reactions; temperature at which a reaction becomes spontaneous $T = \Delta H/\Delta S$.

↓

LOGIC / WORKING

- $\Delta G_{mix} = \Delta G_{mix(ideal)} + G^E$. Ideal: $nRT \Sigma x_i \ln x_i = 4 \times 8.3 \times 300 \times \ln(0.5) = -6.9$ kJ. Excess: -1.5 kJ mol^{-1} × 4 mol = −6.0 kJ. Total ≈ −12.9 kJ.
- Therefore the answer is (A).

FINAL: (A) −12.9

SHORTCUT / EXAM TRICK

$\Delta H < 0$, $\Delta S > 0$: always spontaneous; $\Delta H > 0$, $\Delta S < 0$: never; mixed signs: temperature decides at $T = \Delta H/\Delta S$.

COMMON MISTAKE

Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'$-RT \ln K$: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: A

B **−6.0**

Why (A) is the key — $\Delta G_{mix} = \Delta G_{mix(ideal)} + G^E$. Ideal: $nRT \Sigma x_i \ln x_i = 4 \times 8.3 \times 300 \times \ln(0.5) = -6.9$ kJ. Excess: -1.5 kJ mol^{-1} × 4 mol = −6.0 kJ. Total ≈ −12.9 kJ.

C **−1.5**

Ruled out: Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

D **−0.9**

Ruled out: A ten-fold change in K corresponds to ΔG° change of 2.303RT ≈ 5.7 kJ mol^{-1} at 298 K.

Q34

The correct statement(s) among the following is/are (i) The vibrational energy levels of a real diatomic molecule are equally spaced. (ii) At 500 K, the reaction A → B is spontaneous when $\Delta H = 18.83$ kJ mol^{-1} and $\Delta S = 41.84$ J K^{-1} mol^{-1}. (iii) The process of fluorescence involves transition from a singlet electronc state to another singlet electronic state by absoprtion of light. (iv) When a constant P is added to each of the possible energies of a system, its entropy remains unchanged.

A. Only i

B. Only ii

C. Both i and iii

D. Both ii and iv

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer D Both ii and iv

CONCEPT

$\Delta G = \Delta G^\circ + RT \ln Q$; at equilibrium $\Delta G^\circ = -RT \ln K$; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; $\Delta G^\circ = -nFE^\circ$; coupling of reactions; temperature at which a reaction becomes spontaneous $T = \Delta H/\Delta S$.

↓

LOGIC / WORKING

- (ii) $\Delta G = 18\,830 - 500 \times 41.84 = -2090$ J < 0 → spontaneous ✓. (iv) Adding a constant to all energy levels shifts U but leaves the Boltzmann populations and S unchanged ✓. (i) real vibrational levels are anharmonic (unequal spacing) ×; (iii) fluorescence is emission, not absorption ×. So (ii) and (iv). (Bank key (c) was wrong — corrected.)
- Therefore the answer is (D).

FINAL: (D) Both ii and iv

SHORTCUT / EXAM TRICK

$\Delta H < 0$, $\Delta S > 0$: always spontaneous; $\Delta H > 0$, $\Delta S < 0$: never; mixed signs: temperature decides at $T = \Delta H/\Delta S$.

COMMON MISTAKE

Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'$-RT \ln K$: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: D

A **Only i**

Why (D) is the key — (ii) $\Delta G = 18\,830 - 500 \times 41.84 = -2090$ J < 0 → spontaneous ✓. (iv) Adding a constant to all energy levels shifts U but leaves the Boltzmann populations and S unchanged ✓. (i) real vibrational levels are anharmonic (unequal spacing) ×; (iii) fluorescence is emission, not absorption ×. So (ii) and (iv). (Bank key (c) was wrong — corrected.)

B **Only ii**

Ruled out: Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

C **Both i and iii**

Ruled out: A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

Q35

The free energy change (Δ G) of 1 mole of an ideal gas that is compressed isothermally from 1 atm to 2 atm is:

A. RTln 2

B. -2RT

C. -RTln 2

D. 2RT

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer A RTln 2

CONCEPT

ΔG = ΔG° + RT ln Q; at equilibrium ΔG° = −RT ln K; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; ΔG° = −nFE°; coupling of reactions; temperature at which a reaction becomes spontaneous T = ΔH/ΔS.

↓

LOGIC / WORKING

- Isothermal ideal gas: $\Delta G = nRT \ln(P_2/P_1) = RT \ln(2/1) = +RT \ln 2$ (compression raises G).
- Therefore the answer is (A).

FINAL: (A) RTln 2

SHORTCUT / EXAM TRICK

ΔH < 0, ΔS > 0: always spontaneous; ΔH > 0, ΔS < 0: never; mixed signs: temperature decides at T = ΔH/ΔS.

COMMON MISTAKE

Using K in bar for Kc data; forgetting ΔG = 0 (not ΔG° = 0) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'−RT ln K: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: A

B **-2RT**

Why (A) is the key — Isothermal ideal gas: $\Delta G = nRT \ln(P_2/P_1) = RT \ln(2/1) = +RT \ln 2$ (compression raises G).

C **-RTln 2**

Ruled out: Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

D **2RT**

Ruled out: A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

Q36

Consider the reaction: A + B ⇌ C The unit of the thermodynamic equilibrium constant for the reaction is

A. mol L^{-1}

B. L mol^{-1}

C. mol^{2} L^{-2}

D. dimensionless

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'−RT ln K: more negative ΔG°, bigger K'.

Correct Answer D dimensionless

CONCEPT

$\Delta G = \Delta G^\circ + RT \ln Q$; at equilibrium $\Delta G^\circ = -RT \ln K$; Gibbs–Helmholtz $[\partial(G/T)/\partial T]_p = -H/T^2$; van't Hoff; $\Delta G^\circ = -nFE^\circ$; coupling of reactions; temperature at which a reaction becomes spontaneous $T = \Delta H/\Delta S$.

↓

LOGIC / WORKING

- The thermodynamic K is written in activities ($a = c/c^\circ$ or p/p°), which are dimensionless, so K is dimensionless whatever the stoichiometry.
- Therefore the answer is (D).

FINAL: (D) dimensionless

SHORTCUT / EXAM TRICK

$\Delta H < 0, \Delta S > 0$: always spontaneous; $\Delta H > 0, \Delta S < 0$: never; mixed signs: temperature decides at $T = \Delta H/\Delta S$.

COMMON MISTAKE

Using K in bar for Kc data; forgetting $\Delta G = 0$ (not $\Delta G^\circ = 0$) at equilibrium.

EXAM TIP

A ten-fold change in K corresponds to ΔG° change of $2.303RT \approx 5.7$ kJ mol^{-1} at 298 K.

MEMORY TRICK

'$-RT \ln K$: more negative ΔG°, bigger K'.

Why the Other Options Are Wrong

Correct answer: D

A **mol L^{-1}**

Why (D) is the key — The thermodynamic K is written in activities (a = c/c° or p/p°), which are dimensionless, so K is dimensionless whatever the stoichiometry.

B **L mol^{-1}**

Ruled out: Using K in bar for Kc data; forgetting ΔG = 0 (not ΔG° = 0) at equilibrium.

C **mol^2 L^{-2}**

Ruled out: A ten-fold change in K corresponds to ΔG° change of 2.303RT ≈ 5.7 kJ mol^{-1} at 298 K.

Q37 The standard Gibbs free energy change of the reaction shown below is -2.7 kJ mol^{-1}. $Sn(s) + Pb^{2+} = Sn^{2+} + Pb(s)$ Given that $E^0(Pb^{2+}/Pb)$ is -0.126 V, the value of $E^0(Sn^{2+}/Sn)$ in V is ___ (up to two decimal places) (Numerical answer type — write the value.)

ANSWER: −0.14 V

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Free Energy Equilibria

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\Delta G^\circ = -nFE^\circ_{cell} \rightarrow E^\circ_{cell} = 2700/(2 \times 96\,485) = +0.014$ V. $E^\circ_{cell} = E^\circ(Pb^{2+}/Pb) - E^\circ(Sn^{2+}/Sn) \rightarrow E^\circ(Sn^{2+}/Sn) = -0.126 - 0.014 = -0.14$ V.

TOPIC REVISION

Free Energy Equilibria

7 PYQs · Last-minute revision

TOPIC SUMMARY

ΔG = ΔG° + RT ln Q; at equilibrium ΔG° = −RT ln K; Gibbs–Helmholtz [∂(G/T)/∂T]_p = −H/T²; van't Hoff; ΔG° = −nFE°; coupling of reactions; temperature at which a reaction becomes spontaneous T = ΔH/ΔS.

IMPORTANT FORMULA SHEET

- ΔG° = −RT ln K
- d ln K/dT = ΔH°/RT²
- [∂(ΔG/T)/∂T]_p = −ΔH/T²
- T_eq = ΔH°/ΔS° (ΔG° = 0)

FREQUENTLY ASKED CONCEPTS

- K from ΔG° at a given T
- Spontaneity windows from signs of ΔH and ΔS
- Gibbs–Helmholtz use
- ΔG vs ΔG°

COMMON MISTAKES & QUICK NOTES

Watch out:
Using K in bar for Kc data; forgetting ΔG = 0 (not ΔG° = 0) at equilibrium. A ten-fold change in K corresponds to ΔG° change of 2.303RT ≈ 5.7 kJ mol⁻¹ at 298 K.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q31 Q32 Q33 Q34 Q35 Q36 Q37

Expect 2 question(s) next session on Free Energy Equilibria.

TOPIC 3

Partial Molar Quantities

6 questions · Easy 1 | Medium 4 | Hard 1 · PYQ frequency: High

Q38

The chemical potential (μ_i) of the i^th component is defined as

A. $\mu_i = ((\partial U)/(\partial n_i))_{T,P}$

B. $\mu_i = ((\partial H)/(\partial n_i))_{T,P}$

C. $\mu_i = ((\partial A)/(\partial n_i))_{T,P}$

D. $\mu_i = ((\partial G)/(\partial n_i))_{T,P}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer D $\mu_i = ((\partial G)/(\partial n_i))_{T,P}$

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- By definition $\mu_i = (\partial G/\partial n_i)_{T,P,n_j}$. It also equals $(\partial U/\partial n_i)_{S,V}$, $(\partial H/\partial n_i)_{S,P}$, $(\partial A/\partial n_i)_{T,V}$ — but only G uses T,P as natural variables.
- Therefore the answer is (D).

FINAL: (D) $\mu_i = ((\partial G)/(\partial n_i))_{T,P}$

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at x = 0.5.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: D

A $\mu_i = ((\partial U)/(\partial n_i))_{T,P}$

Why (D) is the key — By definition $\mu_i = (\partial G/\partial n_i)_{T,P,n_j}$. It also equals $(\partial U/\partial n_i)_{S,V}$, $(\partial H/\partial n_i)_{S,P}$, $(\partial A/\partial n_i)_{T,V}$ — but only G uses T,P as natural variables.

B $\mu_i = ((\partial H)/(\partial n_i))_{T,P}$

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

C $\mu_i = ((\partial A)/(\partial n_i))_{T,P}$

Ruled out: ΔG_mix is always negative for ideal mixing and most negative at x = 0.5.

