OCR A A Level Ideal Gases 2 worksheet

35-40 minutes independent practice + 15-20 minutes review

Specification points covered

- 5.1.4(b) State assumptions of the kinetic model of gases: a large number of molecules in random motion; negligible molecular volume; perfectly elastic collisions; negligible forces except during collisions.
- 5.1.4(c) Explain the pressure of a gas in terms of the kinetic model and Newton's laws.
- 5.1.4(e) Use $pV = \frac{1}{3}Nmc^2$ and explain its origin qualitatively; a derivation is not required.
- 5.1.4(f) Define and interpret root-mean-square (r.m.s.) speed and the Maxwell-Boltzmann distribution.
- 5.1.4(g) State and use the Boltzmann constant $k = R/N_A$.
- 5.1.4(h) Use $pV = NkT$ and derive $\frac{1}{2}mc^2 = \frac{3}{2}kT$ from the kinetic-theory equations.
- 5.1.4(i) Describe the internal energy of an ideal gas as kinetic only and dependent on temperature.

Asteria gas analyser

A deep-space probe uses a collision cell and a time-of-flight detector to identify trace gases near an icy moon. Engineers test the analyser with monatomic noble gases before launch.
Show working, keep intermediate values unrounded and use precise quantity language in written answers.

Use throughout

$k = 1.38 \times 10^{-23}$ J K^{-1} $R = 8.31$ J mol^{-1} K^{-1}
Molar masses: helium 4.00, neon 20.2, argon 39.9 and xenon 131 g mol^{-1}.

1. Kinetic model and pressure

1. Engineers model the neon in the analyser as an ideal gas. State any two assumptions of the kinetic model of gases. [2 marks]

2. Explain how the moving neon atoms produce a pressure on the wall of the analyser cell. Refer to momentum and Newton's laws. [3 marks]

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2. From gas pressure to molecular energy

3. In $pV = \frac{1}{3}Nmc^2$, state precisely what c^2 represents. **[1 mark]**

4. The gas also obeys $pV = NkT$. Starting with the two expressions for pV, show that the mean kinetic energy of one atom is $\frac{1}{2}mc^2 = \frac{3}{2}kT$. **[2 marks]**

5. Calculate the mean kinetic energy of one neon atom at 460 K. **[1 mark]**

6. The analyser cell contains 2.40×10^{21} neon atoms at 460 K. Calculate the total internal energy of the gas. **[1 mark]**

7. A second cell contains an ideal monatomic gas at pressure 2.80×10^4 Pa in a volume of 6.00×10^{-4} m^3. Use the kinetic-theory equations to calculate its internal energy. **[1 mark]**

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2. Internal energy and energy changes

8. Describe the internal energy of an ideal gas and explain why, for a fixed number of atoms, it depends only on absolute temperature. [2 marks]

9. A control system keeps the pressure and volume of a test cell constant while 20% of its atoms escape. The initial temperature is 300 K. Calculate the new temperature. State what happens to the mean kinetic energy per atom and to the total internal energy of the remaining gas. [2 marks]

3. Root-mean-square speed

10. Describe the three mathematical operations used to calculate the r.m.s. speed from a set of molecular speeds. [1 mark]

11. A simulation records five molecular speeds: 240, 310, 390, 470 and 560 m s^{-1}. Calculate the r.m.s. speed. [2 marks]

12. Calculate the arithmetic mean speed for the data in question 11 and compare it with the r.m.s. speed. [1 mark]

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3. Root-mean-square speed continued

13. The mass of one neon atom is 3.35×10^{-26} kg. Calculate the r.m.s. speed of the neon atoms at 460 K. [1 mark]

14. A xenon atom has mass 2.18×10^{-25} kg. Both gases are at 460 K. Calculate the ratio of the neon r.m.s. speed to the xenon r.m.s. speed without calculating either speed separately. [1 mark]

15. A time-of-flight detector measures an r.m.s. speed of 790 m s^{-1} for a monatomic gas at 500 K. Calculate its molar mass and use the data table to identify the gas. [2 marks]

16. A detector cell contains 4.50×10^{20} neon atoms, each of mass 3.35×10^{-26} kg. Their r.m.s. speed is 620 m s^{-1} and the cell volume is 2.40×10^{-4} m^3. Calculate the gas pressure. [1 mark]

17. Faulty software uses the arithmetic mean speed in $pV = \frac{1}{3}Nmc^2$. Explain why this gives a pressure that is too small. [1 mark]

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4. Reading a Maxwell-Boltzmann distribution

