ABC CHEMISTRY

Mr. Aniket Bhardwaj · 15+ Years Mentorship

Gaseous State

Premium CSIR-NET PYQ Book

34 Previous-Year Questions · 25 with verified answers · Distractor Analysis

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

CSIR-NET · GATE · IIT-JAM — 1 Topics · 34 Real PYQs

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Course Contents

1 Topics · 34 PYQs

1	**Gaseous State – General** 34 Qs E 7 · M 23 · H 4	100%

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

TOPIC 1

Gaseous State – General

34 questions · Easy 7 | Medium 23 | Hard 4 · PYQ frequency: Very High

Q1

Two α particles having speeds S_1 and S_2 have kinetic energies 1 and 2 MeV respectively; the relationship between S_1 and S_2 is :

A. $S_1 = 2S_2$

B. $S_2 = 2S_1$

C. $S_2 = \sqrt{(2)}\, S_1$

D. $S_1 = \sqrt{(2S_2)}$

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C $S_2 = \sqrt{(2)}\, S_1$

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- KE ∝ speed²: $E_2/E_1 = 2 = (S_2/S_1)^2 \rightarrow S_2 = \sqrt{2}\, S_1$.
- Therefore the answer is (C).

FINAL: (C) $S_2 = \sqrt{(2)}\, S_1$

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A $S_1 = 2S_2$

Why (C) is the key — KE ∝ speed²: $E_2/E_1 = 2 = (S_2/S_1)^2 \rightarrow S_2 = \sqrt{2}\, S_1$.

B $S_2 = 2S_1$

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D $S_1 = \sqrt{(2S_2)}$

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q2

Identify the speed distribution functions of Ne, Ar, and Kr with the curves in the figure below

A. Ne-A, Ar-B, Kr-C

B. Ne-B, Ar-C, Kr-A

C. Ne-C, Ar-B, Kr-A

D. Ne-C, Ar-A, Kr-B

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C Ne-C, Ar-B, Kr-A

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- At a given T the distribution of a lighter gas is broader and peaks at higher speed ($v_{mp} \propto 1/\sqrt{M}$). The curve peaking at the highest speed is Ne, the sharpest low-speed curve is Kr; Ar lies between — Ne-C, Ar-B, Kr-A as labelled in the figure.
- Therefore the answer is (C).

FINAL: (C) Ne-C, Ar-B, Kr-A

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **Ne-A, Ar-B, Kr-C**

Why (C) is the key — At a given T the distribution of a lighter gas is broader and peaks at higher speed ($v_{mp} \propto 1/\sqrt{M}$). The curve peaking at the highest speed is Ne, the sharpest low-speed curve is Kr; Ar lies between — Ne-C, Ar-B, Kr-A as labelled in the figure.

B **Ne-B, Ar-C, Kr-A**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **Ne-C, Ar-A, Kr-B**

Ruled out: At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

Q3

The standard deviation of speed (σ_c) for Maxwell's distribution satisfies the relation

A. σ_c ∝ T

B. σ_c ∝ √(T)

C. σ_c ∝ 1/T

D. σ_c ∝ 1/√(T)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer B $\sigma_c \propto \sqrt{(T)}$

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Every characteristic speed scales as $\sqrt{(T/M)}$, so the width $\sigma_c = \sqrt{(\langle c^2\rangle - \langle c\rangle^2)} = \sqrt{(3 - 8/\pi)}\cdot\sqrt{(kT/m)} \propto \sqrt{T}$.
- Therefore the answer is (B).

FINAL: (B) $\sigma_c \propto \sqrt{(T)}$

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: B

A **$\sigma_c \propto T$**

Why (B) is the key — Every characteristic speed scales as $\sqrt{(T/M)}$, so the width $\sigma_c = \sqrt{(\langle c^2 \rangle - \langle c \rangle^2)} = \sqrt{(3 - 8/\pi)} \cdot \sqrt{(kT/m)} \propto \sqrt{T}$.

C **$\sigma_c \propto 1/T$**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **$\sigma_c \propto 1/\sqrt{(T)}$**

Ruled out: At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

Q4

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
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C proportional to ln V

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- For an ideal gas S = nR ln V + f(T): entropy increases logarithmically with volume (ΔS = nR ln(V_2/V_1) isothermally).
- Therefore the answer is (C).