Q39

Molar composition of a mixture of P and Q at equilibrium is 3 : 1 (P : Q). A small disturbance in composition results in change of chemical potential of P by 10 J mol⁻¹. The chemical potential of Q will change (in J mol⁻¹) by (1) 30 (2) 3.3 (3) -30 (4) -3.3 Options

A 1

B 2

C 3

D 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer C 3

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- Gibbs–Duhem: $n_P \, d\mu_P + n_Q \, d\mu_Q = 0 \rightarrow 3(10) + 1 \cdot d\mu_Q = 0 \rightarrow d\mu_Q = -30$ J mol^{-1} (option 3).
- Therefore the answer is (C).

FINAL: (C) 3

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at x = 0.5.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: C

A

1

Why (C) is the key — Gibbs–Duhem: $n_P\, d\mu_P + n_Q\, d\mu_Q = 0 \rightarrow 3(10) + 1 \cdot d\mu_Q = 0 \rightarrow d\mu_Q = -30\ J\ mol^{-1}$ (option 3).

B

2

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

D

4

Ruled out: ΔG_{mix} is always negative for ideal mixing and most negative at $x = 0.5$.

Q40

The change in chemical potential (in J) of one mole of an ideal gas, when it is compressed isothermally at 300 K from 1.0 atm to 2.0 atm, is closest to (ln 2 = 0.69)

A 1225

B 1725

C 2425

D 2725

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer B 1725

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- $\Delta\mu = RT \ln(P_2/P_1) = 8.314 \times 300 \times 0.69 = 1721$ J ≈ 1725 J. (Bank key (c) 2425 was wrong — corrected.)
- Therefore the answer is (B).

FINAL: (B) 1725

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at x = 0.5.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: B

A — **1225**

Why (B) is the key — $\Delta\mu = RT \ln(P_2/P_1) = 8.314 \times 300 \times 0.69 = 1721$ J ≈ 1725 J. (Bank key (c) 2425 was wrong — corrected.)

C — **2425**

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

D — **2725**

Ruled out: ΔG_mix is always negative for ideal mixing and most negative at x = 0.5.

Q41

The chemical potential of component 1 in a solution of binary mixture is $\mu_1 = \mu_1^0 + RT\ln p_1$, when p_1 is the partial pressure of component 1 vapour phase. The standard state μ_1^0 is:

A. Independent of temperature and pressure

B. Depends on temperature and pressure both

C. Depends on temperature only

D. Depends on pressure only

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer C Depends on temperature only

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- $\mu_1 = \mu_1^\circ + RT \ln p_1$ — the standard state is the pure component vapour at unit pressure (1 bar); since the pressure is fixed by the standard-state definition, μ_1° depends on temperature only.
- Therefore the answer is (C).

FINAL: (C) Depends on temperature only

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at $x = 0.5$.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: C

A — **Independent of temperature and pressure**

Why (C) is the key — $\mu_1 = \mu_1^\circ + RT \ln p_1$ — the standard state is the pure component vapour at unit pressure (1 bar); since the pressure is fixed by the standard-state definition, μ_1° depends on temperature only.

B — **Depends on temperature and pressure both**

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

D — **Depends on pressure only**

Ruled out: ΔG_mix is always negative for ideal mixing and most negative at x = 0.5.

Q42

A thermodynamic equation that relates the chemical potential to the composition of a mixture is known as

A. Gibb's-Helmholtz equation

B. Gibbs-Duhem equation

C. Joule-Thomson equation

D. Debye-Huckel equation

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer B Gibbs-Duhem equation

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- Gibbs–Duhem: $\Sigma n_i \, d\mu_i = 0$ at constant T, P — relates the variation of chemical potentials with composition.
- Therefore the answer is (B).

FINAL: (B) Gibbs-Duhem equation

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at x = 0.5.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: B

A **Gibb's-Helmholtz equation**

Why (B) is the key — Gibbs–Duhem: $\Sigma n_i \, d\mu_i = 0$ at constant T, P — relates the variation of chemical potentials with composition.

C **Joule-Thomson equation**

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

D **Debye-Huckel equation**

Ruled out: ΔG_mix is always negative for ideal mixing and most negative at x = 0.5.

Q43

The chemical potential (μ) of a 2 molar Na_2SO_4 solution is expressed in terms of mean ionic activity co-efficient ($\gamma_{\pm}$) as

A. $\mu^o + 5RT\ln 2 + 3RT\ln\gamma_{\pm}$

B. $\mu^o + 53T\ln 2 + 3RT\ln\gamma_{\pm}$

C. $\mu^o + +3RT\ln\gamma_{\pm}$

D. $\mu^o + +4RT\ln\gamma_{\pm}$

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Partial Molar Quantities

PYQ FREQUENCY
High · 5 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
'Partial molar = slope of the total vs n'.

Correct Answer A $\mu^{o} + 5RT\ln 2 + 3RT\ln y_{\pm}$

CONCEPT

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

↓

LOGIC / WORKING

- $Na_2SO_4 \rightarrow 2Na^+ + SO_4^{2-}$ ($\nu = 3$): $\mu = \mu^\circ + 3RT \ln a_\pm$; $a_\pm = \gamma_\pm m_\pm$, $m_\pm = (\nu_+^{\nu_+} \nu_-^{\nu_-})^{1/\nu} m = 4^{1/3} \cdot 2 \rightarrow a_\pm^3 = 32\gamma_\pm^3 = 2^5\gamma_\pm^3 \rightarrow \mu = \mu^\circ + 5RT \ln 2 + 3RT \ln \gamma_\pm$.
- Therefore the answer is (A).

FINAL: (A) $\mu^{o} + 5RT\ln 2 + 3RT\ln y_{\pm}$

SHORTCUT / EXAM TRICK

If one component's partial molar property rises with composition, the other's must fall (Gibbs–Duhem).

COMMON MISTAKE

Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

EXAM TIP

ΔG_{mix} is always negative for ideal mixing and most negative at $x = 0.5$.

MEMORY TRICK

'Partial molar = slope of the total vs n'.

Why the Other Options Are Wrong

Correct answer: A

B **μ^{o} + 53Tln 2 + 3RTlnγ_±**

Why (A) is the key — $Na_2SO_4 \rightarrow 2Na^{+} + SO_4^{2-}$ (ν = 3): μ = μ° + 3RT ln a±; a± = γ±m±, m± = (ν₊^ν₊ ν₋^ν₋)^{1/ν}m = 4^{1/3}·2 → a±³ = 32γ±³ = 2^5γ±³ → μ = μ° + 5RT ln 2 + 3RT ln γ±.

C **μ^{o} + +3RTlnγ_±**

Ruled out: Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).

D **μ^{o} + +4RTlnγ_±**

Ruled out: ΔG_mix is always negative for ideal mixing and most negative at x = 0.5.

TOPIC REVISION

Partial Molar Quantities

6 PYQs · Last-minute revision

TOPIC SUMMARY

Partial molar volume $\bar{V}_i = (\partial V/\partial n_i)_{T,p,n_j}$; $V = \Sigma n_i \bar{V}_i$; Gibbs–Duhem $\Sigma n_i \, d\bar{V}_i = 0$; chemical potential is the partial molar Gibbs energy; ideal solution $\mu_i = \mu_i^* + RT \ln x_i$.

IMPORTANT FORMULA SHEET

- $V = n_A \bar{V}_A + n_B \bar{V}_B$
- $\Sigma \, n_i \, d\bar{V}_i = 0$ (Gibbs–Duhem)
- $\mu_i = \mu_i^\circ + RT \ln a_i$
- $\Delta G_{mix(ideal)} = nRT \Sigma \, x_i \ln x_i$; $\Delta S_{mix} = -nR \Sigma \, x_i \ln x_i$; $\Delta H_{mix} = 0$

FREQUENTLY ASKED CONCEPTS

- Volume of a mixture from partial molar volumes
- Gibbs–Duhem to get the other component
- Ideal mixing functions
- Method of intercepts

COMMON MISTAKES & QUICK NOTES

Watch out:
Using molar volumes of pure components for a non-ideal mixture (partial molar volumes can even be negative, e.g. $MgSO_4$ in water).
ΔG_{mix} is always negative for ideal mixing and most negative at x = 0.5.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q38 Q39 Q40 Q41 Q42 Q43

Expect 1 question(s) next session on Partial Molar Quantities.

TOPIC 4

Thermodynamics – General

75 questions · Easy 28 | Medium 47 | Hard 0 · PYQ frequency: Very High

Q44

For a system of constant composition, the pressure (P) is given by.

A. -((∂ U)/(∂ S))_V

B. -((∂ U)/(∂ V))_S

C. ((∂ V)/(∂ S))_T

D. ((∂ U)/(∂ V))_T

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B -((∂ U)/(∂ V))_S

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- From dU = TdS − PdV: (∂U/∂V)_S = −P, so P = −(∂U/∂V)_S.
- Therefore the answer is (B).

FINAL: (B) -((∂ U)/(∂ V))_S

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **-((∂ U)/(∂ S))_V**

Why (B) is the key — From dU = TdS − PdV: (∂U/∂V)_S = −P, so P = −(∂U/∂V)_S.

C **((∂ V)/(∂ S))_T**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **((∂ U)/(∂ V))_T**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q45

For the reaction $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$, the value of $\Delta H - \Delta U$ (in kJ) at 300 K and 1 bar is

A. –5.0

B. 0.0

C. 2.5

D. 5.0

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A –5.0

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- ΔH − ΔU = Δn_g RT; Δn_g = 2 − (1 + 3) = −2 (water is liquid). = −2 × 8.314 × 300 = −4.99 ≈ −5.0 kJ.
- Therefore the answer is (A).

FINAL: (A) –5.0

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **0.0**

Why (A) is the key — ΔH − ΔU = Δn_g RT; Δn_g = 2 − (1 + 3) = −2 (water is liquid). = −2 × 8.314 × 300 = −4.99 ≈ −5.0 kJ.

C **2.5**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **5.0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q46

The internal pressure $(\partial U/\partial V)_T$ of a real gas is related to the compressibility factor Z = ptildeV/RT by [where, tildeV is the molar volume]

A $(\partial U/\partial V)_T = RT(\partial Z/\partial V)_T$

B $(\partial U/\partial V)_T = RT(tildeVZ)$

C $(\partial U/\partial V)_T = (RT_2/tildeV)(\partial Z/\partial T)_V$

D $(\partial U/\partial V)_T = (tildeV/RT_2)(\partial Z/\partial T)_V$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C $(\partial U/\partial V)_T = (RT_2/\tilde{V})(\partial Z/\partial T)_V$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Internal pressure $(\partial U/\partial V)_T = T(\partial P/\partial T)_V - P$. With $P = ZRT/\tilde{V}$: $T(\partial P/\partial T)_V = (RT/\tilde{V})[Z + T(\partial Z/\partial T)_V]$; subtracting P leaves $(RT^2/\tilde{V})(\partial Z/\partial T)_V$.
- Therefore the answer is (C).

FINAL: (C) $(\partial U/\partial V)_T = (RT_2/\tilde{V})(\partial Z/\partial T)_V$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **$(\partial U/\partial V)_T = RT(\partial Z/\partial V)_T$**

Why (C) is the key — Internal pressure $(\partial U/\partial V)_T = T(\partial P/\partial T)_V - P$. With $P = ZRT/\tilde{V}$: $T(\partial P/\partial T)_V = (RT/\tilde{V})[Z + T(\partial Z/\partial T)_V]$; subtracting P leaves $(RT^2/\tilde{V})(\partial Z/\partial T)_V$.