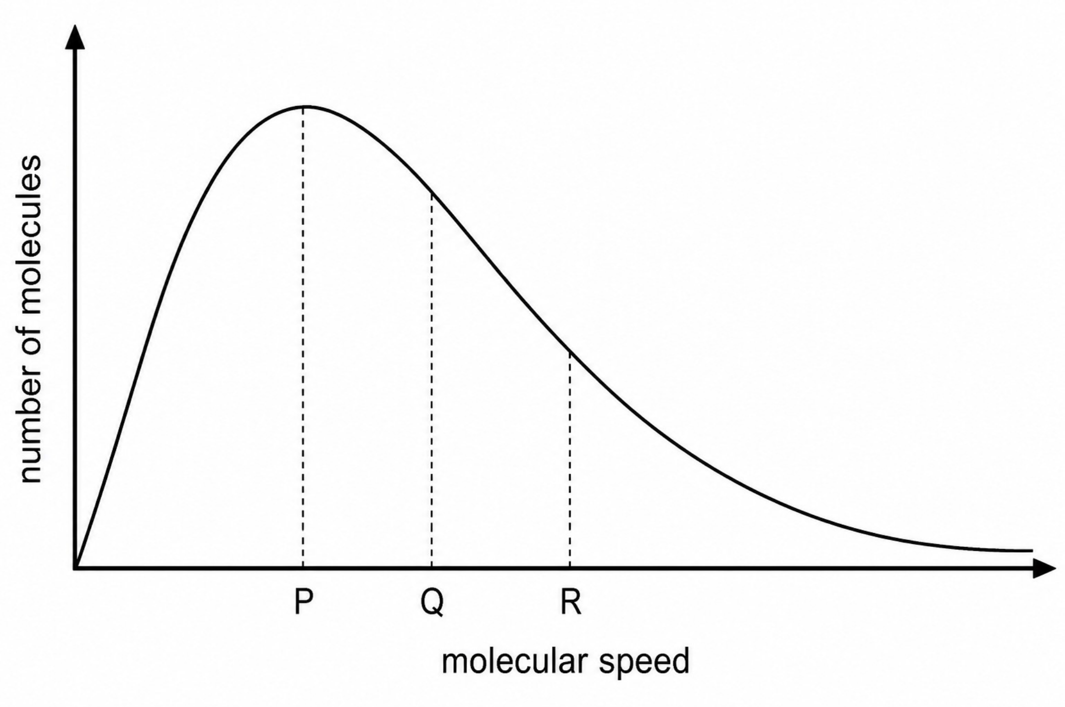

Figure 1: molecular-speed distribution

18. Figure 1 shows a Maxwell-Boltzmann distribution for one gas. Identify the speeds marked P, Q and R. [3 marks]

19. Explain why the curve contains very few molecules at speeds close to zero and at extremely high speeds. [1 mark]

20. State what the area under a Maxwell-Boltzmann distribution represents. [1 mark]

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5. Heating a fixed sample

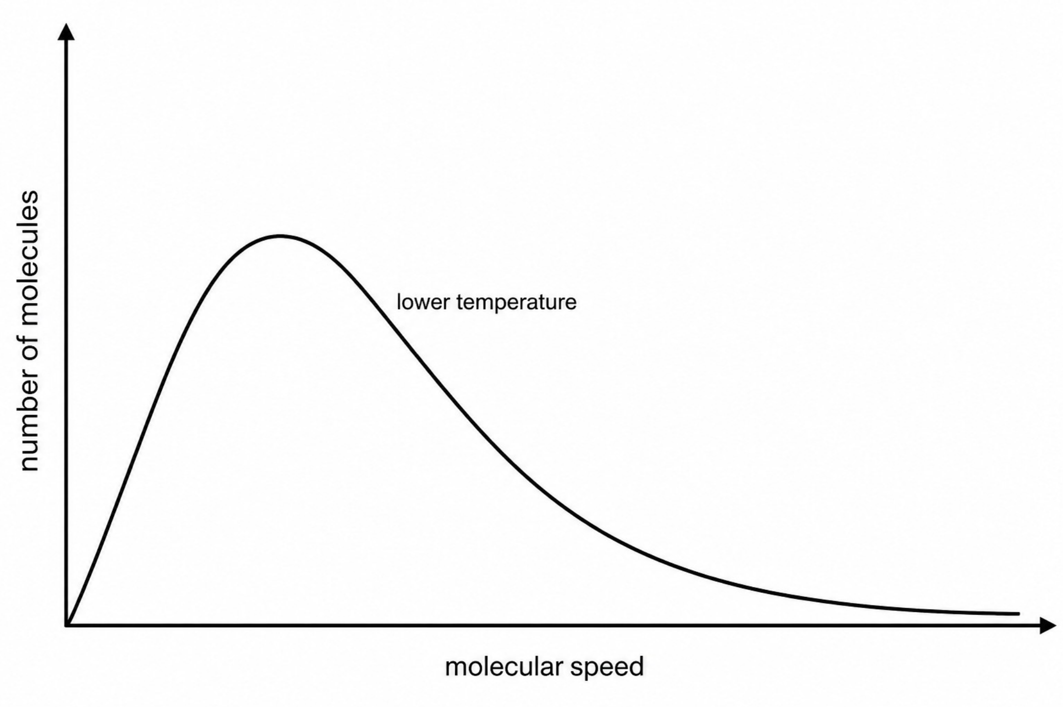

Figure 2: distribution at the lower temperature

21. Figure 2 shows the distribution for a fixed sample at a lower temperature. On the figure, sketch the distribution after the gas is heated. [2 marks]

22. Describe how the most probable speed, the height of the peak and the width of the distribution change when the gas is heated. Use quantity-based language. [2 marks]

23. The detector counts only molecules faster than a threshold speed. Explain why heating the gas increases the fraction of molecules detected. [1 mark]

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6. Apply and connect the ideas

24. Helium and xenon samples contain the same number of atoms at the same temperature. Compare their mean kinetic energies and their Maxwell-Boltzmann distributions. [2 marks]

25. Cells X and Y have the same volume and temperature. X contains 2N atoms of mass m; Y contains N atoms of mass 4m. Compare X with Y for: pressure, mean kinetic energy per atom, r.m.s. speed and total internal energy. Give a ratio for each quantity. [4 marks]

Review and improve

- ◻ I distinguish mean speed, mean square speed and r.m.s. speed.
- ◻ I can derive the mean molecular kinetic-energy equation from the two pV equations.
- ◻ I describe graph changes using speed, peak height, width and area.

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