Mark schemes

1 A

[1]

2 D

[1]

3

(a) kinetic energy of ball = $\frac{1}{2} \times mv^2 = \frac{1}{2} \times 0.060 \times (50)^2 = 75$ J **(1)**

(1)

(b) kinetic energy of one atom $\frac{3}{2}\ kT$ **(1)** ($\frac{3}{2} \times 1.38 \times 10^{-23} \times T$)

one gram contains $\frac{1}{4} \times N_A$ (= 1.5×10^{23}) atoms **(1)**

total internal energy = $1.5 \times 10^{23} \times \frac{3}{2} \times 1.38 \times 10^{-23} \times 48 = 150$ J **(1)**

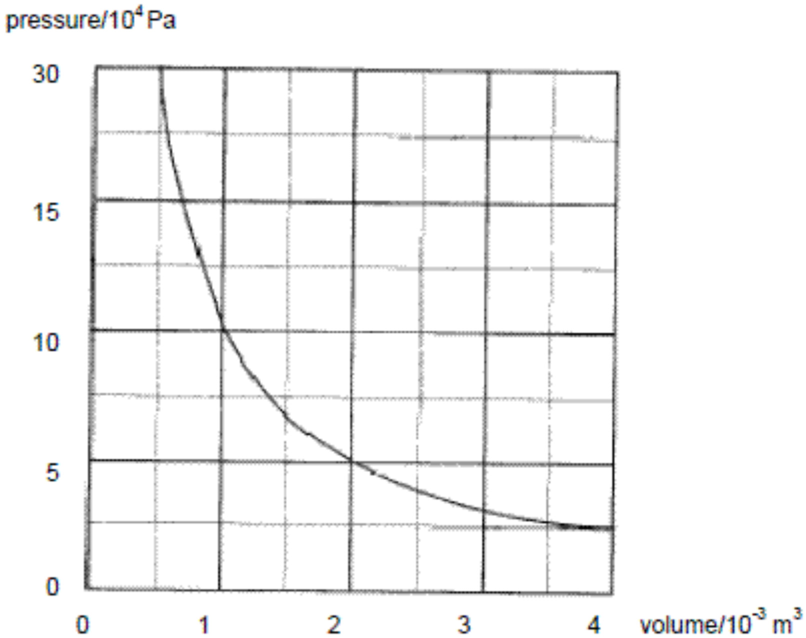
(3)

(c) energy of helium gas at 48 K is twice that of tennis ball
∴energies equal when helium gas has a temperature of 24 K **(1)**

(1)

[5]

4 (a)



3

curve with decreasing negative gradient that passes through the given point which does not touch the *x* axis **(1)**

designated points	
pressure/10^4 Pa	volume/10^{-3} m^3
10	1.0
5.0	2.0
4.0	2.5
2.5	4.0

2 of the designated points **(1)(1)** (one mark each)

(b) (i) $N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3}/1.38 \times 10^{-23} \times 290$ **(1)**

[or alternative use of $PV = nRT$
$5 \times 10^4 \times 2.0 \times 10^{-3}/8.31 \times 290 = 0.0415$ moles]
$= 2.50 \times 10^{22}$ molecules **(1)**

2

(ii) (mean) kinetic energy of a molecule
$= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ **(1)** (= 6.00×10^{-21} J)

(total kinetic energy = mean kinetic energy × N)
= $6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ **(1)**

= 150 (J) **(1)**

3

(c) all molecules/atoms are identical

molecules/atoms are in random motion

Newtonian mechanics apply

gas contains a large number of molecules

the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses

no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions

collisions are elastic or **kinetic** energy is conserved

and of negligible duration

any 4 ***(1)(1)(1)(1)***

max 4

[12]

5 (a) (i) collisions with/bombardment by air molecules (condone particles)

B1

1

(ii) motion of air molecules ("they are") random (in all directions)

B1

fast moving

B1

max 2

air molecules small or much smaller than smoke particles

B1

(b) (i) 3/2kT or substituted values (independent of powers)

do not allow all equations written

C1

6.21×10^{-21} J

A1

2

(ii) $pV = 1/3\ Nm\langle c^2\rangle$

C1

relates Nm/V to ρ

C1

$2.4 \times 10^5\ m^2s^{-2}$

A1

(allow compensation of ½ $m\langle c^2\rangle$ for 1)

3

(iii) there will be a range of speeds

B1

there will be molecules with lower speeds
than mean /average
means higher and lower values

B1

2

[10]

6 (a) number of molecules in a gas is very large
duration of collision much less than time between collisions
total volume of molecules small compared with gas volume
molecules are in random motion
collisions are (perfectly) elastic
there are no forces between molecules (any four) **(4)**

(any 4)

(b) (i) heat (energy) transferred to gas from warmer air outside
mean kinetic energy of gas molecules increases
or molecules move faster
momentum of molecules increases
more collisions per second
each collision (with container walls) transfers more momentum
force (per unit area) on container wall increases (any four) **(4)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part.