B **$(\partial U/\partial V)_T = RT(\text{tildeVZ})$**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **$(\partial U/\partial V)_T = (\text{tildeV}/RT_2)(\partial Z/\partial T)_V$**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q47

A carnot takes up 90 J of heat from the source kept at 300K. The correct statement among the following is

A. It transfers 60 J of heat to the sink at 200K

B. It transfers 50 J of heat to the sink at 200K

C. It transfers 60 J of heat to the sink at 250 K

D. It transfers 50 J of heat to the sink at 250 K

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A It transfers 60 J of heat to the sink at 200K

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Carnot: $q_c/q_h = T_c/T_h$. Sink at 200 K: $q_c = 90 \times 200/300 = 60$ J ✓. (Sink at 250 K would give 75 J, not in the options.)
- Therefore the answer is (A).

FINAL: (A) It transfers 60 J of heat to the sink at 200K

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **It transfers 50 J of heat to the sink at 200K**

Why (A) is the key — Carnot: $q_c/q_h = T_c/T_h$. Sink at 200 K: $q_c = 90 \times 200/300 = 60$ J ✓. (Sink at 250 K would give 75 J, not in the options.)

C **It transfers 60 J of heat to the sink at 250 K**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **It transfers 50 J of heat to the sink at 250 K**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q48

The correct thermodynamics relation among the following is

A ((∂ U)/(∂ V))_S = -P

B ((∂ H)/(∂ V))_S = -P

C ((∂ G)/(∂ V))_S = -P

D ((∂ A)/(∂ V))_S = -P

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A ((∂ U)/(∂ V))_S = -P

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- dU = TdS − PdV → (∂U/∂V)_S = −P. For H: (∂H/∂P)_S = V; for A: (∂A/∂V)_T = −P (not at constant S); for G: (∂G/∂P)_T = V.
- Therefore the answer is (A).

FINAL: (A) ((∂ U)/(∂ V))_S = -P

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **((∂ H)/(∂ V))_S = -P**

Why (A) is the key — dU = TdS − PdV → (∂U/∂V)_S = −P. For H: (∂H/∂P)_S = V; for A: (∂A/∂V)_T = −P (not at constant S); for G: (∂G/∂P)_T = V.

C **((∂ G)/(∂ V))_S = -P**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **((∂ A)/(∂ V))_S = -P**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q49

The heat capacity of 10 mol of an ideal gas at a certain temperature is 300 JK^{-1} at constant pressure. The heat capacity of the same gas at the same temperature and at constant volume would be

A. 383 JK^{-1}

B. 217 JK^{-1}

C. 134 JK^{-1}

D. 466 JK^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B 217 JK^{-1}

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $C_P - C_V = nR = 10 \times 8.314 = 83.1\ J\ K^{-1} \rightarrow C_V = 300 - 83 = 217\ J\ K^{-1}$.
- Therefore the answer is (B).

FINAL: (B) 217 JK^{-1}

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **383 JK⁻¹**

Why (B) is the key — $C_P - C_V = nR = 10 \times 8.314 = 83.1$ J K⁻¹ → $C_V = 300 - 83 = 217$ J K⁻¹.

C **134 JK⁻¹**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **466 JK⁻¹**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q50

Work (w) involved in isothermal reversible expansion from V_i to V_f of n moles of an ideal gas is

A. $w = -nRT\ln(V_f/V_i)$

B. $w = nRT\ln(V_f/V_i)$

C. $w = -nRT(V_f/V_i)$

D. $w = -nRT\log(V_f/V_i)$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A $w = -nRT\ln(V_f/V_i)$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $w = -\int P\,dV = -nRT \int dV/V = -nRT \ln(V_f/V_i)$ (sign convention: work done on the system; negative for expansion).
- Therefore the answer is (A).

FINAL: (A) $w = -nRT\ln(V_f/V_i)$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **w = nRTln(V_f/Vᵢ)**

Why (A) is the key — w = −∫P dV = −nRT ∫dV/V = −nRT ln(V_f/V_i) (sign convention: work done on the system; negative for expansion).

C **w = -nRT(V_f/Vᵢ)**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **w = -nRTlog(V_f/Vᵢ)**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q51

For a process in a closed system, temperature is equal to

A ((∂ H)/(∂ P))_S

B -((∂ A)/(∂ V))_T

C ((∂ G)/(∂ P))_T

D ((∂ H)/(∂ S))_P

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D ((∂ H)/(∂ S))_P

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- dH = TdS + VdP → T = (∂H/∂S)_P. (Also T = (∂U/∂S)_V.)
- Therefore the answer is (D).

FINAL: (D) ((∂ H)/(∂ S))_P

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **((∂ H)/(∂ P))_S**

Why (D) is the key — dH = TdS + VdP → T = (∂H/∂S)_P. (Also T = (∂U/∂S)_V.)

B **-((∂ A)/(∂ V))_T**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **((∂ G)/(∂ P))_T**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q52

Given the following two relations, $x_1\, d\mu_1 + x_2\, d\mu_2 = 0$ And $x_1\, dtildeV_1 + x_2\, dtildeV_2 = 0$ for a binary liquid mixture at constant temperature and pressure, the true statement is that,

A. Both the relations are correct

B. Relation A is correct, but B is not

C. Relation B is correct, but A is not

D. Both the relations are incorrect, except for very dilute solutions

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A Both the relations are correct

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- The Gibbs–Duhem equation $\Sigma x_i \, dY_i = 0$ holds for every partial molar property (μ, $\bar{V}$, $\bar{H}$ …) at constant T and P, so both relations are correct for any binary mixture.
- Therefore the answer is (A).

FINAL: (A) Both the relations are correct

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **Relation A is correct, but B is not**

Why (A) is the key — The Gibbs–Duhem equation $\Sigma x_i \, dY_i = 0$ holds for every partial molar property (μ, $\bar{V}$, $\bar{H}$ …) at constant T and P, so both relations are correct for any binary mixture.

C **Relation B is correct, but A is not**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **Both the relations are incorrect, except for very dilute solutions**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q53

At high pressure, the fugacity coefficient of a real gas is greater than one, because

A. Attractive term overweighs the repulsive term

B. Repulsive term overweighs the attractive term

C. Repulsive term is equal to the attractive term

D. The system is independent of both the attractive and repulsive terms

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B Repulsive term overweighs the attractive term

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $\ln \varphi = \int (Z - 1)/P \, dP$. At high P repulsion dominates, $Z > 1$, so $\varphi = f/P > 1$ (the gas 'escapes' more readily than an ideal gas).
- Therefore the answer is (B).

FINAL: (B) Repulsive term overweighs the attractive term

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A — **Attractive term overweighs the repulsive term**

Why (B) is the key — ln φ = ∫(Z − 1)/P dP. At high P repulsion dominates, Z > 1, so φ = f/P > 1 (the gas 'escapes' more readily than an ideal gas).

C — **Repulsive term is equal to the attractive term**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D — **The system is independent of both the attractive and repulsive terms**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q54

The value of Δ U - Δ H for the reaction $Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$ is

A. -3RT

B. +3RT

C. +RT

D. -RT

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A -3RT

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $\Delta H - \Delta U = \Delta n_g RT$ with $\Delta n_g = +3$ (only CO is gaseous) → $\Delta U - \Delta H = -3RT$.
- Therefore the answer is (A).

FINAL: (A) -3RT

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **+3RT**

Why (A) is the key — $\Delta H - \Delta U = \Delta n_g RT$ with $\Delta n_g = +3$ (only CO is gaseous) → $\Delta U - \Delta H = -3RT$.

C **+RT**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **-RT**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q55

Δ H of a reaction is equal to slope of the plot of

A. Δ G vs (1/T)

B. Δ G vs T

C. (Δ G/T) vs T

D. (Δ G/T) vs (1/T)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D (Δ G/T) vs (1/T)

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Gibbs–Helmholtz: $[\partial(\Delta G/T)/\partial(1/T)]_P = \Delta H$, so a plot of ΔG/T against 1/T has slope ΔH.
- Therefore the answer is (D).

FINAL: (D) (Δ G/T) vs (1/T)

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **Δ G vs (1/T)**

Why (D) is the key — Gibbs–Helmholtz: $[\partial(\Delta G/T)/\partial(1/T)]_P = \Delta H$, so a plot of ΔG/T against 1/T has slope ΔH.

B **Δ G vs T**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **(Δ G/T) vs T**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q56 **A reversible expansion of 1.0 mol of an ideal gas is carried out from 1.0 L to 4.0 L under isothermal condition at 300K. Δ G for this process is**

A 300Rln 2

B 600Rln 2

C -600Rln 2

D -300Rln 2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C -600RIn 2

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Isothermal ideal gas: $\Delta G = nRT \ln(P_2/P_1) = nRT \ln(V_1/V_2) = 300R \ln(1/4) = -600R \ln 2$.
- Therefore the answer is (C).

FINAL: (C) -600RIn 2

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **300RIn 2**

Why (C) is the key — Isothermal ideal gas: $\Delta G = nRT \ln(P_2/P_1) = nRT \ln(V_1/V_2) = 300R \ln(1/4) = -600R \ln 2$.

B **600RIn 2**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **-300RIn 2**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q57

Triple point pressure of substances A, B, C and D are 0.2, 0.5, 0.8 and 1.2 bar, respectively. The substance which sublimes under standard conditions on increasing temperature is

A. A

B. B

C. C

D. D

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D D

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- A substance sublimes at 1 bar when its triple-point pressure exceeds 1 bar — then no liquid can exist at 1 bar. Only D (1.2 bar) qualifies (cf. CO_2, 5.1 bar).
- Therefore the answer is (D).

FINAL: (D) D

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A

Why (D) is the key — A substance sublimes at 1 bar when its triple-point pressure exceeds 1 bar — then no liquid can exist at 1 bar. Only D (1.2 bar) qualifies (cf. CO_2, 5.1 bar).

B

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q58

The partial derivative ((∂ T)/(∂ V))_P is equal to

A -((∂ P)/(∂ S))_T

B -((∂ P)/(∂ S))_V

C -((∂ P)/(∂ S))ₙ

D -((∂ P)/(∂ S))_H

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A -((∂ P)/(∂ S))_T

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Maxwell relation from dG = −SdT + VdP: (∂S/∂P)_T = −(∂V/∂T)_P. Inverting both sides: (∂T/∂V)_P = −(∂P/∂S)_T.
- Therefore the answer is (A).

FINAL: (A) -((∂ P)/(∂ S))_T

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **-((∂ P)/(∂ S))_V**

Why (A) is the key — Maxwell relation from dG = −SdT + VdP: (∂S/∂P)_T = −(∂V/∂T)_P. Inverting both sides: (∂T/∂V)_P = −(∂P/∂S)_T.

C **$-((\partial P)/(\partial S))_n$**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **-((∂ P)/(∂ S))_H**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q59

The equation of state for one mole of a gas is given by P(V - b) = RT, where b and R are constants. The value of ((∂ H)/(∂ P))_T is

A. V - b

B. b

C. 0

D. (RT)/(P) + b

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B b

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $(\partial H/\partial P)_T = V - T(\partial V/\partial T)_P$. From $P(V - b) = RT$: $(\partial V/\partial T)_P = R/P \rightarrow V - RT/P = V - (V - b) = b$.
- Therefore the answer is (B).

FINAL: (B) b

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **V - b**

Why (B) is the key — $(\partial H/\partial P)_T = V - T(\partial V/\partial T)_P$. From $P(V - b) = RT$: $(\partial V/\partial T)_P = R/P \rightarrow V - RT/P = V - (V - b) = b$.

