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Class 12
Physics

Chapter 16

Printed Notes

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Class XII – Physics

Domain C: Heat and Thermodynamics

Kinetic Theory of Gases | MCQs & Short Questions with Answers

SLO	Description
P-12-C-01	Molecular movement causes pressure exerted by gas
P-12-C-02	Derive & use: $pV = Nm/3 \langle c^2 \rangle$, mean-square speed, 1D → 3D
P-12-C-03	Calculate root-mean-square speed of an ideal gas
P-12-C-04	Derive & use formula for average translational K.E. of a gas
P-12-C-05	Illustrate model of ideal gases used as a base

SECTION A: Multiple Choice Questions (MCQs)

Each question carries 1 mark. Choose the best answer.

1. The pressure exerted by a gas on the walls of its container is due to:
   - A) Gravitational attraction of molecules
   - B) Continuous collisions of gas molecules with the walls
   - C) The weight of the gas
   - D) Electromagnetic forces between molecules
   - ✔ Answer: (B) Continuous collisions of gas molecules with the walls [SLO: P-12-C-01]

2. According to the kinetic theory, gas molecules move in:
   - A) One fixed direction
   - B) Circular paths
   - C) Random directions with varying speeds
   - D) Parabolic paths
   - ✔ Answer: (C) Random directions with varying speeds [SLO: P-12-C-01]

3. When gas molecules collide with the walls of a container, the collisions are assumed to be:
   - A) Inelastic
   - B) Perfectly elastic
   - C) Partially elastic
   - D) Non-existent
   - ✔ Answer: (B) Perfectly elastic [SLO: P-12-C-01]

4. The kinetic theory equation for gas pressure is $pV = Nm/3$. Here, N represents:
   - A) Number of moles
   - B) Avogadro's number
   - C) Total number of molecules
   - D) Number of atoms per molecule
   - ✔ Answer: (C) Total number of molecules [SLO: P-12-C-02]

5. In the expression pV = Nm/3, the symbol represents:

A) The speed of the fastest molecule
B) The mean-square speed of molecules
C) The root-mean-square speed
D) The average speed
✔ Answer: (B) The mean-square speed of molecules [SLO: P-12-C-02]

6. The relation 1/3 = is obtained by extending the one-dimensional model to three dimensions. This is valid because:

A) Gas molecules always move in the x-direction
B) Motion is symmetrical in all three directions, so = =
C) Gas pressure is equal in two dimensions only
D) All molecules have the same speed
✔ Answer: (B) Motion is symmetrical in all three directions, so = = [SLO: P-12-C-02]

7. The root-mean-square (rms) speed of gas molecules is defined as:

A) The average of all molecular speeds
B) The square root of the mean-square speed
C) Half of the maximum speed
D) The most probable speed
✔ Answer: (B) The square root of the mean-square speed [SLO: P-12-C-03]

8. The formula for rms speed of an ideal gas molecule is:

A) c_{rms} = sqrt(3RT/M)
B) c_{rms} = sqrt(2RT/M)
C) c_{rms} = sqrt(RT/M)
D) c_{rms} = sqrt(3kT/m) only
✔ Answer: (A) c_rms = sqrt(3RT/M) [SLO: P-12-C-03]

9. If the temperature of an ideal gas is doubled (in Kelvin), its rms speed:

A) Doubles
B) Becomes four times
C) Increases by a factor of sqrt(2)
D) Remains unchanged
✔ Answer: (C) Increases by a factor of sqrt(2) [SLO: P-12-C-03]

10. At constant temperature, if the molar mass of a gas is increased four times, its rms speed:

A) Doubles
B) Becomes half
C) Becomes four times
D) Remains the same
✔ Answer: (B) Becomes half [SLO: P-12-C-03]

11. The average translational kinetic energy of one molecule of an ideal gas is:

A) (1/2)kT
B) kT
C) (3/2)kT

D) 3kT

✔ Answer: (C) (3/2)kT, where k is the Boltzmann constant and T is absolute temperature [SLO: P-12-C-04]