(ii) $T = 273 + 27 = 300\text{K}$ **(1)**

mean kinetic energy = $\frac{3}{2}kT$

$= 1.5 \times 1.38 \times 10^{-23} \times 300 = 6.2 \times 10^{-21}$ J **(1)**

(allow e.c.f. for incorrect T)

(6)

[10]

7 (a) p: pressure <u>and</u> V: volume **(1)**
N: number of molecules **(1)**
m: mass of one molecule / particle / atom **(1)**
$\overline{c^2}$: mean square speed **(1)**

4

(b) (i) molecules have a range of speeds **(1)**
they have no preferred direction of movement **(1)**

(ii) elastic collisions
intermolecular forces are negligible (except during collisions)
volume of molecules negligible (compared to volume of container)
time of collisions negligible (compared to time between collisions)
all molecules identical
laws of statistics apply or large number of molecules
Newtonian laws apply any two **(1)** **(1)**

max 3

(c) molecules collide (with the walls) **(1)**
walls exert a force on the molecules **(1)**
molecules exert an (equal) force (on the walls) **(1)**
creating pressure **(1)**
molecule momentum changes

max 4

[11]

8 (a) (i) graph:

scales (points spread over at least half graph paper, each) **(1)**
correct points (plotted within ½ square) **(1)**
best fit line (if origin shown, line must pass through it) **(1)**

E_k at 350 K = 7.22 × 10^{-21}J (accept 7.23 to 7.27) **(1)**

(ii) gradient (= $\frac{(8.28 \times 6.21)10^{-21}}{400 - 300}$

= 2.07 × 10^{-23}(JK^{-1}) (accept 2.00 to 2.15)

(use of $\frac{3}{2}\ kT = E_k$ gives) gradient = $\frac{3}{2}\ k$ **(1)** (accept C.E for gradient)

$k = \left(\frac{2 \times 2.07 \times 10^{-23}}{3}\right)$ = 1.38 ×10^{-23} **(1)** J K^{-1} **(1)**

8

(b) (i) kinetic energy is conserved **(1)**

(ii) time of collision is negligible (compared to time between collisions)
[or large number of molecules,
volume negligible (compared to volume of container),
no intermolecular forces,
rapid random motion] **(1)**

(iii) temperature proportional to E_k **(1)**
at 0 K, E_k would be zero **(1)**
[or sketch graph of E_k vs T / K to give straight line through origin **(1)**
graph explained **(1)**]

4

[12]

Examiner reports

4

Part (a) proved difficult for less able candidates. Some drew straight lines and others tried to force the curve to intercept the volume axis. The less able candidates sometimes marked correct points on the grid but did not draw a line. It seemed that some less able candidates followed the wrong order in tackling this part. They drew the curve before they marked points on the grid. As a result the points were just randomly placed on the curve they had drawn.

Part (b) (i) was done well by most. Candidates who used the alternative equation $PV = nRT$ often stopped when they had found the number of moles of gas. Part (b) (ii) was much more discriminating with less than 50% of candidates obtaining the correct answer. Many candidates did not have a clue whereas others could find the mean kinetic energy but then did not follow this up by finding the total kinetic energy.

Although part (c) looks like a basic question it did discriminate well. It was only the more able candidates who scored full marks. Many did not know what the question was getting at and guessed. Sometimes these candidates did score the mark associated with molecules moving in random motion. In other cases candidates did not complete their statements fully. For example, stating ‘atoms travel in straight lines’, rather than, ‘atoms travel in straight lines between collisions’.

5

(a) (i) Most candidates recognised that the random motion of the smoke particles was due to collision with air molecules. A minority simply mentioned Brownian movement without any explanation.

(ii) The majority of candidates suggested that air molecules moved randomly but few were able to link a second property, which could be inferred from the observation of the smoke particles.

(b) (i) Most candidates were able to quote the correct equation and substitute appropriate values to gain the answer 6.21×10^{-21} J. A minority of candidates used $\frac{2}{3}kT$ or missed the minus sign for the power of 10.

(ii) Although most candidates recognised the equation $pV = \frac{1}{3} Nm\langle c^2 \rangle$, a high proportion failed to see how the density related to this equation and then either fudged its substitution, or else made no progress beyond quoting the equation. A significant number of candidates went on to quote the rms speed and were then penalised if they had not quoted the mean square value with its unit.

(iii) Few candidates gave a totally convincing argument that there was a distribution of molecular speeds and that at a higher temperature there would still be molecules moving with speeds well below the mean speed.

6 A small minority of candidates clearly were not prepared for kinetic theory in any detail and produced nonsense answers in part (a). Most candidates remembered two of the assumptions and either left the final two unanswered or, quite commonly, were content to rephrase their first two assumptions. On the other hand many candidates did get all four assumptions correct.

Very few candidates achieved all four marks for the explanation in part (b)(i). Many made no reference to molecules or to the kinetic theory but invoked the general gas law. Most candidates knew that gas molecules move faster on average when heat energy is transferred into the gas from the warmer surroundings and related this to an increased collision rate with the container wall. Few candidates made any mention of momentum exchange. Most candidates used the correct expression $\frac{3}{2}kT$ for the mean kinetic energy in part (ii), but few used the absolute temperature in the calculation. A surprising number of candidates, having arrived at a correct answer, lost the mark by omitting the unit.

7 Weaker candidates experienced considerable problems with this question. In part (a) these candidates found it difficult to explain what the symbols in the equation represented and errors such as stating that p represented momentum and that c was the speed of light or the specific heat capacity were quite common.

Answers to part (b) were much better and it was clear that candidates were well prepared for this type of question. Part (c) however, caused more problems and although most candidates scored some marks the descriptions were generally vague.

8 In part (a) the majority of candidates gained high marks for correct plotting of the graph, the only major error being due to poor choice of scale. Determining the average kinetic energy of gas molecules at 350° from the graph and calculating the gradient of the straight line was usually carried out correctly, but very few candidates, however, were able to deduce a correct value for the Boltzmann constant. The vast majority assumed that the gradient equalled the constant.

Part (b) of the question was answered with mixed success. A significant minority could not explain what was meant by an elastic collision and part (iii) was not well answered since there appeared to be some confusion as to what exactly was required. It seemed a common misconception that absolute zero occurred at –273 K.