Mark schemes

Q1.

(a) n = 43.1 ✓ (≥ 2 SF)

$$n = \frac{105 \times 10^3 \times 1}{8.31 \times (273 + 20.0)}$$

1

(b) Use of $m = \frac{\rho V}{nN_A}$ OR $m = \rho V$

OR use of $m_{\text{molecule}} = \frac{m_{\text{gas}}}{N_A}$ OR $N = nN_A$

OR $(c_{\text{rms}})^2 = \frac{3p}{\rho}$ seen in any form

OR use of their mass with $pV = \frac{1}{3}Nm(c_{\text{rms}})^2$

OR use of $\frac{1}{2}m(c_{\text{rms}})^2 = \frac{3}{2}kT$ ✓1

Correct answer see table ✓2

Correct SF see table ✓3

n	✓2 c_{rms}/m s^{-1}	✓3 SF
Without *n*	500-503	3 SF (501-503)
n more than 3SF	500-503	3 SF (501-503)
43.1	500-503	3 SF (501-503)
43	500-503	2 SF (500)
40 (no evidence of *n* = 43 in **part (a)**)	482-484 or 500	2 or 1 SF (480 or 500)
40 (evidence of *n* = 43 in part **part (a)**)	482-484 or 500	1 SF (500)

Allow ecf for incorrect T and/or n in part ***(a)***

Several approaches are possible

$$m = \frac{pV}{nN_A} = \frac{1.25 \times 1.00}{43.1 \times 6.02 \times 10^{23}} = 4.82 \times 10^{-26}$$

(5.1 × 10^{-26} if 40 used)

$$c_{\text{rms}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 293}{4.82 \times 10^{-26}}} = 502$$

OR

$pV = \frac{1}{3}Nm(c_{rms})^2 \quad p\frac{Nm}{\rho} = \frac{1}{3}Nm(c_{rms})^2$

$(c_{rms})^2 = \frac{3p}{\rho}\left(= \frac{3pV}{Nm} = \frac{3p\times1}{\rho}\right)$

$c_{rms} = \sqrt{\frac{3\times105\times10^3}{1.25}} = 502$

3

(c) T = 4 × 293 or 4 times the starting temperature in K ✓

change in temperature = 879 (K) ✓ (correct answer gains both marks)

Alternative

$T = \frac{m(2c_{rms})^2}{3k}$ correctly calculated for their m, c_{rms} ✓

Their calculated T - 293 ✓ 7709

mp1 Using $\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT$ so $(c_{rms})^2 \propto T$

$\frac{(c_{rms})^2}{293} = \frac{(2\times c_{rms})^2}{T}$

T = 293 × 4 = 1172 K

mp2 change in temperature = 1172 - 293 = 879 K

Allow answer that rounds to 880 (K)

If no other marks awarded award max 1 when T is 4 times original and Δθ = 60

2

(d) Max 2 from: ✓✓

- Calculation of mass of water condensed in one hour 1.25 × 960 × (0.0057 - 0.0037) = 2.4 (kg)
- use of their mass with $mc\Delta\theta$ (expect 4.5 × 10^4 (J))
- use of their mass with mL (expect 5.5(2) × 10^6 (J))

heat energy removed = 5.6 × 10^6 (J) ✓

3

[9]

Q2.

(a) total kinetic energy of the particles ✓

Condone "molecules" or "atoms" for "particles"

Kinetic energy will be taken to mean total kinetic energy but do not accept use of mean kinetic energy or reference to kinetic energy of a single particle.

Do not allow any reference that implies there is potential energy or any other energy added to the kinetic energy.

1

(b) (the speed before and after a collision is the same in the elastic collision)

Δp (= p_f - p_i) = - mc - mc = -2mc ✓

Use of subscripts i and f or before and after do not need explanation.

Δ will be assumed to mean (final - initial).

Either the initial momentum or the final momentum must be described clearly enough to justify the negative final answer

1

(c) Time between colliding with **W** $\left(= \frac{s}{c}\right) = \frac{2l}{c}$

$f = \frac{1}{T}\left(= \frac{c}{2l}\right)$ ✓

Must show evidence of a time calculation using distance and speed

Do not allow any attempted use of v = f λ

1

(d) Reference to a Newton law **AND** $P = \frac{F}{A}$ ✓₁

$P\left(= \frac{F}{A} = \frac{mc^2}{l} \times \frac{1}{l^2}\right) = \frac{mc^2}{V}$ ✓₂

The reference to Newton law could be a simple link between Newton's name and an equation.