12. The average translational kinetic energy of a gas depends on:
    A) The type of gas only
    B) Absolute temperature only
    C) Pressure only
    D) Volume and pressure
    ✔ Answer: (B) Absolute temperature only [SLO: P-12-C-04]

13. For one mole of an ideal gas, the total translational kinetic energy is:
    A) (1/2)RT
    B) RT
    C) (3/2)RT
    D) 3RT
    ✔ Answer: (C) (3/2)RT, where R is the universal gas constant [SLO: P-12-C-04]

14. The Boltzmann constant k is related to the universal gas constant R and Avogadro's number N_A by:
    A) $k = R \times N_A$
    B) $k = R / N_A$
    C) $k = N_A / R$
    D) $k = R^2 / N_A$
    ✔ Answer: (B) k = R / N_A [SLO: P-12-C-04]

15. An ideal gas is defined as one in which:
    A) Molecules have zero volume and no intermolecular forces
    B) Molecules have large volumes and strong forces
    C) All molecules move at the same speed
    D) Molecules lose energy on every collision
    ✔ Answer: (A) Molecules have zero volume and no intermolecular forces [SLO: P-12-C-05]

16. The kinetic theory model of an ideal gas assumes that collisions between molecules are:
    A) Inelastic, causing energy loss
    B) Perfectly elastic, conserving kinetic energy
    C) Partially elastic
    D) Non-existent
    ✔ Answer: (B) Perfectly elastic, conserving kinetic energy [SLO: P-12-C-05]

17. According to kinetic theory, the time of a collision between a molecule and the wall is:
    A) Very long compared to time between collisions
    B) Very short compared to time between collisions
    C) Equal to the time between collisions
    D) Infinite
    ✔ Answer: (B) Very short compared to time between collisions [SLO: P-12-C-05]

18. At absolute zero temperature (0 K), the average kinetic energy of gas molecules is:

A) Maximum
B) Constant
C) Zero (theoretically)
D) Equal to (3/2)R

✔ Answer: (C) Zero (theoretically), as KE = (3/2)kT [SLO: P-12-C-04]

19. The pressure of an ideal gas in a container is increased by doubling the number of molecules at constant temperature. The new pressure will be:

A) Same
B) Half
C) Double
D) Four times

✔ Answer: (C) Double — pressure is directly proportional to number of molecules [SLO: P-12-C-02]

20. Oxygen molecules (M = 32 g/mol) and hydrogen molecules (M = 2 g/mol) are at the same temperature. Their ratio of rms speeds $c_{rms}(H_2)$ / $c_{rms}(O_2)$ is:

A) 4
B) 16
C) 1/4
D) sqrt(16) = 4

✔ Answer: (A) 4 — c_rms ∝ 1/sqrt(M), so ratio = sqrt(32/2) = sqrt(16) = 4 [SLO: P-12-C-03]

21. In deriving pV = Nm/3, which assumption is NOT made?

A) Molecules are identical
B) Intermolecular forces are negligible
C) All molecules travel at the same speed
D) Collisions are elastic

✔ Answer: (C) All molecules travel at the same speed — they have a distribution of speeds [SLO: P-12-C-02]

22. The unit of Boltzmann constant (k) is:

A) $J{\cdot}mol^{-1}{\cdot}K^{-1}$
B) $J{\cdot}K^{-1}$
C) $kg{\cdot}m^{2}{\cdot}s^{-2}$
D) J·K

✔ Answer: (B) J·K■^{1} (Joules per Kelvin) [SLO: P-12-C-04]

23. If the volume of a gas is halved at constant temperature, the pressure:

A) Doubles (Boyle's Law)
B) Halves
C) Remains unchanged
D) Becomes four times

✔ Answer: (A) Doubles — from pV = Nm/3 = constant at fixed T [SLO: P-12-C-02]

24. The mean-square speed is related to rms speed as:

A) = c_{rms}

B) $= c_{rms}^2$
C) $= \text{sqrt}(c_{rms})$
D) $= 2c_{rms}$
✔ Answer: (B) = c_rms² by definition [SLO: P-12-C-03]

25. The ideal gas model is useful in practice because:
A) Real gases behave exactly like ideal gases
B) It gives a simplified but good approximation for many real gases at low pressure and high temperature
C) It only applies to noble gases
D) No gas ever deviates from ideal behavior
✔ Answer: (B) It provides a good approximation for real gases under suitable conditions [SLO: P-12-C-05]

SECTION B: Short Questions with Answers

Each question carries 2–3 marks.

