Past-paper walk-through

The gaseous state: ideal and real gases and $pV = nRT$ ▪ 4.1

eXercise

Questions in this set

- 9701/11 N25 Q11 ▪ 1 mark
- 9701/12 N25 Q8 ▪ 1 mark
- 9701/51 N25 Q2 ▪ 14 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 11

9701/11 N25 ▪ Q11 ▪ 1 mark

11 1.00 g of nitrogen gas is stored in a 2.00 dm^3 vessel at 40.0 °C.

What is the pressure in the vessel?

A 5940 Pa **B** 11 900 Pa **C** 46 400 Pa **D** 92 900 Pa

Solution 11

Answer: **C**

Why

- Moles: $1.00/28.0 = 0.0357$ (N_2 is diatomic – using 14.0 doubles the answer).
- Convert: $V = 2.00 \times 10^{-3}$ m^3 and $T = 40.0 + 273 = 313$ K.
- $p = nRT/V = (0.0357)(8.31)(313)/(2.00 \times 10^{-3}) = 4.64 \times 10^4$ Pa.

Question 8

9701/12 N25 ▪ Q8 ▪ 1 mark

8 A pure sample of a gas has a density of 2.62 g dm^{-3} at 101 000 Pa and 25 °C. The gas behaves ideally under these conditions.

Which expression gives the M_r of the gas?

A $$\frac{101000 \times 0.001}{2.62 \times 8.31 \times 25}$$

B $$\frac{101000 \times 0.001}{2.62 \times 8.31 \times 298}$$

C $$\frac{2.62 \times 8.31 \times 25}{101000 \times 0.001}$$

Question 8

D $\dfrac{2.62 \times 8.31 \times 298}{101000 \times 0.001}$

Solution 8

Answer: **D**

Why

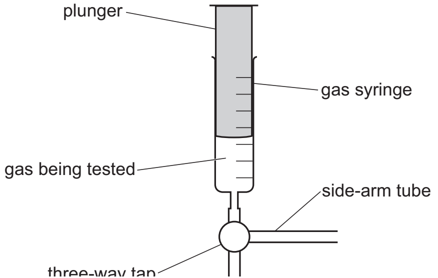
- $M_r = \rho RT/p$, with the density expressed per cubic metre.
- 2.62 g dm^{-3} is $2.62/0.001$ g m^{-3}, and $25\,^\circ$C is 298 K.
- So $M_r = 2.62 \times 8.31 \times 298/(0.001 \times 101\,000)$; A and C use 25 instead of 298.

Question 2

9701/51 N25 ▪ Q2 ▪ 14 marks

2 Effusion is the process in which a gas escapes through a small hole.

A student investigates the relationship between rate of effusion and relative molar mass of a gas using the apparatus shown in Fig. 2.1.



Question 2

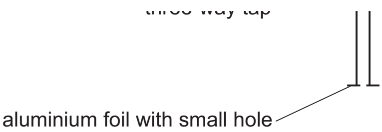


Fig. 2.1

The following method is used:

step 1 Turn the tap and remove any gas from the syringe through the side-arm tube, by pushing in the plunger.

step 2 Add 50 cm^3 of the gas being tested to the syringe through the side-arm tube.

step 3 Remove the gas from the syringe, through the side-arm tube, by pushing in the plunger.

step 4 Add 70 cm^3 of the gas being tested to the syringe through the side-arm tube.

Question 2

step 5 Turn the tap to connect the syringe to the tube with the aluminium foil and small hole.

step 6 Allow the syringe plunger to fall and start a timer when the volume of gas in the syringe reaches $60\,cm^3$.

step 7 Stop the timer when the volume of gas in the syringe reaches $10\,cm^3$. Record the time taken.

step 8 Repeat steps 1 to 7 with different gases.

(a) Suggest why the student adds $50\,cm^3$ of the gas being tested to the syringe in step 2 and then removes this gas in step 3.

Question 2

(b) The student's results are shown in Table 2.1.

Table 2.1

gas	hydrogen, H_2	helium, He	neon, Ne	argon, Ar	krypton, Kr
relative molar mass, M	2.0	4.0	20.2	39.9	83.8
$\sqrt{\frac{1}{M}}$					
time taken / s	10.8	15.3	34.5	39.7	70.4
rate of effusion					

Question 2

$/ cm^3 s^{-1}$					

Question 2

$$\text{rate of effusion} = \frac{\text{volume of gas}}{\text{time taken}}$$

(i) Complete Table 2.1.