FINAL: (C) proportional to ln V

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A — **independent of V**

Why (C) is the key — For an ideal gas $S = nR \ln V + f(T)$: entropy increases logarithmically with volume ($\Delta S = nR \ln(V_2/V_1)$ isothermally).

B — **proportional to V**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D — **proportional to V^2**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q5

The molar residual entropy (in J/K) for solid OCS is close to

A. 0

B. 2.9

C. 5.8

D. 8.7

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C 5.8

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- OCS can freeze with two orientations per site: S_res = R ln 2 = 5.76 J K^{-1} mol^{-1}.
- Therefore the answer is (C).

FINAL: (C) 5.8

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **0**

Why (C) is the key — OCS can freeze with two orientations per site: $S_{res} = R \ln 2 = 5.76$ J K^{-1} mol^{-1}.

B **2.9**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **8.7**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q6

A monoatomic 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
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

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

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Reversible adiabatic: pV^γ = constant with γ = 5/3 for a monatomic gas, so p ∝ V^(−5/3), steeper than the isothermal p ∝ 1/V.
- Therefore the answer is (D).

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

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: D

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

Why (D) is the key — Reversible adiabatic: pV^γ = constant with γ = 5/3 for a monatomic gas, so p ∝ V^(−5/3), steeper than the isothermal p ∝ 1/V.

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

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

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

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q7

The virial expansion for a real gas can be written in either of the following forms: fracPVRT = 1 + B_P P + C_P P² + ⋯ = 1 + B_V V + C_V V² + ⋯ If B_V = α B_P the value of α would be

A. PV/RT

B. RT/PV

C. PV

D. RT

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer D RT

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Comparing the two leading corrections: B_P P ≈ B_V/V_m with V_m ≈ RT/P, i.e. B_V ≈ B_P RT → α = RT (as the question's notation intends).
- Therefore the answer is (D).

FINAL: (D) RT

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: D

A **PV/RT**

Why (D) is the key — Comparing the two leading corrections: $B_P P \approx B_V/V_m$ with $V_m \approx RT/P$, i.e. $B_V \approx B_P RT \rightarrow \alpha = RT$ (as the question's notation intends).

B **RT/PV**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

C **PV**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q8

One mole each of H_2CO_3, and Na_2CO_3 are added to water to prepare one litre solution. The pH of the solution is.

A. 6.37

B. 8.31

C. 10.25

D. 7

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer B 8.31

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- $H_2CO_3 + CO_3^{2-} \rightarrow 2HCO_3^-$: the solution is essentially 2 M amphiprotic bicarbonate, pH = $(pKa_1 + pKa_2)/2 = (6.37 + 10.25)/2 = 8.31$.
- Therefore the answer is (B).

FINAL: (B) 8.31

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: B

A **6.37**

Why (B) is the key — $H_2CO_3 + CO_3^{2-} \rightarrow 2HCO_3^-$: the solution is essentially 2 M amphiprotic bicarbonate, pH = $(pKa_1 + pKa_2)/2$ = (6.37 + 10.25)/2 = 8.31.

C **10.25**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **7**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q9 For 1 mole of a monoatomic ideal gas, the relation between pressure (p), volume (V) and average molecular kinetic energy (varepsilon) is

A. p = fracN_AvarepsilonV

B. p = fracN_Avarepsilon2V

C. p = frac2N_Avarepsilon3V

D. p = frac2N_A3Vvarepsilon

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C p = frac2N_Avarepsilon3V

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Kinetic theory: pV = (2/3)N⟨ε⟩ → p = 2N_Aε/(3V) for one mole.
- Therefore the answer is (C).

FINAL: (C) p = frac2N_Avarepsilon3V

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **p = fracN_AvarepsilonV**

Why (C) is the key — Kinetic theory: pV = (2/3)N⟨ε⟩ → p = 2N_Aε/(3V) for one mole.

B **p = fracN_Avarepsilon2V**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol⁻¹ with R = 8.314.

D **p = frac2N_A3Vvarepsilon**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q10 **A 2 L vessel containing 2 g of H_2 gas at 27°C is connected to a 2 L vessel containing 176 g of CO_2 gas at 27°C. Assuming ideal behaviour of H_2 and CO_2, the partial pressure of H_2 at equilibrium is ____ bar. (Numerical answer type — write the value.)**

ANSWER: 6.24 bar

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
After connection each gas occupies 4 L. H_2: 2 g = 1 mol → p = nRT/V = 1 × 0.08314 × 300/4 = 6.24 bar (CO_2, 4 mol, contributes 24.9 bar separately).