C **0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **(RT)/(P) + b**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q60

For a closed system in the absence of non-PV work, the correct statement is

A. dU = TdS - PdV

B. dG = VdP + SdT

C. dU = TdS + PdV

D. dU = VdP - SdT

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A dU = TdS - PdV

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Fundamental equation: $dU = TdS - PdV$ (closed system, PV work only). Correspondingly $dG = VdP - SdT$, so (b) and (d) have wrong signs.
- Therefore the answer is (A).

FINAL: (A) dU = TdS - PdV

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **dG = VdP + SdT**

Why (A) is the key — Fundamental equation: dU = TdS − PdV (closed system, PV work only). Correspondingly dG = VdP − SdT, so (b) and (d) have wrong signs.

C **dU = TdS + PdV**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **dU = VdP - SdT**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q61

The volume change in a certain phase transition is 2.0 mL mol^{-1} at the transition point. From this, we may conclude that the transition is most likely to

A. First order phase transition

B. Second order phase transition

C. Third order phase transition

D. Î» phase transition

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A First order phase transition

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Ehrenfest: a first-order transition has discontinuous first derivatives of G — finite ΔV and ΔS (latent heat). A non-zero $\Delta V = 2$ mL mol^{-1} marks a first-order transition.
- Therefore the answer is (A).

FINAL: (A) First order phase transition

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B — **Second order phase transition**

Why (A) is the key — Ehrenfest: a first-order transition has discontinuous first derivatives of G — finite ΔV and ΔS (latent heat). A non-zero ΔV = 2 mL mol^{-1} marks a first-order transition.

C — **Third order phase transition**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D — **Î» phase transition**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q62

(C_p - C_v) for a non-ideal gas differs from (C_p - C_v) for a perfect gas by the expression (1) ((∂ P)/(∂ T))_V((∂ U)/(∂ P))_S (2) ((∂ V)/(∂ T))_P((∂ U)/(∂ V))_T (3) -(1)/(T)((∂ V)/(∂ T))_P((∂ U)/(∂ V))_T (4) ((∂ P)/(∂ T))_V((∂ U)/(∂ T))_P

A 1

B 2

C 3

D 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B 2

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $C_P - C_V = [P + (\partial U/\partial V)_T](\partial V/\partial T)_P$. The $P(\partial V/\partial T)_P$ part is the ideal-gas value nR; the extra term is $(\partial U/\partial V)_T (\partial V/\partial T)_P$, zero for a perfect gas (option 2).
- Therefore the answer is (B).

FINAL: (B) 2

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **1**

Why (B) is the key — $C_P - C_V = [P + (\partial U/\partial V)_T](\partial V/\partial T)_P$. The $P(\partial V/\partial T)_P$ part is the ideal-gas value nR; the extra term is $(\partial U/\partial V)_T (\partial V/\partial T)_P$, zero for a perfect gas (option 2).

C **3**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **4**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q63

A monatomic perfect gas undergoes expansion from (p_1, V_1) to (p_2, V_2) under isothermal or adiabatic conditions. The pressure of the gas will fall more rapidly under adiabatic conditions because

A $p \propto (1)/(V)$

B $p \propto (1)/(V^{7}/5)$

C $p \propto (1)/(V^{3}/2)$

D $p \propto (1)/(V^{5}/3)$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D $p \propto (1)/(V^{5}/3)$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Monatomic ideal gas: γ = C_P/C_V = (5/2)/(3/2) = 5/3. Reversible adiabat PV^γ = const → p ∝ 1/V^{5/3}, steeper than the isotherm p ∝ 1/V.
- Therefore the answer is (D).

FINAL: (D) $p \propto (1)/(V^{5}/3)$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **p ∝ (1)/(V)**

Why (D) is the key — Monatomic ideal gas: γ = C_P/C_V = (5/2)/(3/2) = 5/3. Reversible adiabat PV^γ = const → p ∝ 1/V^{5/3}, steeper than the isotherm p ∝ 1/V.

B **p ∝ (1)/(V⁷/5)**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **p ∝ (1)/(V³/2)**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q64

For a van der Waals gas, the partial derivative is ((∂ U)/(∂ V))_T

A. $(V_m)/(a)$

B. $(V_m^2)/(a)$

C. $(a)/(V_m^2)$

D. $(a)/(V_m)$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C (a)/(V_m^2)

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- (∂U/∂V)_T = T(∂P/∂T)_V − P. vdW: P = RT/(V_m − b) − a/V_m², (∂P/∂T)_V = R/(V_m − b) → T(∂P/∂T)_V − P = a/V_m².
- Therefore the answer is (C).

FINAL: (C) (a)/(V_m^2)

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A $(V_m)/(a)$

Why (C) is the key — $(\partial U/\partial V)_T = T(\partial P/\partial T)_V - P$. vdW: $P = RT/(V_m - b) - a/V_m^2$, $(\partial P/\partial T)_V = R/(V_m - b) \rightarrow T(\partial P/\partial T)_V - P = a/V_m^2$.

B $(V_m^2)/(a)$

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D $(a)/(V_m)$

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q65

The vapour of a pure substance, when cooled under a pressure less than its triple-point pressure,

A. Liquefies

B. Liquefies first and then solidifies

C. Solidifies directly

D. Remains unchanged

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C Solidifies directly

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Below the triple-point pressure the liquid cannot exist; cooling the vapour crosses the sublimation curve and it deposits directly as solid.
- Therefore the answer is (C).

FINAL: (C) Solidifies directly

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **Liquefies**

Why (C) is the key — Below the triple-point pressure the liquid cannot exist; cooling the vapour crosses the sublimation curve and it deposits directly as solid.

B **Liquefies first and then solidifies**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **Remains unchanged**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q66

The quantities, which are held fixed in a canonical ensemble are

A. N, T and P

B. V, T and N

C. N, V and E

D. μ, V and P

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B V, T and N

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Canonical ensemble: fixed N, V, T (closed, isothermal). Microcanonical: N, V, E. Grand canonical: μ, V, T.
- Therefore the answer is (B).

FINAL: (B) V, T and N

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **N, T and P**

Why (B) is the key — Canonical ensemble: fixed N, V, T (closed, isothermal). Microcanonical: N, V, E. Grand canonical: μ, V, T.

C **N, V and E**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **μ, V and P**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q67

An ideal gas was subjected to a reversible, adiabatic, expansion and then its initial volume was restored by a reversible, isothermal compression. If 'q' denotes the heat added to the system and 'w' the work done by the system, then

A. $w < 0, q < 0$

B. $w > 0, q < 0$

C. $w < 0, q > 0$

D. $w > 0, q > 0$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B w > 0, q < 0

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Adiabatic expansion: q = 0, gas does work (w > 0) and cools to T_2. Isothermal compression at T_2 back to V_1: heat is released (q < 0) and work done on the gas = $RT_2 \ln(V_2/V_1)$ which is less than the expansion work $C_V(T_1 - T_2)$. Net: w > 0 (by system), q < 0.
- Therefore the answer is (B).

FINAL: (B) w > 0, q < 0

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **w < 0, q < 0**

Why (B) is the key — Adiabatic expansion: q = 0, gas does work (w > 0) and cools to T_2. Isothermal compression at T_2 back to V_1: heat is released (q < 0) and work done on the gas = $RT_2 \ln(V_2/V_1)$ which is less than the expansion work $C_V(T_1 - T_2)$. Net: w > 0 (by system), q < 0.

C **w < 0, q > 0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **w > 0, q > 0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q68

The lowest pressure at which the liquid phase of a pure substance can exist is known as

A. critical point pressure

B. super-incumbent pressure

C. triple-point pressure

D. saturation vapour pressure

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C triple-point pressure

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- The liquid region of a phase diagram starts at the triple point; below the triple-point pressure only solid and vapour exist.
- Therefore the answer is (C).

FINAL: (C) triple-point pressure

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: $G = H - TS$'.

Why the Other Options Are Wrong

Correct answer: C

A **critical point pressure**

Why (C) is the key — The liquid region of a phase diagram starts at the triple point; below the triple-point pressure only solid and vapour exist.

B **super-incumbent pressure**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **saturation vapour pressure**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q69

Which of the following statements is true for a cyclic process?

A. $\partial q = 0$

B. $\partial w = 0$

C. Heat can be completely converted into work

D. Work can be completely converted into heat

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D Work can be completely converted into heat

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Kelvin–Planck: heat cannot be completely converted to work in a cycle (some must be rejected), but work can be completely converted to heat (friction, Joule heating). $\oint dq = -\oint dw \neq 0$ in general.
- Therefore the answer is (D).

FINAL: (D) Work can be completely converted into heat

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A ∂ q = 0

Why (D) is the key — Kelvin–Planck: heat cannot be completely converted to work in a cycle (some must be rejected), but work can be completely converted to heat (friction, Joule heating). $\oint dq = -\oint dw \neq 0$ in general.

B ∂ w = 0

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

C Heat can be completely converted into work

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q70

The figure below represents the path followed by a gas during expansion from A → B. The work done is (L atm)

A. 0

B. 9

C. 5

D. 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D 4

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Constant-volume drop from 5 to 1 atm does no work; the expansion at 1 atm from 1 to 5 L gives $w = p\Delta V = 4$ L atm.
- Therefore the answer is (D).

FINAL: (D) 4

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **0**

Why (D) is the key — Constant-volume drop from 5 to 1 atm does no work; the expansion at 1 atm from 1 to 5 L gives w = pΔV = 4 L atm.

B **9**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **5**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q71

The number of phases, components and degrees of freedom, when Ar is added to an equilibrium mixture of NO, O_2 and NO_2 in gas phase are, respectively,

A. 1, 3, 5

B. 1, 4, 5

C. 1, 3, 4

D. 1, 4, 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C 1, 3, 4

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- All gases: P = 1. Species NO, O_2, NO_2, Ar = 4, one equilibrium ($2NO + O_2 \rightleftharpoons 2NO_2$) → C = 3. F = C − P + 2 = 3 − 1 + 2 = 4.
- Therefore the answer is (C).

FINAL: (C) 1, 3, 4

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **1, 3, 5**

Why (C) is the key — All gases: P = 1. Species NO, O_2, NO_2, Ar = 4, one equilibrium ($2NO + O_2 \rightleftharpoons 2NO_2$) → C = 3. F = C − P + 2 = 3 − 1 + 2 = 4.

B **1, 4, 5**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **1, 4, 4**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q72

Two phases α and β of a species are in equilibrium. The correct relations observed among the variables, T, p and μ are

A. $T_\alpha = T_\beta; p_\alpha \neq p_\beta; \mu_\alpha = \mu_\beta$

B. $T_\alpha \neq T_\beta; p_\alpha = p_\beta; \mu_\alpha = \mu_\beta$

C. $T_\alpha = T_\beta; p_\alpha = p_\beta; \mu_\alpha = \mu_\beta$

D. $T_\alpha = T_\beta; p_\alpha \neq p_\beta; \mu_\alpha \neq \mu_\beta$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C $T_\alpha = T_\beta; p_\alpha = p_\beta; \mu_\alpha = \mu_\beta$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Phase equilibrium requires thermal ($T_\alpha = T_\beta$), mechanical ($p_\alpha = p_\beta$) and chemical ($\mu_\alpha = \mu_\beta$) equilibrium — all three equal. (Bank key (a) with $p_\alpha \neq p_\beta$ applies only to curved interfaces — verify.)
- Therefore the answer is (C).

