Access Tuition

A-Level Physics

Ideal Gases

Mark Scheme

Time available: 75 minutes
Marks available: 49 marks

Mark schemes

1. (a) Any two from ✓✓

- Volume of molecules is negligible compared to that of the container
- Collision time is negligible or small compared to the time between collisions
- Collisions are elastic or kinetic energy is conserved
- There are negligible forces between molecules (except during collisions)
- Newtonian mechanics apply

2

(b) (NI) molecules do not maintain a constant velocity (when hitting the walls) so they must experience a force. ✓$_1$
owtte.

(NII) Molecules have a rate of change of momentum when bouncing off the walls and force =/is related to rate of change of momentum. ✓$_2$
owtte.

(NIII) A force is exerted by the wall on the molecules so the molecules exert a force on the wall. ✓$_3$
owtte

For each mark the essence of the Newton law must be given in the context of the gas.

Just quoting a Newton law is not enough for a mark.

✓$_2$ *'rate of change' must be used.*

3

(c) Use of $E_k = \frac{3}{2}kT$ to find a temperature ✓$_1$

$$(T = \frac{2\times}{3\times}\frac{6.7\times10^{-21}}{1.38\times10^{-23}} = 324\ \text{K})$$

Use of $PV = nRT$ with calculated temperature ✓$_2$

$$(n = \left(\frac{PV}{RT} = \frac{220\times10^{3}\times0.35}{8.31\times324}\right))$$

amount of gas = 29 (mol) ✓$_3$ (28.6 mol)

✓$_1$ *for rearranged equation with data that may have powers of 10 or transcript errors with constants as symbols. A temperature answer is needed or the fully substituted equation.*

✓$_2$ *for rearranged equation with data that includes the calculated temperature and may have powers of 10 or simple transcript errors with constants as symbols*

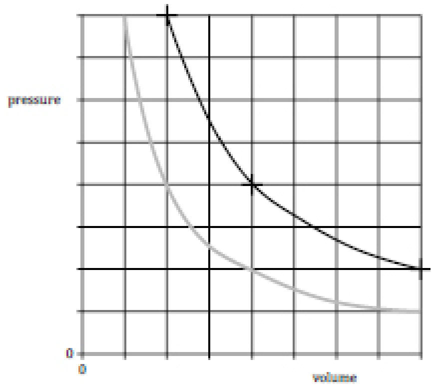
✓$_3$ *no ecf, correct answer only*

3

(d) Drawn graph with concave shape passing through at least one of the data points. (data points are shown as crosses on the graph) ✓

Passing through coordinates (2,8), (4,4) and (8,2) ✓
(coordinates refer to cm intervals on the graph)

Drawn line must be within a small square (2 mm) of a data point to count.



2

[10]

2. (a) attempts two calculations that would lead to a conclusion $_1$✓

for $_1$✓ the result of at least one calculation of $M \times y$ must be correct (see table) otherwise withhold both marks;

allow use of y in m but reject POT error

1

a reasoned judgement explaining why y not inversely proportional to M $_2$✓

M / kg	y / mm	acceptable $M \times y$	min sf
0.5	89(.0)	44.5 / 45	2
1.0	82(.0)	82(.0)	
1.5	76(.0)	114(.0)	3
2.0	71(.0)	142(.0)	
2.5	66.5	166(.3)	
3.0	62.5	187.5 / 188	

for $_2$✓ two correct calculations of $M \times y$; see table for min sf in result for $M \times y$

OR

one correct calculation of $M \times y$ and an appropriate reverse-working calculation;

statement rejecting inverse-proportion supported by suitable quantitative reasoning, eg calculation of the percentage difference between the results of their calculations;

condone weaker 'large' / 'significant differences' (between calculation results);

reject 'values are different' / 'not constant' / 'not close enough'

reasoning must be based on the data points, eg reject 'best-fit line crosses y-axis'

for $_{12}$✓ condone use of two rows of data to show that when M doubles, y does not halve

1

(b) (as **P** moves down) trapped air expands $_1$✓

(so) pressure of trapped air is reduced $_2$✓

pressure of trapped air becomes <u>less than</u> atmospheric pressure $_3$✓

pressure difference across **P** produces upwards force which balances weight of **P** $_4$✓

pressure difference across **P** × area of piston = weight of piston $_5$✓

for $_1$✓ allow 'volume (of trapped air) increases' / 'is less compressed'

for $_3$✓ reject 'atmospheric pressure constant'