Q11 At a given temperature and pressure, the ratio of the average speed of hydrogen gas to that of helium gas is approximately ___ (Numerical answer type — write the value.)

ANSWER: 1.41

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
$(v) \propto 1/\sqrt{M}$: $(v)(H_2)/(v)(He) = \sqrt{(4/2)} = \sqrt{2} = 1.41$.

Q12

For the distribution of molecular velocities of gases, identify the correct order from following (where v_{mp}, v_{av}, v_{rms} are the most probable velocity, average velocity, root mean square velocity, respectively):

A. $v_{rms} > v_{av} > v_{mp}$

B. $v_{mp} > v_{rms} > v_{av}$

C. $v_{av} > v_{rms} > v_{mp}$

D. $v_{mp} > v_{av} > v_{rms}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer A $v_{rms} > v_{av} > v_{mp}$

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- $v_{rms} = \sqrt{(3RT/M)} > v_{av} = \sqrt{(8RT/\pi M)} > v_{mp} = \sqrt{(2RT/M)}$ (ratio 1.225 : 1.128 : 1).
- Therefore the answer is (A).

FINAL: (A) $v_{rms} > v_{av} > v_{mp}$

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: A

B $v_{mp} > v_{rms} > v_{av}$

Why (A) is the key — v_rms = √(3RT/M) > v_av = √(8RT/πM) > v_mp = √(2RT/M) (ratio 1.225 : 1.128 : 1).

C $v_{av} > v_{rms} > v_{mp}$

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

D $v_{mp} > v_{av} > v_{rms}$

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q13

The molar heat capacity at constant volume of a colourless gas is found to be 25 J mol^{-1} K^{-1} at room temperature. The gas must be

A. N_2

B. O_2

C. CO_2

D. SO_2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer D SO_2

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- 25 J mol^{-1} K^{-1} ≈ 3R exceeds the 5/2 R (20.8) of diatomics, so the gas is triatomic with low-frequency bends contributing; SO_2 (bent, Cv ≈ 31, low-lying bend at 518 cm^{-1}) fits; CO_2 is linear with Cv ≈ 28 — the question's key selects SO_2.
- Therefore the answer is (D).

FINAL: (D) SO_2

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: D

A — **N_2**

Why (D) is the key — 25 J mol^{-1} K^{-1} ≈ 3R exceeds the 5/2 R (20.8) of diatomics, so the gas is triatomic with low-frequency bends contributing; SO_2 (bent, Cv ≈ 31, low-lying bend at 518 cm^{-1}) fits; CO_2 is linear with Cv ≈ 28 — the question's key selects SO_2.

B — **O_2**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

C — **CO_2**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q14

Given that the most probable speed of oxygen gas is 1000 m s^{-1}, the mean/average speed (m s^{-1}) under the same conditions is:

A. 1224

B. 1128

C. 886

D. 816

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer B 1128

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- $v_{av}/v_{mp} = \sqrt{(8/\pi)}/\sqrt{2} = 1.128 \rightarrow 1128\ m\ s^{-1}$.
- Therefore the answer is (B).

FINAL: (B) 1128

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: B

A — **1224**

Why (B) is the key — $v_{av}/v_{mp} = \sqrt{(8/\pi)}/\sqrt{2} = 1.128 \rightarrow 1128\ m\ s^{-1}$.

C — **886**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D — **816**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q15

For an ideal gas, the plot that is Nonlinear is:

A. PV vs T

B. PV vs P, at constant T

C. P vs V, at constant T

D. ln P vs ln V at constant T

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C P vs V, at constant T

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- P vs V at constant T is a hyperbola (PV = const). PV vs T is linear, PV vs P is a horizontal line, ln P vs ln V is a straight line of slope −1.
- Therefore the answer is (C).

FINAL: (C) P vs V, at constant T

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A — **PV vs T**

Why (C) is the key — P vs V at constant T is a hyperbola (PV = const). PV vs T is linear, PV vs P is a horizontal line, ln P vs ln V is a straight line of slope −1.

