4 **(a)** State the value of absolute zero on:

(i) the Celsius temperature scale

temperature = ... °C [1]

(ii) the thermodynamic temperature scale. Give a unit with your answer.

temperature = ... unit .... [1]

(b) A sample contains a fixed amount of gas. The gas has pressure *p*, volume *V* and thermodynamic temperature *T*.

Fig. 4.1 shows the variation of *pV* with *kT* for the sample, where *k* is the Boltzmann constant.

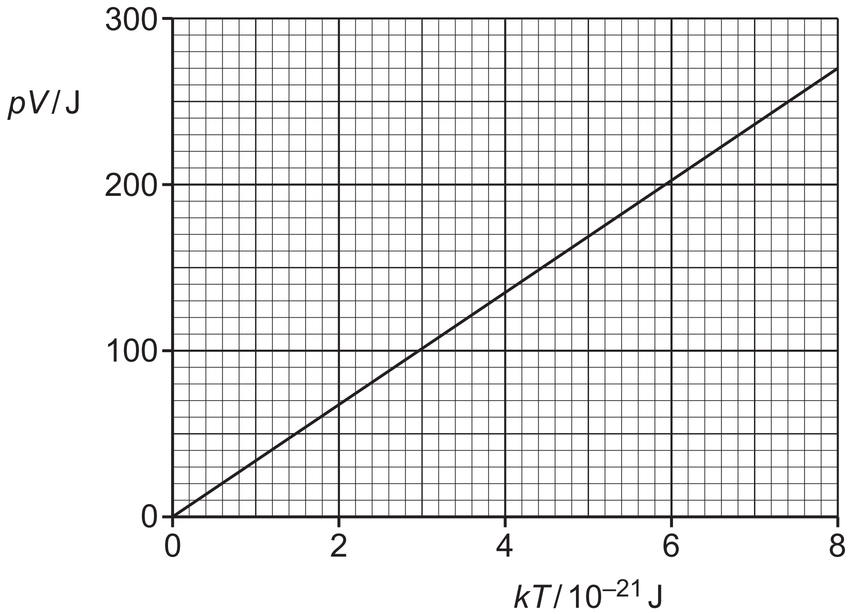


Fig. 4.1

(i) State what is indicated about the nature of the gas from the variation shown in Fig. 4.1.

.... [1]

(ii) Determine the number *N* of molecules of the gas in the sample.

N = ... [2]

(iii) Use your answer in **(b)(ii)** to determine the amount n of gas in the sample.

n = ... mol [1]

(c) The root-mean-square (r.m.s.) speed of the molecules of the gas is $1900\,\text{m}\,\text{s}^{-1}$ when pV is equal to 270 J.

Determine the mass, in u, of one molecule of the gas, where u is the unified atomic mass unit.

mass = ... u [4]

[Total: 10]

2 A student investigates the cooling of a liquid in a beaker.

The temperature θ_R of the laboratory is measured using a thermometer.

Hot water is added to an insulated beaker, as shown in Fig. 2.1.

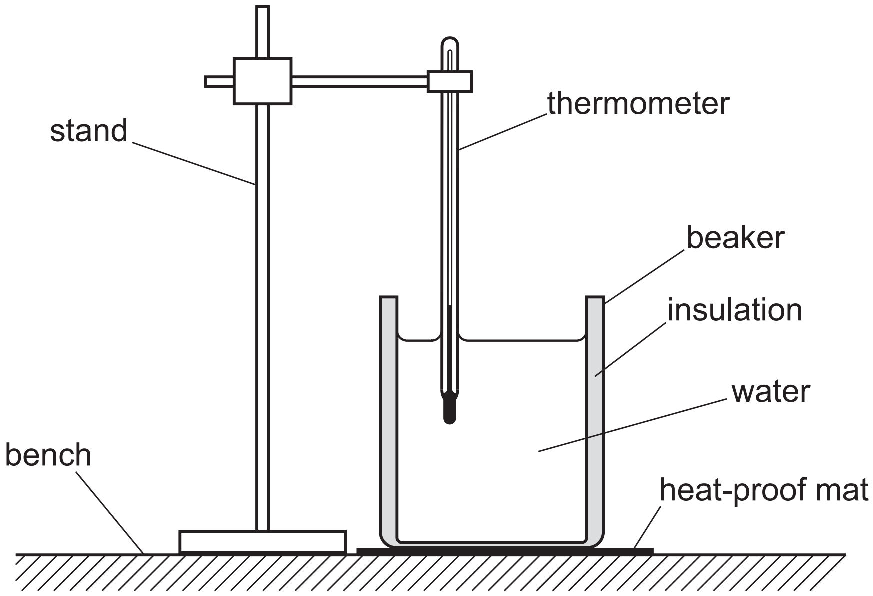


Fig. 2.1

The thermometer measures the temperature of the water. At time t the temperature of the water is θ.

A series of readings of t and θ are taken.

It is suggested that θ and t are related by the equation

$$\theta = \theta_R + (\theta_0 - \theta_R)e^{-\left(\frac{t}{K}\right)}$$

where θ_0 is the temperature at $t = 0$ and K is a constant.

(a) A graph is plotted of $\ln(\theta - \theta_R)$ on the y-axis against t on the x-axis.

Determine expressions for the gradient and y-intercept.

gradient = ...

y-intercept = ...

[1]

` **(b)** Values of t and θ are given in Table 2.1.