2

[5]

Q3.

(a) Attempt to calculate either volume using correct equation ✓1

Subtracts their two volumes ✓2

n = 3.09 **OR** 6.46 **OR** attempt to find one n using $\frac{pV}{RT}$

with correct temperature ✓3

Calculates Δn = 3.37 (mol)

OR

Determines both values of n with correct T and p

AND calculates their Δn ✓4

Molar mass = 0.028 (kg mol^{-1}) ✓5

✓1

Condone POT.

$$\frac{\pi h d^2}{4} = \frac{\pi \times 370 \times 10^{-3} \times (660 \times 10^{-3})^2}{4}$$

0.1265 m³

OR

$$\frac{\pi h d^2}{4} = \frac{\pi \times 370 \times 10^{-3} \times (330 \times 10^{-3})^2}{4}$$

0.0316 m³

✓2 V = 0.1265 - 0.0316 = 0.0949 (m³)

Correct answer will be given ✓1 ✓2

✓3 Correct answer will be given ✓1 ✓2

$$\frac{pV}{RT} = \frac{1.01 \times 10^5 \times 0.0949}{8.31 \times (100 + 273)}$$ *= (3.09) or*

$$\frac{pV}{RT} = \frac{2.11 \times 10^5 \times 0.0949}{8.31 \times (100 + 273)}$$ *= (6.46)*

✓4 Δn = 6.46 - 3.09 = 3.37 (mol)

Correct answer will be given ✓3 ✓4

✓5 molar mass = $\frac{14.991 - 14.897}{3.37} = \frac{0.094}{3.37}$

= 0.028 (kg mol

5

(b) (Carrying out the check) at a higher temperature increases the pressure in the tyre. ✓$_1$

(Thus) the tyre could pass the check with a smaller amount of gas in the tyre.

OR

(When the tyre is hot) you can achieve the same pressure but with less gas. ✓$_2$

✓$_1$ For linking pressure to temperature.

Condone comments suggesting $p \propto T$

✓$_2$ For linking less gas/smaller n to a passing check. ***OR*** *For a comparison between the amount of gas in the tyre that produces a certain pressure when the tyre is hot and cold*

2

[7]

Q4.

(a) Combining and making use of $Q = Pt$ and $Q = mc\Delta\theta$ equations without the need to make t the subject. ✓1

t = 27 (s) ✓2

✓1 numerical errors are ignored for this mark.

Provided the temperature difference is correct then subsequent changes that involve 273 °C can be ignored.

✓2 $t = (1.2 \times 450)\frac{(125-20)}{2100}$

No ecf for the second mark but correct answer gains both marks

Condone use of c_{water} *for* c_{metal}

2

(b) (The power supplied in time t raises the temperature of m kg of water and converts it to steam)

Use of appropriate equation. ✓1

The award of MP3 is dependent on the award of MP1 OR MP2.

Evidence for MP1 can be seen in MP2 via the correct answers in the exemplars below.

Correct evaluation of Δm or P. No ecf. ✓2

Condone error in time / temperature change / POT for MP1.
Use of m from the metal is not condoned

✓1 $Pt = mc_w\Delta\theta + ml$ OR $P = \frac{mc_w\Delta\theta + ml}{t}$

✓2 Several methods can be followed including in 1 minute
2100 × 60

$= \Delta m \times 4200 \times (100 - 20) + \Delta m \times 2.3 \times 10^6$

Δm = 0.048 kg min^{-1}

OR

in one second 2100

$= \Delta m \times 4200 \times (100 - 20) + \Delta m \times 2.3 \times 10^6$

Deduction that claim is false (consistent with their value) supported by their calculated quantity
OR
Deduction that their calculated quantity is greater / smaller than required ✓3

Δm = 0.00080 kg s^{-1}

OR

P =

$$= \frac{0.060 \times 4200 \times (100 - 20) + 0.060 \times 2.3 \times 10^6}{60}$$

P = 2.6(4) × 10^3 W

OR

Comparing the energy supplied in time eg in a minute (126000 J) with energy needed (138000 + 20160 = 158000 J)

OR

Calculation of time taken to obtain 60 g of steam = 75.3 s.