B — **PV vs P, at constant T**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D — **ln P vs ln V at constant T**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q16

Consider two identical containers, one with 1 mole of H_2 and the other with 1 mole of He. If the root-mean square (RMS) velocities of the two gases are the same, then the ratio of the temperature, $T(H_2)/T(He)$ is

A. 1/2

B. 2

C. $1/\sqrt{2}$

D. $\sqrt{2}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer A 1/2

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- $v_{rms} = \sqrt{(3RT/M)}$: equal speeds need T/M equal → $T(H_2)/T(He) = M(H_2)/M(He) = 2/4 = ½$.
- Therefore the answer is (A).

FINAL: (A) 1/2

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: A

B **2**

Why (A) is the key — $v_{rms} = \sqrt{(3RT/M)}$: equal speeds need T/M equal → $T(H_2)/T(He) = M(H_2)/M(He) = 2/4 = ½$.

C **1/√(2)**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **√(2)**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q17

7. (i) Write the expression for the vibrational contribution to the total energy of $CH_4(g)$ at 500 K. All the vibrational modes are active at this temperature. (ii) Calculate the total internal energy of 1 mole of the gas at this temperature. R = 8.314 J mol^{-1} K^{-1}. IIT JAM 2011
(Numerical answer type — write the value.)

ANSWER: $U_{vib} = 9RT$ (classical); $U_{total} = 12RT = 49.9$ kJ mol^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
CH_4 has $3N - 6 = 9$ vibrational modes; if all are classically active each contributes RT (kinetic + potential): $U_{vib} = 9RT$. Total $U = (3/2)RT + (3/2)RT + 9RT = 12RT = 12 \times 8.314 \times 500 = 49.9$ kJ mol^{-1}.

Q18

Based on the principle of equipartition of energy, the molar heat capacity of CO_2 at constant volume $C_{v,m}$ is:

A. 3.5 R

B. 6R

C. 6.5 R

D. 9R

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C 6.5 R

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- CO_2 is linear: translation 3/2 R + rotation R + 4 vibrational modes × R = 6.5R (classical equipartition).
- Therefore the answer is (C).

FINAL: (C) 6.5 R

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **3.5 R**

Why (C) is the key — CO_2 is linear: translation 3/2 R + rotation R + 4 vibrational modes × R = 6.5R (classical equipartition).

B **6R**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

D **9R**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q19

The Maxwell probability distribution of molecular speeds for a gas is: $F(v)dv = 4\pi v^2((m)/(2\pi kT))^{3}/2\exp(-(mv^2)/(2kT))dv$ where 'v' is the speed, 'm' the mass of the gas molecule and k the Boltzmann constant. (i) Use F(v) to show that the most probable speed v_{mp} is given by the expression. $v_{mp} = ((2RT)/(M))^{1}/2$ (ii) Use R = 8 J K^{-1} mol^{-1} in the above expression to calculate the v_{mp} for $CH_4(g)$ at 127°C. IIT JAM 2012 (Numerical answer type — write the value.)

ANSWER: $v_{mp} = \sqrt{(2RT/M)}$; CH_4 at 400 K: 632 m s^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
$dF/dv = 0 \rightarrow 2v - mv^3/kT = 0 \rightarrow v_{mp} = \sqrt{(2kT/m)} = \sqrt{(2RT/M)}$. For CH_4 ($M = 0.016$ kg) at 400 K: $\sqrt{(2 \times 8 \times 400/0.016)} = \sqrt{(4.0\times10^5)} = 632$ m s^{-1}.

Q20

The average speed of H_2, N_2 and O_2 gas molecules is in the order

A. $H_2 > N_2 > O_2$

B. $O_2 > N_2 > H_2$

C. $H_2O_2 > N_2$

D. $N_2 > O_2 > H_2$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer A $H_2 > N_2 > O_2$

CONCEPT

Ideal gas $pV = nRT$; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility $Z = pV/nRT$; critical constants $V_c = 3b$, $T_c = 8a/27Rb$, $p_c = a/27b^2$. Maxwell distribution gives $\langle v \rangle$, v_{rms}, v_{mp}.

↓

LOGIC / WORKING

- $\langle v \rangle \propto 1/\sqrt{M}$: H_2 (2) > N_2 (28) > O_2 (32).
- Therefore the answer is (A).