Q1. [SLO: P-12-C-01] How does molecular movement cause pressure in a gas?

Gas molecules are in constant, random motion. They collide with the walls of the container continuously. Each collision exerts a tiny force on the wall. The cumulative effect of billions of such collisions per second results in a measurable, steady pressure on the walls. The pressure is the average force per unit area exerted by the molecules.

Q2. [SLO: P-12-C-01] State three main assumptions of the kinetic theory of gases.

1. Gas consists of a large number of identical molecules in continuous, random motion.
2. The size (volume) of molecules is negligible compared to the volume of the container.
3. Collisions between molecules and with the walls are perfectly elastic (no net energy loss).
4. Intermolecular forces are negligible except during collisions.
5. The time of collision is very short compared to the time between collisions.

Q3. [SLO: P-12-C-02] Write the kinetic theory equation for gas pressure and define each symbol.

The equation is: pV = (1/3) Nm

- p = Pressure of the gas
- V = Volume of the container
- N = Total number of molecules
- m = Mass of one molecule
- = Mean-square speed of molecules

This is derived by considering molecules moving in one dimension and then extending to three dimensions using the symmetry argument: = = = /3.

Q4. [SLO: P-12-C-02] Explain how 1/3 = is justified when extending from one to three dimensions.

When we first consider molecules moving only along the x-axis, the pressure contribution involves . When extended to three dimensions, molecules move in all directions randomly. By symmetry, there is no preferred direction, so the mean-square velocity components are equal:

= =

Since = + + = 3, it follows that:

= /3

Hence, 1/3 = , which is used in deriving the 3D pressure equation.

Q5. [SLO: P-12-C-03] Define root-mean-square (rms) speed. Write its formula for an ideal gas.

The root-mean-square speed is the square root of the average of the squares of all molecular speeds:

c_rms = sqrt()

For an ideal gas:

c_rms = sqrt(3RT/M) (molar form)

or equivalently:

c_rms = sqrt(3kT/m) (per molecule form)

Where R = universal gas constant, T = absolute temperature (K), M = molar mass, k = Boltzmann constant, m = mass of one molecule.

Q6. [SLO: P-12-C-03] How does rms speed depend on temperature and molar mass?

From c_rms = sqrt(3RT/M):

1. Temperature dependence: c_rms ∝ sqrt(T). If temperature doubles, rms speed increases by factor sqrt(2) ≈ 1.41.

2. Molar mass dependence: c_rms ∝ 1/sqrt(M). Lighter gases move faster than heavier gases at the same temperature.

Example: At 300 K, hydrogen (M=2) moves 4 times faster than oxygen (M=32) since sqrt(32/2) = 4.

Q7. [SLO: P-12-C-03] Calculate the rms speed of nitrogen molecules (M = 28 g/mol) at 27°C. (R = 8.314 J·mol■^{1}·K■^{1})

T = 27 + 273 = 300 K, M = 0.028 kg/mol

c_rms = sqrt(3RT/M)

c_rms = sqrt(3 × 8.314 × 300 / 0.028)

c_rms = sqrt(7482.6 / 0.028)

c_rms = sqrt(267,235)

c_rms ≈ 517 m/s

Q8. [SLO: P-12-C-04] Derive the expression for average translational kinetic energy of a gas molecule.

From kinetic theory: pV = (1/3) Nm ... (1)

From ideal gas law: pV = NkT ... (2)

Comparing (1) and (2):

(1/3) m = kT

(1/2) m = (3/2) kT

Since (1/2)m = average translational kinetic energy (KE_avg):

KE_avg = (3/2) kT

This shows that the average kinetic energy of a molecule depends only on absolute temperature.