FINAL: (C) $T_\alpha = T_\beta; p_\alpha = p_\beta; \mu_\alpha = \mu_\beta$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **$T_\alpha = T_\beta; p_\alpha \neq p_\beta; \mu_\alpha = \mu_\beta$**

Why (C) is the key — Phase equilibrium requires thermal ($T_\alpha = T_\beta$), mechanical ($p_\alpha = p_\beta$) and chemical ($\mu_\alpha = \mu_\beta$) equilibrium — all three equal. (Bank key (a) with $p_\alpha \neq p_\beta$ applies only to curved interfaces — verify.)

B **$T_\alpha \neq T_\beta; p_\alpha = p_\beta; \mu_\alpha = \mu_\beta$**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **$T_\alpha = T_\beta; p_\alpha \neq p_\beta; \mu_\alpha \neq \mu_\beta$**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q73

Heat capacity of a species is independent of temperature if it is

A. tetratomic

B. triatomic

C. diatomic

D. monatomic

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D monatomic

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- A monatomic gas has only translational energy: $C_V = (3/2)R$ at all temperatures. Rotational/vibrational contributions of polyatomics switch on with T.
- Therefore the answer is (D).

FINAL: (D) monatomic

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **tetratomic**

Why (D) is the key — A monatomic gas has only translational energy: C_V = (3/2)R at all temperatures. Rotational/vibrational contributions of polyatomics switch on with T.

B **triatomic**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **diatomic**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q74

((∂ H)/(∂ P))_T has the dimension of

A. pressure

B. volume

C. temperature

D. heat capacity

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B volume

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $(\partial H/\partial P)_T = V - T(\partial V/\partial T)_P$: both terms are volumes (the isothermal Joule–Thomson coefficient has units of volume, J $Pa^{-1} = m^3$).
- Therefore the answer is (B).

FINAL: (B) volume

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **pressure**

Why (B) is the key — $(\partial H/\partial P)_T = V - T(\partial V/\partial T)_P$: both terms are volumes (the isothermal Joule–Thomson coefficient has units of volume, J Pa^{-1} = m^3).

C **temperature**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **heat capacity**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q75

For an ideal gas at 300 K

A ((∂ U)/(∂ V))_T = 0

B ((∂ U)/(∂ T))_V = 0

C ((∂ H)/(∂ T))_P = 0

D ((∂ G)/(∂ T))_P = 0

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A $((\partial U)/(\partial V))_T = 0$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Ideal gas: U depends on T only, so $(\partial U/\partial V)_T = 0$ (zero internal pressure). $(\partial U/\partial T)_V = C_V \neq 0$, $(\partial H/\partial T)_P = C_P \neq 0$, $(\partial G/\partial T)_P = -S \neq 0$.
- Therefore the answer is (A).

FINAL: (A) $((\partial U)/(\partial V))_T = 0$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **((∂ U)/(∂ T))_V = 0**

Why (A) is the key — Ideal gas: U depends on T only, so (∂U/∂V)_T = 0 (zero internal pressure). (∂U/∂T)_V = C_V ≠ 0, (∂H/∂T)_P = C_P ≠ 0, (∂G/∂T)_P = −S ≠ 0.

C **((∂ H)/(∂ T))_P = 0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **((∂ G)/(∂ T))_P = 0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q76

The correct statement for any cyclic thermodynamic process is

A. oint dq = 0

B. oint dw = 0

C. oint dU = 0

D. oint V dq = 0

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C oint dU = 0

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- For any cyclic process the system returns to its initial state, so every state function (U, H, S, G) has zero net change: ∮dU = 0. q and w are path functions and need not be zero.
- Therefore the answer is (C).

FINAL: (C) oint dU = 0

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **oint dq = 0**

Why (C) is the key — For any cyclic process the system returns to its initial state, so every state function (U, H, S, G) has zero net change: ∮dU = 0. q and w are path functions and need not be zero.

B **oint dw = 0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **oint V dq = 0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q77

A phase transition process is always

A. isothermal - isoentropic

B. isochoric - isothermal

C. isobaric - isochoric

D. isothermal - isobaric

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D isothermal - isobaric

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Two phases coexist at a fixed T for a given P (Clapeyron curve); during the transition both T and P stay constant → isothermal–isobaric. (Entropy and volume change, so not isentropic/isochoric.)
- Therefore the answer is (D).

FINAL: (D) isothermal - isobaric

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **isothermal - isoentropic**

Why (D) is the key — Two phases coexist at a fixed T for a given P (Clapeyron curve); during the transition both T and P stay constant → isothermal–isobaric. (Entropy and volume change, so not isentropic/isochoric.)

B **isochoric - isothermal**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **isobaric - isochoric**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q78

The correct statement for any cyclic thermodynamic process is

A. dq = 0

B. dw = 0

C. dU = 0

D. Vdq = 0

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C dU = 0

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- For any cyclic process the system returns to its initial state, so every state function (U, H, S, G) has zero net change: $\oint dU = 0$. q and w are path functions and need not be zero.
- Therefore the answer is (C).

FINAL: (C) dU = 0

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **dq = 0**

Why (C) is the key — For any cyclic process the system returns to its initial state, so every state function (U, H, S, G) has zero net change: $\oint dU = 0$. q and w are path functions and need not be zero.

B **dw = 0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **Vdq = 0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q79

The fugacity of a real gas is less than the pressure (P) of an ideal gas at the same temperature (T) only when (T_b is the Boyle temperature of the real gas)

A. high P, $T < T_b$

B. low P, $T < T_b$

C. high P, $T > T_b$

D. low P, $T > T_b$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B low P, T < T_b

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- f < P needs Z < 1 (attractions dominate). Z < 1 occurs at low–moderate P below the Boyle temperature; above T_B or at high P repulsion gives Z > 1 and f > P.
- Therefore the answer is (B).

FINAL: (B) low P, T < T_b

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A — **high P, T < T_b**

Why (B) is the key — f < P needs Z < 1 (attractions dominate). Z < 1 occurs at low–moderate P below the Boyle temperature; above T_B or at high P repulsion gives Z > 1 and f > P.

C — **high P, T > T_b**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D — **low P, T > T_b**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q80

The minimum work required by an engine to transfer 5 J of heat from a reservoir at 100 K to one at 300 K is

A. 5 J

B. 10 J

C. 15 J

D. 20 J

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B 10 J

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Reversible refrigerator: $w_{min} = q_c (T_h - T_c)/T_c = 5 \times (300 - 100)/100 = 10$ J.
- Therefore the answer is (B).

FINAL: (B) 10 J

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **5 J**

Why (B) is the key — Reversible refrigerator: w_min = q_c (T_h − T_c)/T_c = 5 × (300 − 100)/100 = 10 J.

C **15 J**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **20 J**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q81

The maximum number of phases that can be simultaneously in equilibrium for a one component system is

A 1

B 2

C 3

D 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C 3

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Phase rule $F = C - P + 2$ with $C = 1$: $F \geq 0 \rightarrow P \leq 3$. Three phases coexist only at the (invariant) triple point.
- Therefore the answer is (C).

FINAL: (C) 3

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **1**

Why (C) is the key — Phase rule F = C − P + 2 with C = 1: F ≥ 0 → P ≤ 3. Three phases coexist only at the (invariant) triple point.

B **2**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **4**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q82

In an adiabatic system, the work done to change its state from A to B is

(A) dependent on path from A to B

(B) independent of path from A to B

(C) path dependence is related to particulars of state A and B

(D) path dependence is related to both states A and B and choice of path

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B independent of path from A to B

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Adiabatic: $q = 0$, so $w = \Delta U$. U is a state function, hence the adiabatic work depends only on the initial and final states, not on the path (this is how the first law defines U).
- Therefore the answer is (B).

FINAL: (B) independent of path from A to B

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **dependent on path from A to B**

Why (B) is the key — Adiabatic: q = 0, so w = ΔU. U is a state function, hence the adiabatic work depends only on the initial and final states, not on the path (this is how the first law defines U).

C **path dependence is related to particulars of state A and B**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **path dependence is related to both states A and B and choice of path**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q83

ΔS^0_{univ} for the following reaction, at 298 K is: $N_2 + 3H_2 \rightarrow 2NH_3$ $\Delta S^0_{sys} = -197\ J\ K^{-1}$, $\Delta H^0_{sys} = -91.8\ kJ$

A. $-197\ J\ K^{-1}$

B. $0\ J\ K^{-1}$

C. $-308\ J\ K^{-1}$

D. $111\ J\ K^{-1}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D 111 J K⁻¹

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- ΔS_surr = −ΔH_sys/T = +91 800/298 = +308 J K⁻¹. ΔS_univ = ΔS_sys + ΔS_surr = −197 + 308 = +111 J K⁻¹ (spontaneous).
- Therefore the answer is (D).

FINAL: (D) 111 J K⁻¹

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **-197 J K⁻¹**

Why (D) is the key — ΔS_surr = −ΔH_sys/T = +91 800/298 = +308 J K⁻¹. ΔS_univ = ΔS_sys + ΔS_surr = −197 + 308 = +111 J K⁻¹ (spontaneous).

B **0 J K⁻¹**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **-308 J K⁻¹**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q84

If a gas obeys the equation of state P(V - nb) = nRT, the ratio ((C_P - C_V))/((C_P - C_V)ideal) is:

A >1

B <1

C 1

D (1 - b)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C 1

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $C_P - C_V = T(\partial P/\partial T)_V(\partial V/\partial T)_P$. For $P(V - nb) = nRT$: $(\partial P/\partial T)_V = nR/(V - nb)$, $(\partial V/\partial T)_P = nR/P \rightarrow C_P - C_V = nR$, identical to the ideal gas → ratio = 1.
- Therefore the answer is (C).

FINAL: (C) 1

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **>1**

Why (C) is the key — $C_P - C_V = T(\partial P/\partial T)_V(\partial V/\partial T)_P$. For $P(V - nb) = nRT$: $(\partial P/\partial T)_V = nR/(V - nb)$, $(\partial V/\partial T)_P = nR/P \rightarrow C_P - C_V = nR$, identical to the ideal gas → ratio = 1.

B **<1**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **(1 - b)**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q85

For an ideal gas

A ((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=0

B ((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=-1

C ((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=+1

D ((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=+2

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B $((\partial P)/(\partial T))_V((\partial T)/(\partial V))_P((\partial V)/(\partial P))_T=-1$

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Cyclic (triple-product) rule for any equation of state $f(P,V,T) = 0$: $(\partial P/\partial T)_V(\partial T/\partial V)_P(\partial V/\partial P)_T = -1$. Check for ideal gas: $(nR/V)(P/nR)(-nRT/P^2) = -nRT/(PV) = -1$.
- Therefore the answer is (B).

FINAL: (B) $((\partial P)/(\partial T))_V((\partial T)/(\partial V))_P((\partial V)/(\partial P))_T=-1$

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=0**

Why (B) is the key — Cyclic (triple-product) rule for any equation of state f(P,V,T) = 0: (∂P/∂T)_V(∂T/∂V)_P(∂V/∂P)_T = −1. Check for ideal gas: (nR/V)(P/nR)(−nRT/P²) = −nRT/(PV) = −1.