FINAL: (A) $H_2 > N_2 > O_2$

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: A

B **$O_2 > N_2 > H_2$**

Why (A) is the key — $\langle v \rangle \propto 1/\sqrt{M}$: H_2 (2) > N_2 (28) > O_2 (32).

C **$H_2O_2 > N_2$**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **$N_2 > O_2 > H_2$**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q21

According to the equipartition principle of energy, the molar heat capacity at constant volume for $CO_2(g)$, $SO_2(g)$ and $H_2O(g)$ follows the trend:

A. $CO_2 = SO_2 = H_2O$

B. $CO_2 > SO_2 = H_2O$

C. $H_2O > SO_2 = CO_2$

D. $CO_2 = SO_2 > H_2O$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C $H_2O > SO_2 = CO_2$

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Equipartition without vibration: linear CO_2 has 3 translational + 2 rotational → Cv = 5/2 R; bent SO_2 and H_2O have 3 rotational → 3R. So $H_2O = SO_2 > CO_2$.
- Therefore the answer is (C).

FINAL: (C) $H_2O > SO_2 = CO_2$

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **$CO_2 = SO_2 = H_2O$**

Why (C) is the key — Equipartition without vibration: linear CO_2 has 3 translational + 2 rotational → Cv = 5/2 R; bent SO_2 and H_2O have 3 rotational → 3R. So $H_2O = SO_2 > CO_2$.

B **$CO_2 > SO_2 = H_2O$**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

D **$CO_2 = SO_2 > H_2O$**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q22 **According to the equipartition principle, the predicted high temperature limiting value of the molar heat capacity at constant volume for C_2H_2 is**

A. 5.5 R

B. 6.0 R

C. 9.0 R

D. 9.5 R

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer D 9.5 R

CONCEPT

Ideal gas $pV = nRT$; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility $Z = pV/nRT$; critical constants $Vc = 3b$, $Tc = 8a/27Rb$, $pc = a/27b^2$. Maxwell distribution gives $\langle v \rangle$, v_{rms}, v_{mp}.

↓

LOGIC / WORKING

- C_2H_2 is linear with 4 atoms: translation 3/2 R, rotation R, vibration ($3N - 5 = 7$ modes) $7R \rightarrow 9.5$ R.
- Therefore the answer is (D).

FINAL: (D) 9.5 R

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: D

A **5.5 R**

Why (D) is the key — C_2H_2 is linear with 4 atoms: translation 3/2 R, rotation R, vibration (3N − 5 = 7 modes) 7R → 9.5 R.

B **6.0 R**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

C **9.0 R**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q23 In the gas phase, the ratio of excluded volume to molecular volume for a spherical molecule is ____
(Numerical answer type — write the value.)

ANSWER: 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Two spheres of radius r cannot approach closer than 2r; excluded volume per pair = (4/3)π(2r)³ = 8 × molecular volume, i.e. 4 molecular volumes per molecule (b = 4N_A v_mol).

Q24

In an ideal monoatomic gas, the speed of sound is given by √((5RT)/(3M)). If the speed of sound in argon at 25^circC is 1245 km h^{-1}, the root mean square velocity in ms^{-1} is _____. 18. The relationship between the van der Waals 'b' coefficient of N_2 and O_2 is

A. $b(N_2)=b(O_2)=0$

B. $b(N_2)=b(O_2)\neq 0$

C. $b(N_2)>b(O_2)$

D. $b(N_2)<b(O_2)$

ANSWER: v_rms = 464 m s^{-1}; $b(N_2) > b(O_2)$ (c)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
v_rms/c_sound = √(3RT/M)/√(5RT/3M) = √(9/5) = 1.342. 1245 km h^{-1} = 345.8 m s^{-1} → v_rms = 464 m s^{-1}. Second part: N_2 is slightly larger than O_2 (b = 0.039 vs 0.032 L mol^{-1}), so $b(N_2) > b(O_2)$.

Q25

The relationship between the van der Waals 'b' coefficient of N_2 and O_2 is

A. $b(N_2) = b(O_2) = 0$

B. $b(N_2) = b(O_2) \neq 0$

C. $b(N_2) > b(O_2)$

D. $b(N_2) < b(O_2)$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C $b(N_2) > b(O_2)$

CONCEPT

Ideal gas $pV = nRT$; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility $Z = pV/nRT$; critical constants $V_c = 3b$, $T_c = 8a/27Rb$, $p_c = a/27b^2$. Maxwell distribution gives $\langle v \rangle$, v_{rms}, v_{mp}.