✓$_3$ *So claim is not true.*

0.048 kg min^{-1} is smaller than 60 g min^{-1}

OR

0.00080 kg s^{-1} = 48 g min^{-1} is smaller than 60 g min^{-1}

OR

2.6 × 10^3 W is greater (than 2.1 kW / power available)

OR

time to generate 60 g of steam is too long.

(The most common ecf will be to leave out the raising of the water temperature before changing the water to steam giving calculated values of Δm = 0.055 kg min^{-1}, or

Δm = 0.00091 kg s^{-1} or P = 2.3 × 10^3 W)

3

[5]

Q5.

(a) Any two from ✓✓

- Volume of molecules/particles is negligible/small compared to the volume of the container
- Collision time is negligible/small compared to the time between collisions
- Collisions are elastic or kinetic energy is conserved
- There are negligible/no forces between molecules/particles except during collisions

Reference to the volume occupied by the gas must be clear for the first point. So 'volume of gas' is not enough.

Condone missing reference to "except during collisions" in bullet 4.

Condone "Newtonian mechanics apply".

2

(b) There is a change in velocity/momentum for the molecules (at the wall) because the direction has changed ✓1

Relates MP1 to Newton I OR II ✓2

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.

(Uses Newton III to) link the force on the wall and the force on the molecule ✓3

Do not accept "rate of change of momentum" in MP1.

Condone "bounces from wall" for "changes direction".

Collision is not a change in direction.

Accept reference to changing velocity/momentum/direction in MP2.

3

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

OR

Using

$pV = \frac{1}{3}Nm(C_{rms})^2$ with $E_k = \frac{1}{2}m(C_{rms})^2$ to find N ✓1

✓1 $T = \frac{2\times 6.7\times10^{-21}}{3\times 1.38\times10^{-23}} = 324\ K$

Correct substitution into $PV = nRT$ to find n

OR

Correct substitution into $N = \frac{3}{2}\frac{PV}{E_k}$ to find N (= 1.7 × 10^{25}) ✓₂

✓₂ for use of the equation.

$n = \left(\frac{PV}{RT} = \frac{220\times10^3\times0.35}{8.31\times324}\right)$ or $N = \frac{3}{2}\times\frac{220\times10^3\times0.35}{6.7\times10^{-21}}$

amount of gas = 29 (mol) ✓₃ (28.6 mol)

✓₃ no ecf, correct answer only

If no other marks are awarded, award one mark:

for an unsupported final answer of 1.7 × 10^{25} which is the number of molecules.

OR

for converting a number of molecules into moles using their

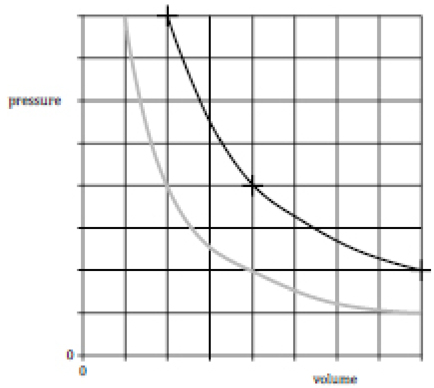
$n = \frac{N}{N_A}$

3

(d) Drawn graph with concave shape always above existing graph 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 ± 1 small square (2 mm) of a data point to count.



Condone a poor quality line.

2

[10]

Q6.

(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

allow use of correct read-offs from valid BFL;

condone use of two rows of data to show that when M doubles, y does not halve;

award of ₂✓ is contingent on valid ₁✓

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 'large' / 'significant differences' (between calculation results) / use of >> etc;

reject 'values are different' / 'not same' / 'not constant' / 'not close enough' use of > etc;

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

1

(b) (as **P** moves down) trapped air expands so)
pressure (of trapped air) is reduced ₁✓

*must address situation in **Figure 3***

for ₁✓ allow 'pressure reaches lower value' reject 'pressure is low' pressure less than atmospheric pressure $_2$✓

for $_2$✓ allow 'there is a pressure difference across ***P*** *' / 'external pressure > pressure of trapped air'*

award $_1$✓$_2$✓ for pressure of air reduced below atmospheric

this leads to an upwards force balancing the weight of **P**

OR

pressure difference across **P** × area of piston = weight of piston $_3$✓

for $_3$✓ allow any ***correct*** *idea about how two opposing forces act to produce equilibrium;*

'no resultant force' is not enough

reject 'weight = gravity' / ideas about 'suction' / equating pressure with force

why **P** falls when the valve is opened $_4$✓

for $_4$✓ idea of external and internal pressures equalising;

reject 'pressure released / returns to normal'