C **((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=+1**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **((∂ P)/(∂ T))_V((∂ T)/(∂ V))_P((∂ V)/(∂ P))_T=+2**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q86

At any temperature T, fugacity coefficient (γ) is given by lnγ=∫₀^P(Z-1)/(P') dP' where Z is the compressibility factor. The fugacity coefficient of a real gas governed by equations of state, P(V-b)=RT with 'b' a constant is given by

A (RT)/(bP)

B e^(RT)/(bP)

C (bP)/(RT)

D e^(bP)/(RT)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D e^(bP)/(RT)

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- $P(V - b) = RT \rightarrow Z = PV/RT = 1 + bP/RT \rightarrow (Z - 1)/P = b/RT$. $\ln y = \int_0^P (b/RT)\, dP' = bP/RT \rightarrow y = e^{bP/RT}$.
- Therefore the answer is (D).

FINAL: (D) e^(bP)/(RT)

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **(RT)/(bP)**

Why (D) is the key — P(V − b) = RT → Z = PV/RT = 1 + bP/RT → (Z − 1)/P = b/RT. ln γ = ∫₀^P (b/RT) dP′ = bP/RT → γ = e^{bP/RT}.

B **e^(RT)/(bP)**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **(bP)/(RT)**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q87

$$((\partial G)/(\partial P))_T =$$

A. V

B. S

C. -S

D. -V

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A V

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- dG = VdP − SdT → (∂G/∂P)_T = V and (∂G/∂T)_P = −S.
- Therefore the answer is (A).

FINAL: (A) V

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **S**

Why (A) is the key — dG = VdP − SdT → (∂G/∂P)_T = V and (∂G/∂T)_P = −S.

C **-S**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **-V**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q88

The maximum non-PV work that a system can perform at constant P is

A. ΔH

B. ΔG

C. ΔS

D. ΔA

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B Δ G

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- At constant T and P, −ΔG = maximum non-expansion (useful) work, e.g. electrical work in a cell. ΔA gives maximum total work at constant T.
- Therefore the answer is (B).

FINAL: (B) Δ G

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **Δ H**

Why (B) is the key — At constant T and P, −ΔG = maximum non-expansion (useful) work, e.g. electrical work in a cell. ΔA gives maximum total work at constant T.

C **Δ S**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **Δ A**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q89 A Carnot engine operates at 55% efficiency. If the temperature of reject steam is 105^circC, then the absolute temperature of input steam is ____
(Numerical answer type — write the value.)

ANSWER: 840 K

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\eta = 1 - T_c/T_h \rightarrow 0.55 = 1 - 378/T_h \rightarrow T_h = 378/0.45 = 840$ K (567 °C).

Q90

33.2 kJ mol⁻¹, the enthalpy change for the reaction $2NO(g)+O_2(g)(g) \rightarrow 2NP_2(g)$ is

A. 16.6 kJ

B. -57.1 kJ

C. -114.2 kJ

D. 57.1 kJ

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C -114.2 kJ

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Using $\Delta H_f°(NO) = 90.25$ and $\Delta H_f°(NO_2) = 33.2$ kJ mol^{-1}: $\Delta H = 2(33.2) - 2(90.25) = -114.1 \approx -114.2$ kJ for the reaction as written (2 mol NO_2). Per mole of NO_2 it is −57.1 kJ — the bank key (b); the question text is truncated, verify which was asked.
- Therefore the answer is (C).

FINAL: (C) -114.2 kJ

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **16.6 kJ**

Why (C) is the key — Using $\Delta H_f^\circ(NO) = 90.25$ and $\Delta H_f^\circ(NO_2) = 33.2$ kJ mol^{-1}: $\Delta H = 2(33.2) - 2(90.25) = -114.1 \approx -114.2$ kJ for the reaction as written (2 mol NO_2). Per mole of NO_2 it is −57.1 kJ — the bank key (b); the question text is truncated, verify which was asked.

B **-57.1 kJ**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **57.1 kJ**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q91

Which one of the following defines the absolute temperature of a system?

A ((∂ U)/(∂ S))_V

B ((∂ A)/(∂ S))_V

C ((∂ H)/(∂ S))_V

D ((∂ G)/(∂ S))_V

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer A ((∂ U)/(∂ S))_V

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- dU = TdS − PdV → T = (∂U/∂S)_V. Likewise T = (∂H/∂S)_P; (∂A/∂S) and (∂G/∂S) are not natural derivatives.
- Therefore the answer is (A).

FINAL: (A) ((∂ U)/(∂ S))_V

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: A

B **((∂ A)/(∂ S))_V**

Why (A) is the key — dU = TdS − PdV → T = (∂U/∂S)_V. Likewise T = (∂H/∂S)_P; (∂A/∂S) and (∂G/∂S) are not natural derivatives.

C **((∂ H)/(∂ S))_V**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **((∂ G)/(∂ S))_V**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q92

Of the following inequalities, the criteria for spontaneity of a chemical reaction is/are (i) $(\Delta G)_{T,P} < 0$ (ii) $(\Delta U)_{S,V} > 0$ (iii) $(\Delta S)_{U,V} > 0$

A (i) only

B (ii) only

C (i) and (ii)

D (i) and (iii)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D (i) and (iii)

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Spontaneity criteria: $(\Delta G)_{T,P} < 0$, $(\Delta A)_{T,V} < 0$, $(\Delta S)_{U,V} > 0$, $(\Delta U)_{S,V} < 0$. Statement (ii) has the wrong sign, so (i) and (iii).
- Therefore the answer is (D).

FINAL: (D) (i) and (iii)

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **(i) only**

Why (D) is the key — Spontaneity criteria: $(\Delta G)_{T,P} < 0$, $(\Delta A)_{T,V} < 0$, $(\Delta S)_{U,V} > 0$, $(\Delta U)_{S,V} < 0$. Statement (ii) has the wrong sign, so (i) and (iii).

B **(ii) only**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

C **(i) and (ii)**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q93

An ideal gas occupies an unknown volume V liters (L) at a pressure of 12 atm. The gas is expanded isothermally against a constant external pressure of 2 atm so that its final volume become 3 L. The work involved for this expansion process is ___ cal. (Round off to two decimal places) (Gas constant R = 0.082 L atm mol^{-1} K^{-1} = 2 cal mol^{-1} K^{-1})
(Numerical answer type — write the value.)

ANSWER: −121.95 cal (121.95 cal done by the gas)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Isothermal, final gas pressure = 2 atm: 12V = 2 × 3 → V = 0.5 L. w = −P_ext ΔV = −2 × (3 − 0.5) = −5 L atm. 1 L atm = 2/0.082 = 24.39 cal → w = −121.95 cal.

Q94 **Δ G_f^0 and Δ H_f^0 for Fe(g) are 370.7 kJ mol^{-1} and 416.3 kJ mol^{-1} at 298 K, respectively. Assuming Δ H_f^0 is constant in the interval 250 K to 375 K, Δ G_f^0 (rounded off to the nearest integer) for Fe(g) at 375 K is:**

A. 338 kJ mol^{-1}

B. 310 kJ mol^{-1}

C. 325 kJ mol^{-1}

D. 359 kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D 359 kJ mol⁻¹

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Gibbs–Helmholtz: $\Delta G_2/T_2 = \Delta G_1/T_1 + \Delta H(1/T_2 - 1/T_1) = 370.7/298 + 416.3(1/375 - 1/298) = 1.2440 - 0.2868 = 0.9571 \rightarrow \Delta G_2 = 0.9571 \times 375 = 359$ kJ mol⁻¹.
- Therefore the answer is (D).

FINAL: (D) 359 kJ mol⁻¹

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **338 kJ mol^{-1}**

Why (D) is the key — Gibbs–Helmholtz: $\Delta G_2/T_2 = \Delta G_1/T_1 + \Delta H(1/T_2 - 1/T_1) = 370.7/298 + 416.3(1/375 - 1/298) = 1.2440 - 0.2868 = 0.9571 \rightarrow \Delta G_2 = 0.9571 \times 375 = 359$ kJ mol^{-1}.

B **310 kJ mol^{-1}**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **325 kJ mol^{-1}**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q95

The van der Waals constants a and b for gaseous CO are given as 1.49 L^2 atm mol^{-2} and 0.0399 L mol^{-1}, respectively. The fugacity (in atm, rounded off to two decimal places) of CO at 35°C and 95 atm is _____ (Given: R = 0.082 L atm K^{-1} mol^{-1}) (Numerical answer type — write the value.)

ANSWER: ≈ 88.4 atm

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Low-order vdW result: ln(f/P) = (b − a/RT)P/RT. RT = 0.082 × 308 = 25.27; a/RT = 0.0590; (b − a/RT) = −0.0191; × 95/25.27 = −0.0717 → f = 95 e^{−0.0717} = 88.4 atm (bank: 88.47).

Q96

A reversible heat engine absorbs 20 kJ of heat from a source at 500 K and dissipates it to the reservoir at 400 K. The efficiency of the heat engine is ___%. (Numerical answer type — write the value.)

ANSWER: 20 %

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Reversible (Carnot) efficiency $\eta = 1 - T_c/T_h = 1 - 400/500 = 0.20 \rightarrow 20\ \%$ (work = 4 kJ).

Q97 **2L of gas at 1 atm pressure is reversibly heated to reach a final volume of 3.5 L. The absolute value of the work done on the gas (rounded off to the nearest integer) is ___ Joules.**
(Numerical answer type — write the value.)

ANSWER: 152 J

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Reversible heating at constant pressure 1 atm: $w = -P\Delta V = -1\ atm \times 1.5\ L = -1.5\ L\ atm = -1.5 \times 101.3 = -152\ J$. $|w| = 152\ J$ (done by the gas).

Q98

(355.1 kJmol⁻¹)
(Numerical answer type — write the value.)

ANSWER: 355.1 kJ mol⁻¹

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
Bank stub: only the printed answer (355.1 kJ mol⁻¹) survives; the question text is missing.

Q99

(f=88.47 atm)
(Numerical answer type — write the value.)

ANSWER: f = 88.47 atm

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
Bank stub: printed answer for the CO fugacity problem (see Q PH0617: vdW CO at 35 °C, 95 atm → f ≈ 88.5 atm).

Q100

A system undergoes two cyclic processes 1 and 2. Process 1 is reversible and process 2 is irreversible. The correct statement relating to the two processes is

A Δ S (for process 1) = 0, while Δ S (for process 2) ≠ 0

B q_cycle = 0 for process 1 and q_cycle ≠ 0 for process 2

C More heat can be converted to work in process 1 than in process 2

D More work can be converted to heat in process 1 than in process 2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C More heat can be converted to work in process 1 than in process 2

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- S is a state function, so $\Delta S_{sys} = 0$ for any cycle, reversible or not; $q_{cycle} = -w_{cycle} \neq 0$. A reversible engine gives the maximum work from a given heat input (Carnot), so more heat is converted to work in process 1.
- Therefore the answer is (C).

FINAL: (C) More heat can be converted to work in process 1 than in process 2

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **Δ S (for process 1) = 0, while Δ S (for process 2) ≠ 0**

Why (C) is the key — S is a state function, so ΔS_sys = 0 for any cycle, reversible or not; q_cycle = −w_cycle ≠ 0. A reversible engine gives the maximum work from a given heat input (Carnot), so more heat is converted to work in process 1.