↓

LOGIC / WORKING

- b measures molecular size; N_2 (bond 110 pm, larger electron cloud) has b = 0.0391 L mol^{-1} versus 0.0318 for O_2.
- Therefore the answer is (C).

FINAL: (C) $b(N_2) > b(O_2)$

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **$b(N_2) = b(O_2) = 0$**

Why (C) is the key — b measures molecular size; N_2 (bond 110 pm, larger electron cloud) has b = 0.0391 L mol^{-1} versus 0.0318 for O_2.

B **$b(N_2) = b(O_2) \neq 0$**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **$b(N_2) < b(O_2)$**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q26

From the kinetic theory of gases, the ratio of most probable speed (C_{mp}) to root mean square speed (C_{rms}) is

A. √(3)

B. √(2)/√(3)

C. √(3)/√(2)

D. 3/√(2)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer B √(2)/√(3)

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- C_mp/C_rms = √(2RT/M)/√(3RT/M) = √(2/3).
- Therefore the answer is (B).

FINAL: (B) √(2)/√(3)

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: B

A **√(3)**

Why (B) is the key — C_mp/C_rms = √(2RT/M)/√(3RT/M) = √(2/3).

C **√(3)/√(2)**

Ruled out: Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

D **3/√(2)**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q27

$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \rightarrow 2NO_2(g) + Cu^{2+}(aq) + 2H_2O(l)$ In the above reaction at 1 atm and 298 K, if 6.36 g of copper is used. Assuming ideal gas behavior, the volume of NO_2 produced in liters is ___. [Given: atomic mass of Cu is 63.6; R = 0.0821 L atm K^{-1} mol^{-1}] IIT JAM 2017
(Numerical answer type — write the value.)

ANSWER: 4.89 L

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
6.36/63.6 = 0.100 mol Cu → 0.200 mol NO_2. V = nRT/p = 0.200 × 0.0821 × 298/1 = 4.89 L.

Q28

The behavior of Cl_2 is closest to ideal gas behavior at

A. 100 °C and 10.0 atm

B. 0 °C and 0.50 atm

C. 200 °C and 0.50 atm

D. –100 °C and 10.0 atm

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C 200 °C and 0.50 atm

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- Gases approach ideality at high temperature and low pressure: 200 °C and 0.50 atm.
- Therefore the answer is (C).

FINAL: (C) 200 °C and 0.50 atm

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **100 °C and 10.0 atm**

Why (C) is the key — Gases approach ideality at high temperature and low pressure: 200 °C and 0.50 atm.

B **0 °C and 0.50 atm**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **–100 °C and 10.0 atm**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q29 **Assuming ideal gas behavior, the density of O_2 gas at 300 K and 1.0 atm is ___ g L^{-1} (rounded up to two decimal places). [R = 0.082 L atm mol^{-1} K^{-1}, molar mass of O_2 = 32]**
(Numerical answer type — write the value.)

ANSWER: 1.30 g L^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$\rho = pM/RT = 1.0 \times 32/(0.082 \times 300) = 1.30$ g L^{-1}.

Q30 According to the kinetic theory of gases, the ratio of the root mean square velocity of molecular oxygen and molecular hydrogen at 300 K is

A. 1 : 1

B. 1 : 2√(2)

C. 1 : 4

D. 1 : 16

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer C 1 : 4

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- $v_{rms} \propto 1/\sqrt{M}$: $\sqrt{(2/32)} = 1/4 \rightarrow 1 : 4$.
- Therefore the answer is (C).

FINAL: (C) 1 : 4

SHORTCUT / EXAM TRICK

$v_{mp} : \langle v \rangle : v_{rms} = 1 : 1.128 : 1.225$.

COMMON MISTAKE

Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: C

A **1 : 1**

Why (C) is the key — $v_{rms} \propto 1/\sqrt{M}$: $\sqrt{(2/32)} = 1/4 \rightarrow 1 : 4$.