Q9. [SLO: P-12-C-04] What is the total translational kinetic energy of 1 mole of an ideal gas?

For one molecule: KE = (3/2) kT

For N_A molecules (1 mole):

KE_total = N_A × (3/2) kT = (3/2) (N_A × k) T = (3/2) RT

Since R = N_A × k

Therefore: KE_total = (3/2) RT

At T = 300 K: KE_total = (3/2) × 8.314 × 300 ≈ 3741 J = 3.74 kJ per mole

Q10. [SLO: P-12-C-04] Calculate the average kinetic energy of an ideal gas molecule at 27°C. (k = $1.38 \times 10^{\blacksquare 23}$ J/K)

T = 27 + 273 = 300 K

KE_avg = (3/2) kT

KE_avg = (3/2) × $1.38 \times 10^{\blacksquare 23}$ × 300

KE_avg = (3/2) × $4.14 \times 10^{\blacksquare 21}$

KE_avg = $6.21 \times 10^{\blacksquare 21}$ J

Q11. [SLO: P-12-C-05] List the key assumptions of the ideal gas model.

1. Gas molecules are point masses — their volume is negligible.
2. There are no intermolecular forces between molecules (except during collision).
3. All collisions (molecule-molecule and molecule-wall) are perfectly elastic.
4. Molecules move in random directions with a range of speeds.
5. The time duration of a collision is negligible compared to time between collisions.
6. The number of molecules is very large, enabling statistical treatment.

These assumptions simplify the model, making it very useful for many real gases at low pressures and high temperatures.

Q12. [SLO: P-12-C-05] Why is the ideal gas model important in physics and chemistry?

The ideal gas model is important because:

1. It provides a simple mathematical framework (pV = NkT or pV = nRT) that describes real gas behaviour well under ordinary conditions.

2. It links microscopic properties (molecular speed, mass) to macroscopic properties (pressure, temperature).

3. It is the foundation for understanding thermodynamics, gas laws (Boyle's, Charles's, Avogadro's).

4. It serves as a baseline — deviations from ideal behaviour (van der Waals gases) tell us about real intermolecular interactions.

5. It is used in engineering applications such as heat engines, refrigerators, and atmospheric models.

Q13. [SLO: P-12-C-01 & C-04] What happens to gas pressure and molecular kinetic energy when the temperature of a gas is increased?

When temperature increases:

1. Pressure increases: From pV = (1/3)Nm, if V is constant, and ∝ T, then pressure p ∝ T.

2. Molecular kinetic energy increases: KE_avg = (3/2)kT increases directly with T.

Physically, hotter molecules move faster, hit the walls harder and more frequently, resulting in greater pressure. The average kinetic energy is a direct measure of the absolute temperature of the gas.

Q14. [SLO: P-12-C-02 & C-03] Differentiate between mean-square speed and root-mean-square speed.

Mean-square speed :

• It is the average of the squares of all molecular speeds: = (c■² + c■² + ... + c■²) / N

• Unit: m²/s²

• It appears directly in the kinetic theory equation: pV = Nm/3

Root-mean-square speed (c_rms):

• It is the square root of the mean-square speed: c_rms = sqrt()

• Unit: m/s

• Formula: c_rms = sqrt(3RT/M)

• It represents a typical molecular speed and is useful for calculations.

Q15. [SLO: P-12-C-03] Two gases A (M=4 g/mol, Helium) and B (M=32 g/mol, Oxygen) are at the same temperature. Compare their rms speeds.

c_rms ∝ 1/sqrt(M) at constant T

c_rms(He) / c_rms(O■) = sqrt(M_O■ / M_He) = sqrt(32/4) = sqrt(8) ≈ 2.83

Helium molecules move approximately 2.83 times faster than oxygen molecules at the same temperature. This explains why lighter gases like helium effuse/diffuse more rapidly than heavier gases (Graham's Law).

Prepared for FBISE Class XII Physics | Domain C: Heat & Thermodynamics | SLOs: P-12-C-01 to P-12-C-05

Total: 25 MCQs + 15 Short Questions | All answers included