B **q_cycle = 0 for process 1 and q_cycle ≠ 0 for process 2**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **More work can be converted to heat in process 1 than in process 2**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q101 **For a cyclic process performed by an ideal gas, changes in some thermodynamic functions are zero. Indicate the set in which all the functions are zero**

A. w, Δ E, Δ H, Δ G

B. q, Δ S, Δ H, Δ A

C. q, Δ E, Δ S, Δ G

D. Δ E, Δ S, Δ H, Δ A

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D Δ E, Δ S, Δ H, Δ A

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- In a cycle every state function returns to its initial value: ΔE (ΔU), ΔS, ΔH, ΔA, ΔG are all zero. q and w are path functions and are generally non-zero.
- Therefore the answer is (D).

FINAL: (D) Δ E, Δ S, Δ H, Δ A

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **w, Δ E, Δ H, Δ G**

Why (D) is the key — In a cycle every state function returns to its initial value: ΔE (ΔU), ΔS, ΔH, ΔA, ΔG are all zero. q and w are path functions and are generally non-zero.

B **q, Δ S, Δ H, Δ A**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **q, Δ E, Δ S, Δ G**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q102

The molar internal energy of a gas at temperature T is $U_m(T)$. The molar internal energy at T = 0 is $U_m(0)$. The correct expression that relates these two with appropriate contributions is :

A $U_m(T) = U_m(0) + 3RT$ [Linear molecule; translation only]

B $U_m(T) = U_m(0) + 5/2\ RT$ [Linear molecule; translation and rotation only]

C $U_m(T) = U_m(0) + 3/2\ RT$ (Nonlinear molecule; translation and rotation only)

D $U_m(T) = U_m(0) + RT$ (Nonlinear molecule; translation only)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B $U_m(T) = U_m(0) + 5/2\ RT$ [Linear molecule; translation and rotation only]

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Equipartition: translation (3/2)RT; rotation RT for linear (2 axes), (3/2)RT for non-linear. Linear molecule, translation + rotation: $U_m(T) = U_m(0) + (5/2)RT$.
- Therefore the answer is (B).

FINAL: (B) $U_m(T) = U_m(0) + 5/2\ RT$ [Linear molecule; translation and rotation only]

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A $U_m(T) = U_m(0) + 3RT$ [Linear molecule; translation only]

Why (B) is the key — Equipartition: translation (3/2)RT; rotation RT for linear (2 axes), (3/2)RT for non-linear. Linear molecule, translation + rotation: U_m(T) = U_m(0) + (5/2)RT.

C $U_m(T) = U_m(0) + 3/2\ RT$ (Nonlinear molecule; translation and rotation only)

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D $U_m(T) = U_m(0) + RT$ (Nonlinear molecule; translation only)

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q103

Choose the INCORECT statement among the following:

A. When ideal gases are mixed, the entropy of mixing is always positive

B. At equilibrium, the chemical potential of a species is the same in all of the phases of the system

C. The total pressure of a mixture of ideal gases is equal to the sum of the partial pressure of each gas in the mixture

D. When a gas is allowed to expand, the maximum work is obtained when the process is carried out irreversibly

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C The total pressure of a mixture of ideal gases is equal to the sum of the partial pressure of each gas in the mixture

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- + The Mo configuration of N2and N2 are 2 2 2 2 2 N2 = σ2s σ2s* π2px π2py σ2pz **8#2** B.O.= =3 **2** + 2 2 2 2 1 N2 = σ2s σ2s* π2px π2py σ2pz **7#2** B.O.= =2.5 **2** $N_2 \rightarrow N_2$ (Bond order decreases) - - Explanation as extracted from the printed page; notation may be imperfect.
- Therefore the answer is (C).

FINAL: (C) The total pressure of a mixture of ideal gases is equal to the sum of the partial pressure of each gas in the mixture

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = $nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **When ideal gases are mixed, the entropy of mixing is always positive**

Why (C) is the key — + The Mo configuration of N2and N2 are 2 2 2 2 2 N2 = σ2s σ2s* π2px π2py σ2pz **8**#**2** B.O.= =3 **2** + 2 2 2 2 1 N2 = σ2s σ2s* π2px π2py σ2pz **7**#**2** B.O.= =2.5 **2** $N_2 \rightarrow$ N_2 (Bond order decreases) - - Explanation as extracted from the printed page; notation may be imperfect.

B **At equilibrium, the chemical potential of a species is the same in all of the phases of the system**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **When a gas is allowed to expand, the maximum work is obtained when the process is carried out irreversibly**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q104

The work done during the free expansion of one mole of an ideal gas at 27^circC to twice its original volume is (given : RT = 2494 J mol⁻¹, ln 2 = 0.7, log 2 = 0.3)

A 1746 J mol⁻¹

B -1746 J mol⁻¹

C zero

D 748.2 J mol⁻¹

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C zero

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Free expansion is against zero external pressure: $w = -P_{ext}\,\Delta V = 0$ (and $q = 0$, $\Delta U = 0$ for an ideal gas), even though the volume doubles.
- Therefore the answer is (C).

FINAL: (C) zero

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: $G = H - TS$'.

Why the Other Options Are Wrong

Correct answer: C

A **1746 J mol^{-1}**

Why (C) is the key — Free expansion is against zero external pressure: w = −P_ext ΔV = 0 (and q = 0, ΔU = 0 for an ideal gas), even though the volume doubles.

B **-1746 J mol^{-1}**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **748.2 J mol^{-1}**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q105 **(a) One mole of an ideal gas initially at 300 K and at a pressure of 10 atm undergoes adiabatic expansion. (i) Reversibly and (ii) Irreversibly against a constant external pressure of 2 atm until the final pressure becomes equal to the external pressure. Calculate Δ S_{system} for (i) and (ii). For (ii), express the final answer in terms of R. Given: Molar heat capacity at constant volume $C_{v,m} = 3R/2$.**

ANSWER: (i) ΔS = 0; (ii) ΔS ≈ 0.65 R

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
(i) Reversible adiabatic → isentropic, ΔS = 0. (ii) Irreversible: $C_V(T_2 - T_1) = -P_{ext}(V_2 - V_1)$ with $V = RT/P$: $(3/2)R(T_2 - 300) = -2R(T_2/2 - 30) \rightarrow T_2 = 204$ K. $\Delta S = C_V \ln(T_2/T_1) + R \ln(V_2/V_1) = (3/2)R \ln(0.68) + R \ln(3.4) = R(-0.585 + 1.224) \approx 0.65 R = 5.4$ J

Q106

The enthalpy of vaporization ($\Delta_{vap}H$) is zero at

A. Boyle temperature

B. critical temperature

C. Inversion temperature

D. boiling temperature

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer B critical temperature

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- At the critical temperature the liquid and vapour become identical, so $\Delta_{vap} H$ (and $\Delta_{vap} V$) vanish.
- Therefore the answer is (B).

FINAL: (B) critical temperature

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: B

A **Boyle temperature**

Why (B) is the key — At the critical temperature the liquid and vapour become identical, so Δ_vap H (and Δ_vap V) vanish.

C **Inversion temperature**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **boiling temperature**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q107

The change in entropy for the following transformations is respectively: (+ indicates increase, - indicates decrease and 0 indicates no change) (i) $SO_2Cl_2(g) \xrightarrow{\Delta} SO_2(g) + Cl_2(g)$ (ii) $mathrmnCH_2=CH_2(g) \xrightarrow{Catalyst} [-CH_2-CH_2-]_n(s)$ (iii) $I_2(s) \xrightarrow{[1\ atmosphere]\Delta} I_2(V)$ (iv) Adiabatic reversible expansion of an ideal gas

A +, -, 0, +

B +, -, 0, 0

C -, +, +, 0

D +, -, +, 0

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer D +, -, +, 0

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- (i) 1 gas → 2 gases: +. (ii) many gas molecules → one solid polymer: −. (iii) sublimation $I_2(s) \rightarrow I_2(g)$: +. (iv) reversible adiabatic = isentropic: 0. Hence +, −, +, 0.
- Therefore the answer is (D).

FINAL: (D) +, -, +, 0

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: D

A **+, -, 0, +**

Why (D) is the key — (i) 1 gas → 2 gases: +. (ii) many gas molecules → one solid polymer: −. (iii) sublimation $I_2(s) \rightarrow I_2(g)$: +. (iv) reversible adiabatic = isentropic: 0. Hence +, −, +, 0.

B **+, -, 0, 0**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

C **-, +, +, 0**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

Q108

Which of the following thermodynamic relation(s) is/are correct?

A $((\partial T)/(\partial V))_S = ((\partial P)/(\partial S))_V$

B $((\partial T)/(\partial P))_S = ((\partial V)/(\partial S))_P$

C $((\partial S)/(\partial V))_T = ((\partial P)/(\partial T))_V$

D $((\partial S)/(\partial P))_T = ((\partial V)/(\partial T))_P$

ANSWER: (b) and (c)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Maxwell relations: $(\partial T/\partial V)_S = -(\partial P/\partial S)_V$; $(\partial T/\partial P)_S = (\partial V/\partial S)_P$ ✓; $(\partial S/\partial V)_T = (\partial P/\partial T)_V$ ✓; $(\partial S/\partial P)_T = -(\partial V/\partial T)_P$. Options (a) and (d) have the sign wrong.

Q109 **Two moles of an ideal gas is expanded isothermally and reversibly from 5 to 1 bar at 298 K. The change in the entropy (in J K⁻¹) of the system is ___ IIT JAM 2016 (Numerical answer type — write the value.)**

ANSWER: ≈ 26.76 J K⁻¹

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Isothermal ideal gas: $\Delta S = nR \ln(P_1/P_2) = 2 \times 8.314 \times \ln 5 = 16.63 \times 1.609 = 26.76$ J K⁻¹.

Q110 The enthalpy of formation for $CH_4(g)$, C(g) and H(g) are –75, 717 and 218 kJ mol^{-1}, respectively. The enthalpy of the C – H bond in kJ mol^{-1} is ___.
(Numerical answer type — write the value.)

ANSWER: 416 kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$CH_4(g) \rightarrow C(g) + 4H(g)$: $\Delta H = 717 + 4(218) - (-75) = 1664$ kJ. Mean C–H bond enthalpy = 1664/4 = 416 kJ mol^{-1}.

Q111

Intensive variable(s) is/are

A. temperature

B. volume

C. pressure

D. density

ANSWER: (a), (c), (d)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
Intensive properties are independent of the amount of substance: temperature, pressure, density. Volume is extensive.

Q112 At 298 K and 1 atm, the molar enthalpies of combustion of cyclopropane and propene are -2091 kJ mol^{-1} and -2058 kJ mol^{-1}, respectively. The enthalpy change (in kJ mol^{-1}) for the conversion of one mole of propene to one mole of cyclopropane is ____
(Numerical answer type — write the value.)

ANSWER: +33 kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Hess: propene → cyclopropane = ΔH_c(propene) − ΔH_c(cyclopropane) = (−2058) − (−2091) = +33 kJ mol^{-1} (cyclopropane is the strained, higher-enthalpy isomer).

Q113 **Consider an isothermal reversible compression of one mole of an ideal gas in which the pressure of the system is increased from 5 atm to 30 atm at 300 K. The entropy change of the surroundings (in J K^{-1}) is ___ (final answer should be rounded off to two decimal places) [Given: R = 8.314 J mol^{-1} K^{-1}] (Numerical answer type — write the value.)**

ANSWER: +14.90 J K^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Reversible isothermal compression: $\Delta S_{sys} = R \ln(P_1/P_2) = 8.314 \ln(5/30) = -14.90$ J K^{-1}; reversible ⇒ $\Delta S_{univ} = 0 \Rightarrow \Delta S_{surr} = +14.90$ J K^{-1}.

