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.

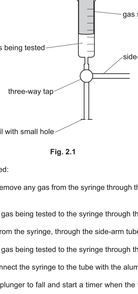

Fig. 2.1

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.

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.

.....

..... [1]

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

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

(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.

..... [1]

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

..... [1]

(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.

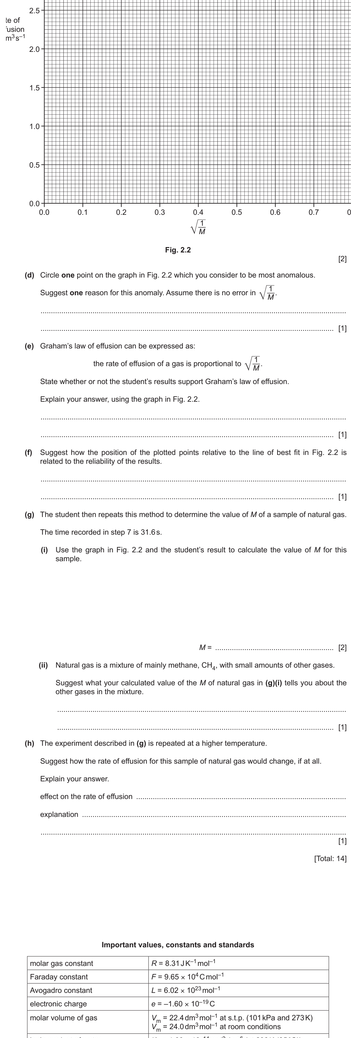

Fig. 2.2

[2]

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

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

.....

..... [1]

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

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.

.....

..... [1]

(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.

.....

..... [1]

(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.

M = ... [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.

.....

..... [1]

(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.

effect on the rate of effusion .....

explanation .....

.....

[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	$e = -1.60 \times 10^{-19}\,C$
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 $J g^{-1} K^{-1}$)