for $_4$✓$_5$✓ allow any correct idea of equilibrium being achieved

Max 3

(c) smooth curve of decreasing negative gradient through all 6 points $_1$✓

curve extrapolated (backwards) to $M = -0.7$ $_2$✓

(clear evidence that) value of y corresponding to $M = -0.7$ read off$_3$✓

y in range 110 mm to 114 mm $_4$✓

OR

for incorrect method

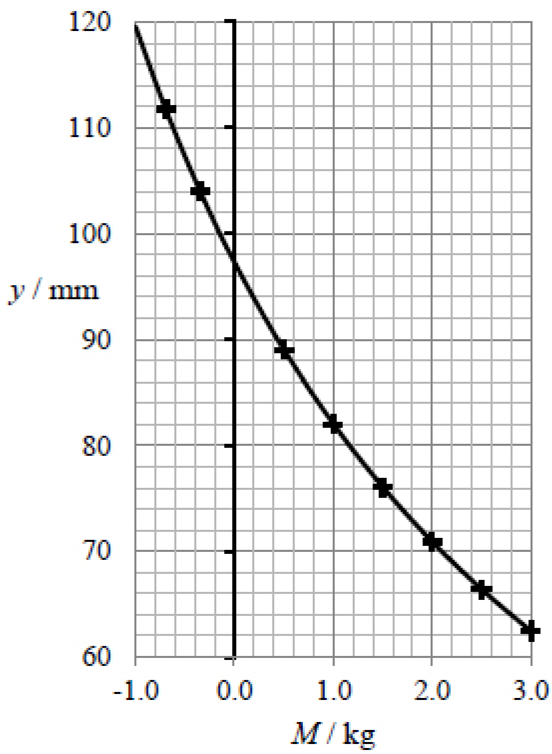
curve extrapolated (backwards) to $M = -0.35$ and (clear evidence that) value of y corresponding to $M = -0.35$ has been read off $_{23}$✓

y in range 103 mm to 105 mm $_4$✓

withhold $_1$✓ for any linear region and annotate clip to explain

condone poorly-marked line but insist that line passes through all 6 points

for $_3$✓ 'clear evidence' means a plausible answer for y clearly obtained by the correct method or suitable working shown on ***Figure 2***



4

(d) correctly identifies error $_1$✓

for $_1$✓ reading has been taken from the top of the meniscus / should have been taken from the bottom of the meniscus

1

correct reading is 35.8 $_2$✓

reject 'sub-divisions are 0.1 cm ^{3} not 0.2 cm^3'

for $_2$✓ CAO 1

1

(e) gradient evaluated as decimal number to ≥ 2 sf from valid method $_1$✓

for $_1$✓ Δ log(V / cm^3) divided by Δ log(P / MPa);

*graph in **Figure 5** has gradient of −1.03(3);*

1

states gradient result ≈ −1 $_2$✓

significance explained $_3$✓

for missing – sign allow $_{12}$✓ = 1 MAX

for $_3$✓ use of $y = mx + c$ expected; – sign essential

eg log$V$ = – log p + <u>constant</u>

do not insist on V = constant × p^{-1}

2

(f) log p = –0.47 $_1$✓

correct answer earns $_{123}$✓✓✓

for $_1$✓ log 0.34 = –0.4685

1

use of at least one other value of

p and corresponding V

OR

log p and corresponding log V $_2$✓

solves for unknown V;

≥ 3 sf result in range 10.5 to 11.5 (cm^3)

OR

11 (cm^3) $_3$✓

for $_2$✓

check their $p \times V$ in range 3.65 to 3.80

OR

their log p + log V = 4.50 to 6.30

expect

*p_1, V_1 values derived from a point on the line in **Figure 5**; use of*

$p_1V_1 = p_2V_2$; sub of p_2 = 0.34 & solve for V_2

OR equivalent based on $\log\frac{p_1}{p_2} = \log\frac{V_2}{V_1}$

for use of ln 0.34 = –1.079 leading to (ln V = 1.665 and) V23✓

2

(g) temperature (of air) $_1$✓

for $_1$✓ accept 'mean ke of air molecules', 'vapour pressure <u>of air</u>'

1

change the pressure of the gas <u>slowly</u> or wtte

OR

wait until the oil level stabilises $_2$✓

for $_2$✓ condone 'keep lab temperature constant';

reject 'do not heat the apparatus' / 'keep windows closed' etc

OR

keep purity of oil constant $_1$✓

choose oil with low evaporation rate $_2$✓

1

[19]

3. (a) (If not in a vacuum) gas atoms will collide with air atoms, changing their direction or speed distribution. ✓

There must be some indication of a change of the oven gas molecules associated with collisions

If temperature change is mentioned this must be related to speed distribution for the mark

1

(b) Finds time taken for one rev AND/OR time for 1/8 rev ✓

(Uses speed = distance/time to get)

$= 0.500 / 1.04 \times 10^{-3} = 480$ m s^{-1} ✓

(so about 500 m s^{-1})

