Kinetic Theory

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. How many moles of gas are in a 21 L container at 2×10^5 N/m^2 and 430 K? (R = 8.31 J/mol K)

(a) 0.12 **(b)** 11.75 **(c)** 2.35 **(d)** 1.18

2. Nitrogen is heated from 410 K to 6560 K. Its rms speed becomes how many times?

(a) 16 **(b)** 8 **(c)** 5 **(d)** 4

3. The average kinetic energy of a gas molecule at 390 K is (k = 1.38×10^{-23} J/K):

(a) 2.69×10^{-21} J **(b)** 5.38×10^{-21} J **(c)** 8.07×10^{-21} J **(d)** 1.61×10^{-20} J

4. For a polyatomic (non-linear) ideal gas (rigid molecules), the molar heat capacity at constant pressure, Cp, is:

(a) 4R **(b)** 9R/2 **(c)** 5R/2 **(d)** 7R/2

5. The ideal gas equation is:

(a) pT = nRV **(b)** pV = RT/n **(c)** p/V = nRT **(d)** pV = nRT

6. A gas is at 380 K. To what temperature must it be heated so that the rms speed of its molecules becomes 4 times?

(a) 6,080 K **(b)** 24,320 K **(c)** 1,520 K **(d)** 6,353 K

7. 5 L of gas at 400 K is cooled to 200 K at constant pressure. Its new volume is:

(a) 2.5 L **(b)** 5 L **(c)** 10 L **(d)** 1.34 L

8. Assertion (A): If the temperature of a gas rises from 810 K to 1620 K, the average kinetic energy of its molecules becomes 4 times.
Reason (R): The average kinetic energy of a molecule is proportional to the absolute temperature.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. A gas occupies 18 L at 5 atm and 400 K. What is its volume at 1 atm and 520 K? (2 decimal places where needed.)

10. How many molecules are there in 49 L of a gas at 9×10^5 N/m^2 and 460 K? (k = 1.38×10^{-23} J/K)

11. A gas at a pressure of 2.0×10^5 N/m^2 has a density of 2.4 kg/m^3. Find the rms speed of its molecules.

12. For a polyatomic (non-linear) ideal gas with rigid molecules, find the degrees of freedom, Cv, Cp and γ (in terms of R and in J/mol K), and the heat capacity at constant volume of 3 mol of it. (R = 8.31 J/mol K)

13. Find the total translational kinetic energy of 4 mol of an ideal gas at 570 K. (R = 8.31 J/mol K) (2 decimal places where needed.)

14. The average kinetic energy of the molecules of a gas is 20×10^{-21} J. Find the temperature of the gas. (k = 1.38×10^{-23} J/K) (2 decimal places where needed.)

15. A tyre holds air at 150 kPa at 280 K. After a long drive the temperature of the air is 320 K. Assuming the volume does not change, find the new pressure. (2 decimal places where needed.)

16. At a certain temperature, the rms speed of oxygen molecules is 2000 m/s. Find the rms speed of hydrogen molecules at the same temperature.

Section C — Word problems — 4 × 4 = 16 marks

17. A cylinder of volume 7 L contains argon (molar mass 40 g/mol) at 10×10^5 N/m^2 and 330 K. Find (a) the number of moles, (b) the mass of gas, (c) the number of molecules. (R = 8.31 J/mol K, $N_a = 6.02 \times 10^{23}$) (2 decimal places where needed.)

18. A gas at 1.0×10^5 N/m^2 and 280 K has density 7.5 kg/m^3. (a) Find the rms speed of its molecules. (b) What is the rms speed at 2520 K? (c) What happens to the average kinetic energy?

19. 2 mol of a diatomic ideal gas is heated through 20 K (a) at constant volume, (b) at constant pressure. Find the heat needed in each case and explain why they differ. (R = 8.31 J/mol K) (2 decimal places where needed.)

20. A student records the pressure and volume of a fixed mass of gas at constant temperature: p = 5 kPa, V = 100 L; p = 10 kPa, V = 50 L; p = 20 kPa, V = ? L; p = 25 kPa, V = 20 L. (a) Show that the data obey Boyle's law. (b) Find the missing volume. (c) Sketch the p–V graph.

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Answer key

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Q	Answer	Working
1	**(d) 1.18**	n = pV/RT
2	**(d) 4**	$v_{rms} \propto \sqrt{T}$
3	**(c) 8.07×10^{-21} J**	(3/2)kT
4	**(a) 4R**	from the degrees of freedom: Cv = (f/2)R, Cp = Cv + R
5	**(d) pV = nRT**	—
6	**(a) 6,080 K**	$v_{rms} \propto \sqrt{T}$
7	**(a) 2.5 L**	V/T is constant (Charles's law)
8	**(d) A is false, but R is true.**	A is false: KE = (3/2)kT, so it becomes 2 times. R is true.
9	**117 L**	$p_1V_1/T_1 = p_2V_2/T_2$
10	**6.95×10^{24}**	N = pV/(kT)
11	**500 m/s**	$p = \frac{1}{3}\rho v^2$, so $v = \sqrt{(3p/\rho)}$
12	**f = 6; Cv = (3)R = 24.93 J/mol K; Cp = (4)R = 33.24 J/mol K; γ = 4/3; 74.79 J/K**	Cv = (f/2)R; Cp = Cv + R
13	**28,420.2 J**	E = (3/2)nRT
14	**966.18 K**	T = 2E/(3k)
15	**171.43 kPa**	p/T is constant at constant volume
16	**8,000 m/s**	$v \propto 1/\sqrt{M}$: $2000 \times \sqrt{(32/2)}$
17	**(a) 2.55 mol; (b) 102.10 g; (c) 1.54×10^{24}**	n = pV/RT
18	**(a) 200 m/s; (b) 600 m/s; (c) it becomes 9 times**	$v = \sqrt{(3p/\rho)}$; $v \propto \sqrt{T}$; KE ∝ T
19	**(a) 831 J; (b) 1,163.4 J. At constant pressure the gas also does work (nRΔT = 332.4 J) as it expands.**	Cv = (f/2)R; Cp = Cv + R
20	**(a) pV = 500 kPa L each time. (b) 25 L. (c) A curve (rectangular hyperbola): as p rises, V falls.**	pV = constant at constant temperature

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