Max 3

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

for $_1$✓ must be a single continuous line for M > 0.5 that overlaps with all 6 ***+****;*

1

line with negative gradient extrapolated (backwards) to $M \le -0.35$ $_2$✓

condone poorly-marked line (note that poor line quality may only be penalised in ***(d)****)*

records y corresponding to $M = -0.7$ $_3$✓

y in range 108 mm to 116 mm $_4$✓

for $_2$✓ condone linear extension of curve with negative gradient for M < +0.5

1

OR

for incorrect M (3 MAX)

smooth curve etc $_1$✓

for $_3$✓ curve must extend to where read off is being made

1

line with negative gradient extrapolated (backwards) to $M \leq -0.35$ $_2$✓

records y corresponding to $M = -0.35$;

y in range 101 mm to 107 mm $_{34}$✓

OR

for linear graph (2 MAX)

ruled line with negative gradient extrapolated (backwards) to $M \leq -0.35$ $_{12}$✓

records y corresponding to $M = -0.7$;

y in range 101 mm to 107 mm $_{34}$✓

award of $_4$✓ is contingent on valid $_3$✓

for $_4$✓ answers that round to nearest mm are acceptable

1

(d) correctly identifies error $_1$✓

*for $_1$✓ reading has been taken at / from the top of the **meniscus** / top of coloured oil / top of liquid*

OR

*should have taken / did not take reading from the bottom / lowest point of the **meniscus** / lowest point on **surface** of coloured oil*

OR

'(student thinks) sub-divisions are 0.1 cm^3 and not (as question states) 0.2 cm^3'

reject 'should have read from bottom of coloured oil' / 'failed to read meniscus properly' / 'read at the top of the air' / 'has read divisions incorrectly' or wtte

1

correct reading is 35.8 $_2$✓

for $_2$✓ CAO

1

(e) gradient from Δ log(V / cm³) divided by Δ log(p / MPa); evaluated to ≥ 3 sf result between −1.05 and −1.01 ₁✓

don't insist on large steps / read off accuracy

accept result that rounds to 3sf between −1.05 and −1.01; sign essential

1

relevant algebra enabling comparison with $y = mx + c$ ₂✓

for ₂✓ (eg Boyle's Law written as)

log V = − log p + constant

condone variation based on Ideal Gas Law in which case must establish that $(nR)T$ / $(Nk)T$ is constant (which then implies Boyle's Law) (recognisable data book symbols only)

OR

*(**Figure 5** shows)*

log V = gradient × log p + constant;

accept (log) k, (log) c etc as recognisable symbols for the constant;

condone (any) numerical value given for the constant eg $10^{1.685}$;

accept m as recognisable symbol for the gradient

1

why gradient ≈ −1 confirms Boyle's Law ₃✓

for ₃✓ allow gradient is / equals / should be −1

if ₂✓ not given accept 'gradient ≈ −1 demonstrates inverse proportion or wtte

1

(f) reads off and attempts to make use of log p_1 AND log V_1 for any point on the line ₁✓

for ₁✓ check log V_1 is within half a grid square of correct position for their log p_1 or vice-versa;

'make use of' excludes use in a gradient calculation

V_2 in range 10.5 to 11.5 (cm³) earns ₁✓₂✓₃✓

1

applies a workable method $_2$✓

for $_2$✓ creditworthy examples are

*a calculation of the intercept in **Figure 5***

eg log V + log p = 0.585

OR

use of gradient = $\dfrac{\Delta \log V}{\Delta \log p}$ *(eg similar triangles idea)*

OR

a calculation of $p \times V$ (by any means)

OR

use of log $V = -1 \times \log 0.34$ + their intercept

no credit for claiming 1.685 (or 1.170) are intercepts; this cannot earn $_2$✓

1

further manipulation to determine unknown V_2 $_3$✓

for $_3$✓ accept result that rounds to 10.5 or 11.5;

accept 2sf 11 (cm^3)

1

(g) temperature (of air) $_1$✓

for $_1$✓ accept 'mean ke of air molecules' (or wtte) / vapour pressure of air'

*'keep mass of air constant' is neutral (this information is given below **Figure 5**)*

1

change the pressure of the gas slowly or wtte

OR

wait (after a change) between taking readings / until the oil level stabilises $_2$✓

award of $_2$✓ is contingent on valid $_1$✓

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

'use a water bath' is neutral

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

1

[19]