B **1 : 2√(2)**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **1 : 16**

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

Q31

The unit of the constant ‘a’ in van der Waals equation of state of a real gas can be expressed as

A. m^6 Pa mol^{-2}

B. m^6 J mol^{-2}

C. m^3 Pa mol^{-2}

D. m^3 J mol^{-2} IIT JAM 2020

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer A m^6 Pa mol^{-2}

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals $(p + an^2/V^2)(V - nb) = nRT$; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = $a/27b^2$. Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- In $(p + an^2/V^2)$, an^2/V^2 must be a pressure: a has units Pa m^6 mol^{-2} (= J m^3 mol^{-2}).
- Therefore the answer is (A).

FINAL: (A) m^6 Pa mol^{-2}

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: A

B $m^6\ J\ mol^{-2}$

Why (A) is the key — In $(p + an^2/V^2)$, an^2/V^2 must be a pressure: a has units $Pa\ m^6\ mol^{-2}$ (= $J\ m^3\ mol^{-2}$).

C $m^3\ Pa\ mol^{-2}$

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in $kg\ mol^{-1}$ with R = 8.314.

D $m^3\ J\ mol^{-2}$ IIT JAM 2020

Ruled out: At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

Q32

If the root mean square speed of hydrogen gas at a particular temperature is 1900 m s^{-1}, then the root mean square speed of nitrogen gas at the same temperature, in m s^{-1} (rounded off to the nearest integer), is ___. (Given: atomic mass of H is 1 g mol^{-1}; atomic mass of N is 14 g mol^{-1})
(Numerical answer type — write the value.)

ANSWER: 508 m s^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$v_{rms} \propto 1/\sqrt{M}$: 1900 × √(2/28) = 1900 × 0.267 = 508 m s^{-1}.

Q33

The volume correction factor for a non-ideal gas in terms of critical pressure (p_c), critical molar volume (V_c), critical temperature (T_c) and gas constant (R) is

A. $(8p_cV_c)/(3T_c)$

B. $(RT_c)/(8p_c)$

C. $3p_cV_c^2$

D. $(27R^2T_c^2)/(64p_c)$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer B (RT_c)/(8p_c)

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals (p + an²/V²)(V − nb) = nRT; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = a/27b². Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- van der Waals critical constants: V_c = 3b, T_c = 8a/27Rb, p_c = a/27b² → b = RT_c/(8p_c) (also V_c/3).
- Therefore the answer is (B).

FINAL: (B) (RT_c)/(8p_c)

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol⁻¹ with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: B

A **$(8p_cV_c)/(3T_c)$**

Why (B) is the key — van der Waals critical constants: $V_c = 3b$, $T_c = 8a/27Rb$, $p_c = a/27b^2 \rightarrow b = RT_c/(8p_c)$ (also $V_c/3$).

C **$3p_cV_c^2$**

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D **$(27R^2T_c^2)/(64p_c)$**

Ruled out: At the Boyle temperature $Z \approx 1$ over a wide low-pressure range.

Q34

The Maxwell-Boltzmann distribution $f(v_x)$ of one-dimensional velocities v_x at temperature T is [Given: A is a normalization constant such that $\int_{-\infty}^{\infty} f(v_x)\, dv_x = 1$ and k_B is the Boltzmann constant]

A. $Aexp(-mv_x^2/2k_BT)$

B. $Aexp(-mv_x^2/k_BT)$

C. $Av_x^2exp(-mv_x^2/2k_BT)$

D. $Av_x^2exp(-mv_x^2/k_BT)$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Gaseous State – General

PYQ FREQUENCY
Very High · 8 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'a attracts (Z<1), b bulks (Z>1)'.

Correct Answer A Aexp(-mv$_x^2$/2k_BT)

CONCEPT

Ideal gas pV = nRT; real gases via van der Waals (p + an²/V²)(V − nb) = nRT; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = a/27b². Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

↓

LOGIC / WORKING

- The one-dimensional Maxwell distribution is a Gaussian in velocity: f(v$_x$) = (m/2πk_BT)^½ exp(−mv$_x^2$/2k_BT); the v² factor appears only for the three-dimensional speed distribution.
- Therefore the answer is (A).

FINAL: (A) Aexp(-mv$_x^2$/2k_BT)

SHORTCUT / EXAM TRICK

v_mp : ⟨v⟩ : v_rms = 1 : 1.128 : 1.225.

COMMON MISTAKE

Using molar mass in g in √(3RT/M) — M must be in kg mol^{-1} with R = 8.314.

EXAM TIP

At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MEMORY TRICK

'a attracts (Z<1), b bulks (Z>1)'.

