4(a)(i)	temperature = –273.15 °C
4(a)(ii)	temperature = 0 K
4(b)(i)	gas is ideal
4(b)(ii)	$pV = NkT$
	$N = 270 / (8.0 \times 10^{-21})$ $= 3.4 \times 10^{22}$
4(b)(iii)	$n = (3.4 \times 10^{22}) / (6.02 \times 10^{23})$ = 0.056 mol
4(c)	$\frac{1}{2} m\langle c^2\rangle = (3 / 2) kT$
	$\frac{1}{2} \times m \times 1900^2 = 1.5 \times 8.0 \times 10^{-21}$ ($m = 6.65 \times 10^{-27}$ kg)
	$m = (6.65 \times 10^{-27}) / (1.66 \times 10^{-27})$
	= 4.0 u

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2(a)	gradient = $-\frac{1}{K}$ y-intercept = $\ln(\theta_0 - \theta_R)$

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2(b)	<table><tr><td>$(\theta - \theta_R)$ / °C</td><td>ln $((\theta - \theta_R)$ / °C)</td></tr><tr><td>56.5 ± 1.0</td><td>4.034 or 4.0342 ± 0.018</td></tr><tr><td>46.0 ± 1.0</td><td>3.829 or 3.8286 ± 0.022</td></tr><tr><td>38.5 ± 1.0</td><td>3.651 or 3.6507 ± 0.026</td></tr><tr><td>31.5 ± 1.0</td><td>3.450 or 3.4500 ± 0.032</td></tr><tr><td>26.0 ± 1.0</td><td>3.258 or 3.2581 ± 0.038</td></tr><tr><td>22.5 ± 1.0</td><td>3.114 or 3.1135 ± 0.044</td></tr></table>
	Values of $(\theta - \theta_R)$ / °C and ln $((\theta - \theta_R)$ / °C)
	Uncertainties in $(\theta - \theta_R)$ and ln $((\theta - \theta_R)$ / °C)
2(c)(i)	Six points from (b) plotted correctly. Must be within half a small square. Diameter of points must be less than half a small square.
	Error bars in ln $((\theta - \theta_R)$ / °C) plotted correctly. All error bars to be plotted. Total length of bar must be accurate to less than half a small square and symmetrical.

2(c)(ii)	Straight line of best fit drawn. Do not accept line from top plot to bottom plot. Line must pass between (31.5, 3.2) and (33.0, 3.2) **and** between (16.0, 3.7) and (17.0, 3.7)
	Worst acceptable line drawn. Steepest or shallowest possible line that passes through all the error bars. All error bars must be plotted.
2(c)(iii)	Gradient must be negative. Gradient determined with clear substitution of data into $\Delta y / \Delta x$; distance between data points must be greater than half the length of the drawn line.
	Gradient determined of worst acceptable line with clear substitution of data into $\Delta y / \Delta x$; uncertainty = (gradient of line of best fit – gradient of worst acceptable line) or uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)
2(c)(iv)	y-intercept determined by substitution of correct point with consistent unit of time into $y = mx + c$
	y-intercept of worst acceptable line determined by substitution into $y = mx + c$. uncertainty = y-intercept of line of best fit – y-intercept of worst acceptable line, or uncertainty = ½ (steepest worst line y-intercept – shallowest worst line y-intercept) Do not accept ecf from false origin method.

2(d)(i)	K determined using gradient **and** K and θ_0 given to 3 or 4 sf. $K = -\dfrac{1}{\text{gradient}}$
	θ_0 determined using y-intercept **and** K and θ_0 given with units with appropriate powers of ten $\theta_0 = e^{y\text{-intercept}} + 18.5$ Unit of K: min or minute(s) unit of θ_0: °C
2(d)(ii)	Absolute uncertainty determined with clear method shown. $\Delta\theta_0 = \left(e^{\max y\text{-intercept}} + 19\right) - (e^{y\text{-intercept}} + 18.5)$ OR $\Delta\theta_0 = (e^{y\text{-intercept}} + 18.5) - \left(e^{\min y\text{-intercept}} + 18\right)$ OR $\Delta\theta_0 = \dfrac{\left(e^{\max y\text{-intercept}} + 19\right) - \left(e^{\min y\text{-intercept}} + 18\right)}{2}$
2(e)	t determined to a minimum of 2sf from **(c)(iii)** and **(c)(iv)** OR **(d)(i)** with correct substitution <u>and</u> correct power of ten. $t = \dfrac{\ln(25.0 - 18.5) - y\text{-intercept}}{\text{gradient}}$ OR $t = -K \times \left(\ln(25.0 - 18.5) - y\text{-intercept}\right)$ OR $t = -K \times \ln\left(\dfrac{25.0 - 18.5}{\theta_0 - 18.5}\right)$