Give the values for $\sqrt{\frac{1}{M}}$ to **three** significant figures.

Give the values for rate of effusion to **two** decimal places. [2]

(ii) Identify the dependent variable in this experiment.

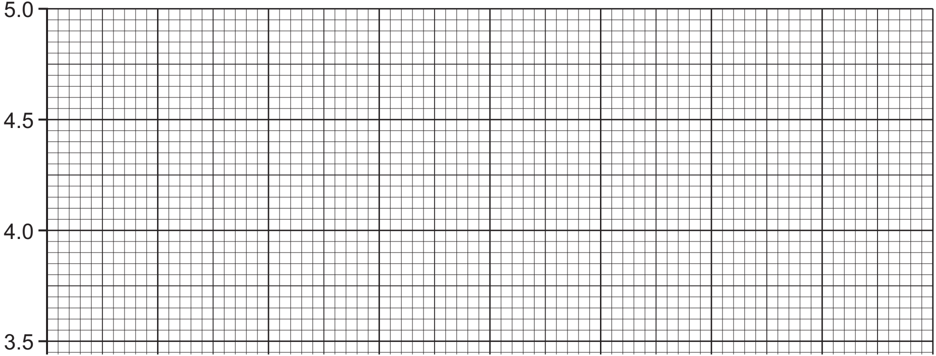
Question 2

(iii) Identify a variable, other than temperature, that is controlled when carrying out this experiment.

Question 2

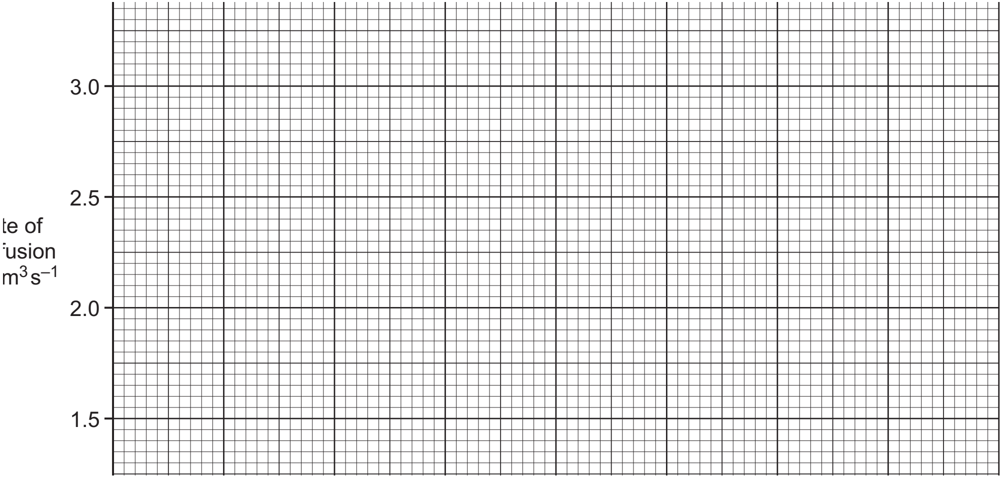
(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between rate of effusion and $\sqrt{\frac{1}{M}}$.

Use a cross (×) to plot each data point. Draw a suitable line of best fit.

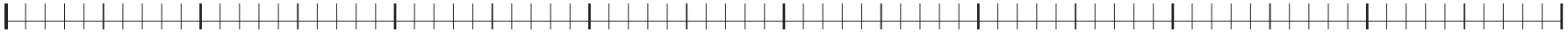


Question 2

Question 2



Question 2



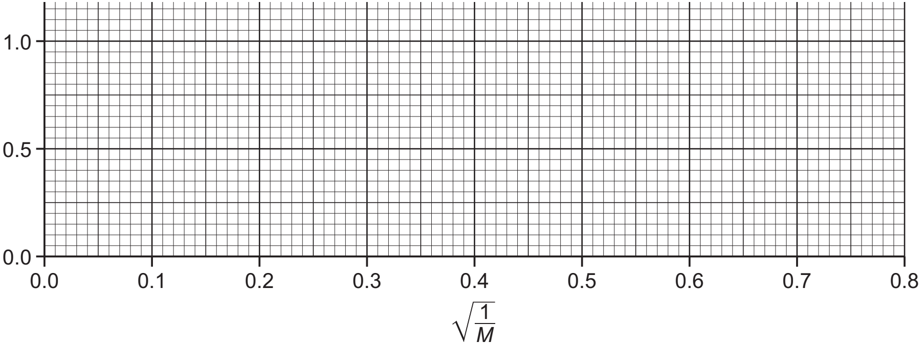


Fig. 2.2

[2]

(d) Circle **one** point on the graph in Fig. 2.2 which you consider to be most anomalous.