1 rev in 1/120 s or 0.00833 s

Time for 45º or 1/8 rev = 1.04 × 10^{-3} s

Must have 2 or more sf answer but 500 m s^{-1} is acceptable as a final answer provided the calculated time for 45º or 1/8 rev is shown and rounded down to 2 sf

2

(c) Mass of one atom = $m = 0.209/N_A = 3.47 \times 10^{-25}$ kg ✓$_1$

✓$_1$ *May be seen in the substitution of the equation that follows*

✓$_2$ $\frac{m}{3k}$*(answer (b))*^{2}

Substitutes m and answer (b) in $\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT\,kT$ and rearranges ✓$_2$

$T = 1930$ K ✓$_3$

✓$_3$ *Accept 2095 K or 2100 K if 500 m s^{-1} used*

A correct answer also gains the second mark

3

(d) (Pressure is due to collisions of atoms with oven walls) With fewer atoms fewer collisions <u>per second</u> ✓$_{1a}$

✓$_{1a}$ There must be a reference to frequency or rate of collision

but average momentum change per collision stays the same
or
therefore the total momentum change per second falls (so pressure drops) ✓$_{2a}$

OR

Reference to $pV = \frac{1}{3}Nm(c_{rms})^2$ ✓$_{1b}$

c_{rms} is constant as T is constant hence p ✓ N (so pressure drops) ✓$_{2b}$

✓$_{1b}$ The equation may be in any equivalent kinetic theory form

$pV = nRT$ is not acceptable unless a connection is made between T and c_{rms}

2

(e) ($pV = nRT$)

leaked $n = \frac{V((p_1 - p_2)}{RT}$ ✓

= 8.42 × 10^{-3} mol

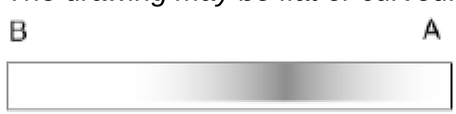
*ecf for T from **(c)***

1

(f) At higher temp atoms will be faster (so drum will not have turned as far) ✓$_{1a}$

Darkest area will be closer to A ✓$_{2a}$

✓$_1$ Accept drawing but allow any degree of maximum darkness. The drawing may be flat or curved.



Allow

more atoms will pass through S as it passes the oven, for the first mark

making the dark patch darker, for the second mark. This must be linked to the more atoms

2

[11]

4. (a) Total energy supplied (= Pt) = 12 × 890 = 10 680 (J) ✓$_1$

✓$_1$ Substitution or answer.

Heat energy to evaporate nitrogen at its boiling point (= ml) = 0.05 × 2.0 × 105 = 10 000 (J) ✓$_2$

✓$_2$ Substitution or answer.

(Use of $Q = mc\Delta\theta$)

Attempt to use $c = \left(\frac{Q}{m \times \Delta\theta}\right) = \frac{(10680-10000)}{0.050 \times (77-70)}$ ✓$_3$

✓$_3$ Allow any attempt at substitution with (77 – 70) or 7 correct but ΔQ does not have to be correct so can even show an addition.

specific heat capacity of liquid nitrogen =

$c = 1.9 \times 10^3$ ✓$_4$ (allow 1 sig fig due to the small temperature difference)

✓$_4$ Allow 1 sig fig due to the small temperature difference. No ecf – correct answer only.

J kg^{-1} K^{-1} or J kg^{-1} $°C^{-1}$ ✓$_5$ {taken from the answer line but if not present can come from the body of the answer space}

✓$_5$ Correct answer Consistent with 4th mark and only in the form shown ie no double or single solidus/oblique lines.

Only penalise the kelvin unit if it has an obvious loop at the top – allow if simply small.

5

(b) (Use of volume = $\frac{m}{\rho}$)

nitrogen gas = $\frac{0.050}{3.8}$ = 0.013 (m^3) ✓$_1$ {if both given both must be correct}

✓$_1$ Substitution or answer and can be seen without label or explanation.

nitrogen liquid = $\frac{0.050}{810}$ = 0.000062 (m^3)

OR

a reference to the volume being negligible ✓$_2$

✓$_2$ Substitution or answer or words.

Work done in expanding (= X = $p\Delta V$)

= $1.0 \times 10^5 \times 0.013 = 1.3 \times 10^3$ (J) ✓$_3$

✓$_3$ Evidence of ΔV or calculation introduced with 'work done =' is required for the mark.

For an ecf the product must be shown in full with the substitution of the ecf being clear.

which is less than 1.0×10^4 J/the energy to change state = Y (ie X < Y) ✓$_4$

✓$_4$ Allow ecf from part (a) for this mark provided the statement is consistent with the figures.

OR

If the ecf comes from the 3rd mark above then the work done in expanding must be clearly labelled for the comparison or have units of J i.e it cannot be compared with a number that just happens to be on the page.

4

[9]