Q114

The correct expression(s) for isothermal expansion of 1 mol of an ideal gas is(are)

A $\Delta A = RT\ln(V_{initial})/(V_{final})$

B $\Delta G = RT\ln(V_{initial})/(V_{final})$

C $\Delta H = RT\ln(V_{final})/(V_{initial})$

D $\Delta S = R\ln(V_{final})/(V_{initial})$

ANSWER: (a), (b), (d)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Isothermal ideal gas: $\Delta U = \Delta H = 0$; $\Delta A = \Delta G = -RT\ln(V_f/V_i) = RT\ln(V_i/V_f)$; $\Delta S = R\ln(V_f/V_i)$. So (a), (b), (d) are correct and (c) is wrong.

Q115 The value of C_v for 1 mol of N_2 gas predicted from the principle of equipartition of energy, ignoring vibrational contribution, is _____ J K^{-1} mol^{-1} (rounded up to two decimal places). [R = 8.3 J K^{-1} mol^{-1}] (Numerical answer type — write the value.)

ANSWER: 20.75 J K^{-1} mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
N_2 (linear): 3 translational + 2 rotational quadratic terms → $C_V = (5/2)R = 2.5 \times 8.3 = 20.75$ J K^{-1} mol^{-1}.

Q116 **The thermodynamic criterion for spontaneity of a process in a system under constant volume and temperature and in the absence of any work other than expansion work (if any) is**

A. change in entropy is positive

B. change in enthalpy is negative

C. change in Helmholtz free energy is negative

D. change in Gibbs free energy is negative

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C change in Helmholtz free energy is negative

CONCEPT

First law $\Delta U = q + w$; enthalpy $H = U + pV$; heat capacities $C_p - C_v = R$ (ideal gas); second law $dS \geq dq/T$; Gibbs $G = H - TS$, $\Delta G < 0$ spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- Constant T and V with only PV work → the Helmholtz criterion: $(dA)_{T,V} < 0$. $\Delta G < 0$ is for constant T and P.
- Therefore the answer is (C).

FINAL: (C) change in Helmholtz free energy is negative

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: $q = w = \Delta U = \Delta H = 0$, $\Delta S = nR \ln(V_2/V_1) > 0$.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **change in entropy is positive**

Why (C) is the key — Constant T and V with only PV work → the Helmholtz criterion: $(dA)_{T,V} < 0$. $\Delta G < 0$ is for constant T and P.

B **change in enthalpy is negative**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that $\Delta S_{universe}$, not ΔS_{system}, decides spontaneity.

D **change in Gibbs free energy is negative**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has $\Delta S > 0$.

Q117 One mole of an ideal gas is subjected to an isothermal increase in pressure from 100 kPa to 1000 kPa at 300 K. The change in Gibbs free energy of the system is _____ kJ mol^{-1}. (Round off to one decimal place) [Given: Gas constant (R) = 8.3 J K^{-1} mol^{-1}]
(Numerical answer type — write the value.)

ANSWER: +5.7 kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\Delta G = RT \ln(P_2/P_1) = 8.3 \times 300 \times \ln 10 = 2490 \times 2.303 = 5733\ J \approx +5.7\ kJ\ mol^{-1}$.

Q118

The standard Gibbs free energy change for the reaction mathrm$H_2O(g) \rightarrow H_2(g) + (1)/(2)O_2(g)$ at 2500 K is +118 kJ mol^{-1}. The equilibrium constant for the reaction is [Given: R = 8.314 J K^{-1} mol^{-1}]

A. 0.994

B. 1.006

C. 3.42×10^{-3}

D. 292.12

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Thermodynamics – General

PYQ FREQUENCY
Very High · 17 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'Good Honest Teachers Serve: G = H − TS'.

Correct Answer C 3.42 × 10⁻³

CONCEPT

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

↓

LOGIC / WORKING

- ln K = −ΔG°/RT = −118 000/(8.314 × 2500) = −5.68 → K = e^{−5.68} = 3.42×10⁻³.
- Therefore the answer is (C).

FINAL: (C) 3.42 × 10⁻³

SHORTCUT / EXAM TRICK

Free expansion of an ideal gas: q = w = ΔU = ΔH = 0, ΔS = nR ln(V_2/V_1) > 0.

COMMON MISTAKE

Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

EXAM TIP

Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MEMORY TRICK

'Good Honest Teachers Serve: G = H − TS'.

Why the Other Options Are Wrong

Correct answer: C

A **0.994**

Why (C) is the key — ln K = −ΔG°/RT = −118 000/(8.314 × 2500) = −5.68 → K = e^{−5.68} = 3.42×10⁻³.

B **1.006**

Ruled out: Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.

D **292.12**

Ruled out: Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

TOPIC REVISION

Thermodynamics – General

75 PYQs · Last-minute revision

TOPIC SUMMARY

First law ΔU = q + w; enthalpy H = U + pV; heat capacities C_p − C_v = R (ideal gas); second law dS ≥ dq/T; Gibbs G = H − TS, ΔG < 0 spontaneous at constant T, p; Maxwell relations; ideal-gas processes (isothermal, adiabatic, isobaric, isochoric).

IMPORTANT FORMULA SHEET

- $w = -nRT \ln(V_2/V_1)$ (rev. isothermal)
- $TV^{(\gamma-1)} = \text{const}$ (rev. adiabatic); $w = C_v \Delta T$
- $\Delta S = nC_p \ln(T_2/T_1) - nR \ln(p_2/p_1)$
- $\Delta G = \Delta H - T\Delta S$; $(\partial G/\partial T)_p = -S$; $(\partial G/\partial p)_T = V$
- Maxwell: $(\partial S/\partial V)_T = (\partial p/\partial T)_V$

FREQUENTLY ASKED CONCEPTS

- Work in each ideal-gas process
- Entropy change of mixing, phase change (ΔS = ΔH/T), free expansion
- Sign conventions
- Joule–Thomson coefficient and inversion temperature

COMMON MISTAKES & QUICK NOTES

Watch out:
Using C_p for an adiabatic work calculation (it is C_v); forgetting that ΔS_universe, not ΔS_system, decides spontaneity.
Reversible adiabatic = isentropic; irreversible adiabatic still has ΔS > 0.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q44 Q45 Q46 Q47 Q48 Q49 Q50 Q51 Q52 Q53 Q54 Q55 Q56 Q57 …

Expect 4 question(s) next session on Thermodynamics – General.

FOR STUDENTS AND EDUCATORS

Government Jobs and Examination News

Keep track of every notification in one place.

Government Jobs

- Latest vacancies
- By category
- By state
- Exams
- Chemistry jobs
- Government Jobs Blog

Scan to Explore

4ab.in/government-jobs

Examination News

- Latest updates
- Exam calendar
- Admit cards
- Results
- UG entrance exams
- PG entrance exams
- NET, SET & PhD exams
- School board exams
- Examination News Blog

Scan to Explore

4ab.in/examination-news

Vacancies, admit cards, results and exam dates: all in one place

FOR EDUCATORS

Teach from the Question Bank, one question at a time

Find the right questions, teach them in class, then take them with you.

1 Find questions

- Browse
- Question search
- Topic packs

2 Teach one by one

Question Bank

Show each question to students on the board, in your own order.

3 Export

PPTX, DOCX, PNG (zip), HTML, Markdown

Take the paper home after class.

Scan to open Question Bank

4ab.in/educators/?m=qb

Many more coming soon

My papers

Social groups

Question Paper Analyser

AI question paper generator

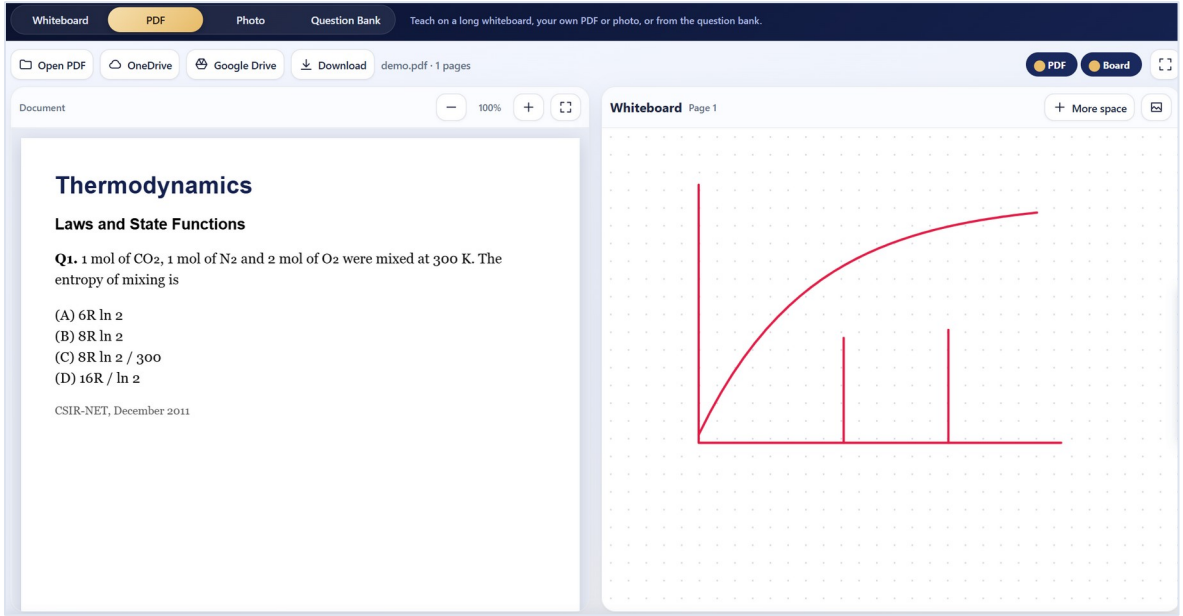
Paid

Lifetime free for educators, except AI tools

TUTOR-BRANDED TEACHING TOOLS

Free whiteboard for educators

Teach on a long whiteboard, your own PDF or photo, or from the question bank.



Start teaching

4ab.in/educators

Need more room? Add more space to the board as you teach.

Tutor pages show a small "Powered by 4AB" line. Premium removes it.

Whiteboard | **PDF** | **Photo** | **Question Bank**

EXPLORE AND USE

Chemistry Labs: symmetry and crystals

Scan a code or click a card to open the tool.

Molecular Symmetry

Explore molecular symmetry

4ab.in/molecular-symmetry/

Molecular Point Groups

Learn molecular point groups

4ab.in/molecular-point-groups/

Crystal Structure

Explore crystal structures

4ab.in/crystal-structure/

Crystal Space Groups

Browse crystal space groups

4ab.in/crystal-space-groups/

EXPLORE AND USE

Chemistry Labs: elements, calculation and drawing

Scan a code or click a card to open the tool.

Periodic Table

Explore the elements

4ab.in/periodic-table/

Chemistry Calculator

Solve chemistry calculations

4ab.in/chemistry-calculator/

Chemistry Typing

Type chemistry text

4ab.in/chemistry-typing/

Structure Editor

Draw structures

4ab.in/educators/draw/

Explore free educator tools

Mr. Aniket Bhardwaj

ABC Chemistry

9212142427

4ab.in/educators

@abcchemistry24 · Instagram · YouTube · Facebook

Scan to explore