Table 2.1

t/min	θ/°C	$(\theta - \theta_R)$/°C	$\ln((\theta - \theta_R)$/°C)
6.0	75.0 ± 0.5		
12.0	64.5 ± 0.5		
18.0	57.0 ± 0.5		
24.0	50.0 ± 0.5		
30.0	44.5 ± 0.5		
36.0	41.0 ± 0.5		

The value of θ_R is (18.5 ± 0.5) °C.

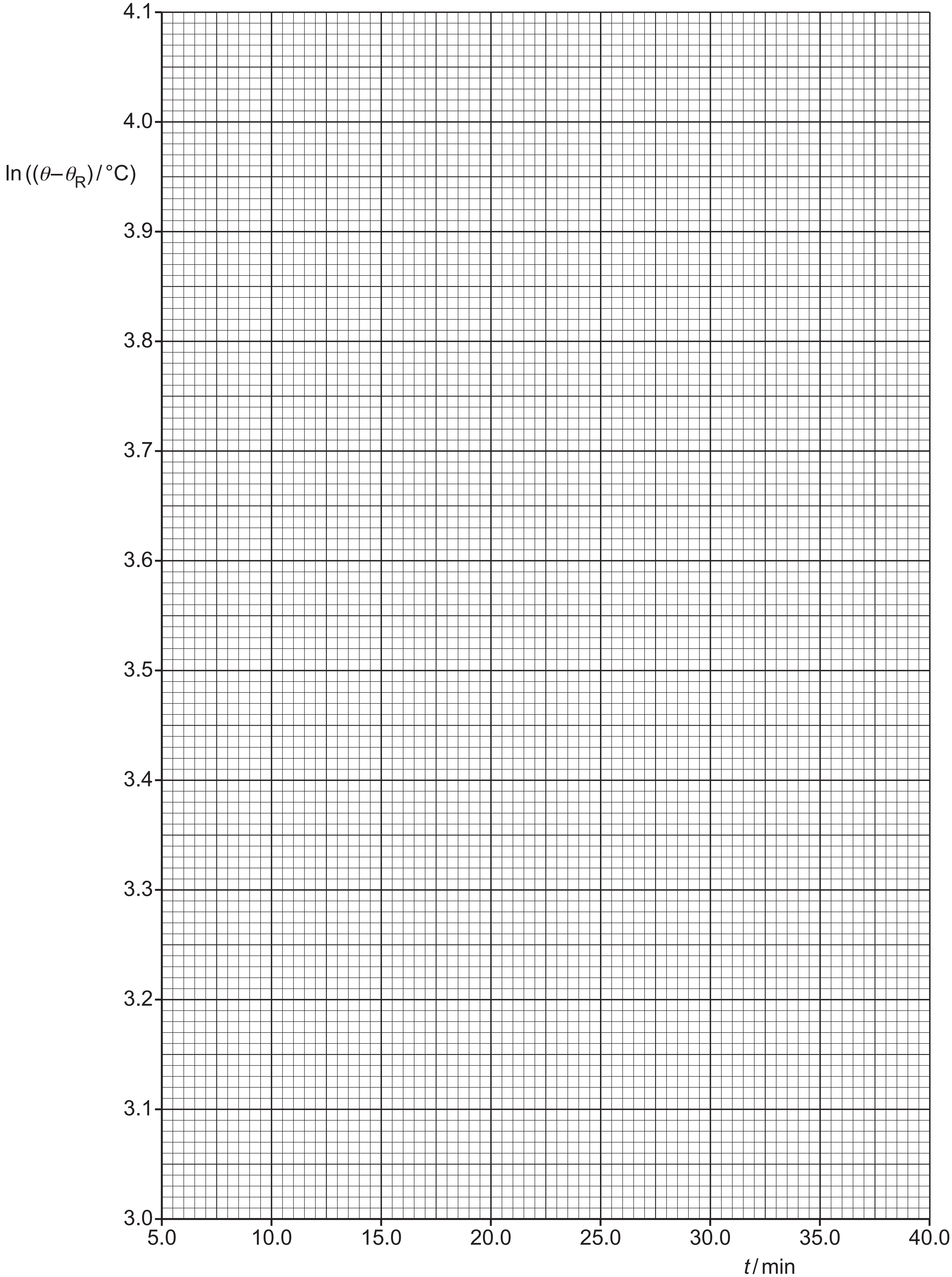
Calculate and record values of $(\theta - \theta_R)$/°C and $\ln((\theta - \theta_R)$/°C) in Table 2.1.
Include the absolute uncertainties in $(\theta - \theta_R)$ and $\ln((\theta - \theta_R)$/°C). [2]

(c) **(i)** Plot a graph of $\ln((\theta - \theta_R)$/°C) against t/min. Include error bars for $\ln((\theta - \theta_R)$/°C). [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient = ... [2]


ln ((θ−θR) / °C)
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
t / min

(iv) Determine the y-intercept of the line of best fit. Include the absolute uncertainty in your answer.

y-intercept = ... [2]

(d) **(i)** Using your answers to **(a)**, **(c)(iii)** and **(c)(iv)**, determine the values of K and θ_0. Include appropriate units.

K = ...

θ_0 = ...
[2]

(ii) Determine the absolute uncertainty in your value of θ_0.

absolute uncertainty = ... [1]

(e) Determine the time t for the temperature to reach 25.0 °C.

t = ... min [1]

[Total: 15]