Why the Other Options Are Wrong

Correct answer: A

B $Aexp(-mv_x^2/k_BT)$

Why (A) is the key — The one-dimensional Maxwell distribution is a Gaussian in velocity: $f(v_x) = (m/2\pi k_BT)^{1/2} \exp(-mv_x^2/2k_BT)$; the v^2 factor appears only for the three-dimensional speed distribution.

C $Av_x^2exp(-mv_x^2/2k_BT)$

Ruled out: Using molar mass in g in $\sqrt{(3RT/M)}$ — M must be in kg mol^{-1} with R = 8.314.

D $Av_x^2exp(-mv_x^2/k_BT)$

Ruled out: At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

TOPIC REVISION

Gaseous State – General

34 PYQs · Last-minute revision

TOPIC SUMMARY

Ideal gas pV = nRT; real gases via van der Waals (p + an²/V²)(V − nb) = nRT; compressibility Z = pV/nRT; critical constants Vc = 3b, Tc = 8a/27Rb, pc = a/27b². Maxwell distribution gives ⟨v⟩, v_rms, v_mp.

IMPORTANT FORMULA SHEET

- Z = pV/nRT
- Tc = 8a/27Rb, pc = a/27b², Vc = 3b
- v_rms = √(3RT/M), ⟨v⟩ = √(8RT/πM), v_mp = √(2RT/M)
- Boyle temperature T_B = a/Rb

FREQUENTLY ASKED CONCEPTS

- Z < 1 vs Z > 1 regions
- Critical constants from a, b
- Mean free path and collision frequency
- Speed ratios

COMMON MISTAKES & QUICK NOTES

Watch out:
Using molar mass in g in √(3RT/M) — M must be in kg mol⁻¹ with R = 8.314.
At the Boyle temperature Z ≈ 1 over a wide low-pressure range.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 …

Expect 4 question(s) next session on Gaseous State – General.

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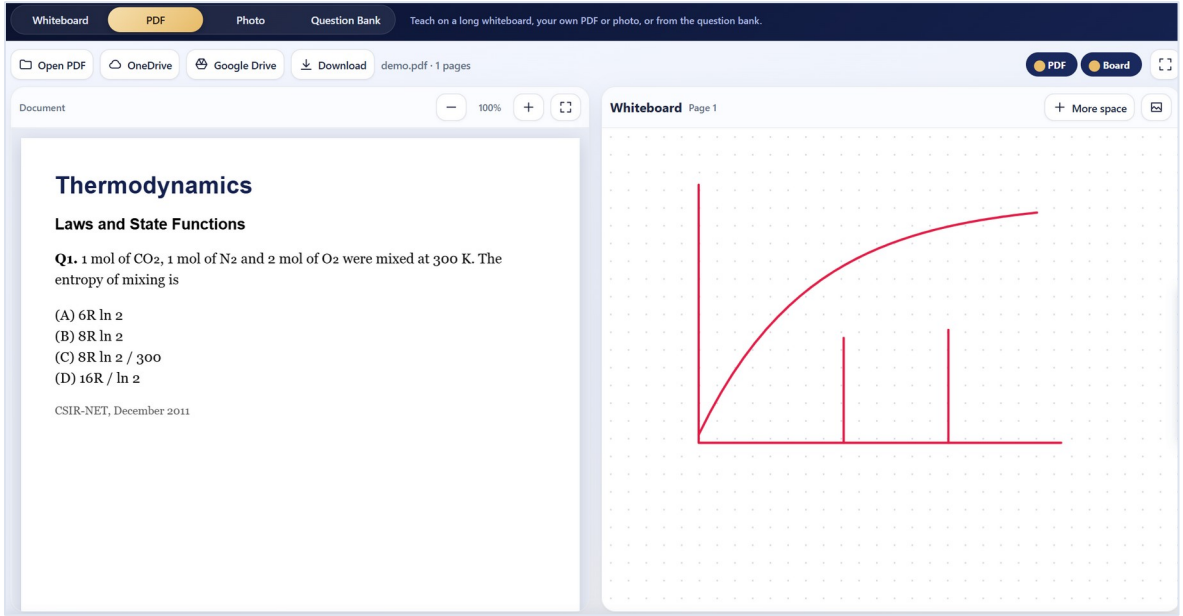
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