Question 2

Suggest **one** reason for this anomaly. Assume there is no error in $\sqrt{\frac{1}{M}}$.

Question 2

(e) Graham's law of effusion can be expressed as:

$$\text{the rate of effusion of a gas is proportional to } \sqrt{\frac{1}{M}}.$$

State whether or not the student's results support Graham's law of effusion.

Explain your answer, using the graph in Fig. 2.2.

Question 2

(f) Suggest how the position of the plotted points relative to the line of best fit in Fig. 2.2 is related to the reliability of the results.

Question 2

(g) The student then repeats this method to determine the value of M of a sample of natural gas.

The time recorded in step 7 is 31.6 s.

(i) Use the graph in Fig. 2.2 and the student's result to calculate the value of M for this sample.

Question 2

(ii) Natural gas is a mixture of mainly methane, CH_4, with small amounts of other gases.

Suggest what your calculated value of the *M* of natural gas in **(g)(i)** tells you about the other gases in the mixture.

(h) The experiment described in **(g)** is repeated at a higher temperature.

Suggest how the rate of effusion for this sample of natural gas would change, if at all.

Explain your answer.

Question 2

[1]

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$

Question 2

molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

15	16	17	18
			2 He helium 4.0
7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
15 P phosphorus 31.0	16 S sulfur 32.1	17 *Cl* chlorine 35.5	18 Ar argon 39.9
33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

Question 2

The Periodic Table of Elements

Group

8	9	10	11	12	13	14
1 H hydrogen 1.0						
					5 B boron 10.8	6 C carbo 12.0
					13 Al aluminium 27.0	14 Si silico 28.1
26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge german 72.6
44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.
76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.
108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl fleroviu –

62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbiu 167.
94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermiu –

Question 2

Key

atomic number atomic symbol name relative atomic mass

1	2	3	4	5	6	7
3 Li lithium 6.9	4 Be beryllium 9.0					
11 Na sodium 23.0	12 Mg magnesium 24.3					
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –

Question 2

Solution 2

(a)

Mark scheme

- To ensure no air / other gas remains in the syringe
- 1

Solution 2

(b)(i) Mark scheme

- 1
- Mr
- 0.707
- 0.500
- 0.222
- 0.158
- 0.109
- Rate of effusion /cm3s-1

Solution 2

- 4.63
- 3.27
- 1.45
- 1.26
- 0.71
- 2

Solution 2

(b)(ii)

Mark scheme

- Time (taken).
- 1

(b)(iii)

Mark scheme

- size of hole
- 1

Solution 2

(c)

Mark scheme

- M1 all 5 points plotted correctly. M2
- Straight line of best fit drawn
- 2

Solution 2

(d) Mark scheme

- Point most anomalous to the plotted line of best fit circled.
- AND
- If point above LOBF
- (Measured rate of effusion is higher than the true rate predicted by LOBF.)
- for this point ...
- measured / recorded (effusion) time $<$ true / actual time
- OR
- If point below LOBF

Solution 2

- (Measured rate of effusion is lower than the true rate predicted by LOBF.)
- for this point ...
- measured / recorded (effusion) time $>$ true / actual time
- 1

Solution 2

(e)

Mark scheme

- Yes AND The graph / LOBF...
- is a straight-line AND it goes through the origin.
- 1

Solution 2

(f)

Mark scheme

- The results are not reliable as there is an anomalous result.
- 1
- 9701/51
- October/November 2025

Solution 2

(g)(i) Mark scheme

- M1 Effusion rate $= 50/31.6 = (1.58)$
- Correct value for
- 1
- Mr read from x-axis
- 1 M2
- Value correctly converted to M.
- 1

Solution 2

(g)(ii)

Mark scheme

- If calculated M $>$ 16
- (The average) M (of the other components) is greater than 16 / calculated value for g(i).
- 1

Solution 2

(h)

Mark scheme

- (Rate of effusion) increases
- AND
- (At higher temperature) gas particles move more quickly.
- 1