Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $P = VI$ (1) • Calculation of gradient (1) • Gradient $= \frac{\Delta m}{\Delta t}$ (1) • Use of $\Delta E = mL$ and $P = \frac{\Delta E}{\Delta t}$ (1) • $L = 2.30 \times 10^6$ (J kg^{-1}) (1) • Comparison of calculated value for L with values in table and appropriate conclusion. (1) (1)	For MP2 and MP3 credit Δm read from graph and used with corresponding Δt value For MP3 and MP4, credit $L = \frac{VI}{\text{gradient}}$ Answers in the range $(2.26 - 2.34) \times 10^6$ J kg^{-1}	
	• But not all of the energy supplied to the liquid will be used to boil the liquid **Or** thermal energy will be transferred to surroundings	<u>Example of calculation</u>: grad= $\frac{(211\text{-}155)\times 10^{-3}\ \text{kg}}{(0\text{-}600)\ \text{s}} = 9.33 \times 10^{-5}$ kg s^{-1} $\therefore \frac{\Delta m}{\Delta t} = 9.33 \times 10^{-5}$ kg s^{-1} $P = 20.5\ \text{V} \times 10.5\ \text{A} = 215\ \text{W}$ $\therefore L = \frac{215\ \text{W}}{9.33 \times 10^{-5}\ \text{kg s}^{-1}} = 2.30 \times 10^6$ J kg^{-1}	7

labelled diagram (2 marks):		
liquid in vessel with electrical heater (submerged) and thermometer	B1	Allow use of joule meter if convincingly connected to heater and power supply i.e. 2 wires from power supply two wires to heater
ammeter connected in series between supply and heater AND voltmeter connected across heater.	B1	
list of measurements (3 marks):		
mass of liquid,	B1	Allow such things as "find mass", "known mass", "10K temp rise", "time for 2 minutes" "known power", etc.
initial and final temperature/change of temp (of the liquid)	B1	
I, V and t values OR energy meter readings OR power and time	B1	
explanation (1 mark):		
$E = mc\Delta\theta$ rearranged to $c = E/m\Delta\theta$	B1	
uncertainties (2 marks) each stated with explanation of remedy: e.g.		Allow $ItV/m\Delta\theta$.
-heat losses (makes E or $\Delta\theta$ uncertain) *(solved by)* insulating beaker/use lid		Do not allow "repeat the experiment".
-false temp reading *(solved by)* stir the liquid	B1	Give credit for valid suggestions if mentioned anywhere in the description of the experiment.
-temp continues to rise after heater switched off measure highest value	B1	
-thermal capacity of vessel (*solved by*) take this into account in calculation	max 2	

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3 Planning (15 marks)

Defining the problem (3 marks)

P *m* is the independent variable and *E* is the dependent variable or vary *m* and measure *E*. Do not allow time. [1]

P Keep the temperature change of water constant. Allow two specified temperatures. Do not allow "keep temperature constant". [1]

P Keep the mass or volume of water constant. [1]

Methods of data collection (5 marks)

M Labelled diagram including labelled thermometer with bulb in water and at least one other label. [1]

M Workable circuit diagram to determine *E*: power supply, heater and ammeter and voltmeter, or joulemeter or wattmeter. [1]

M Method to determine change in temperature: measure initial temperature, measure final temperature and subtract, or measure initial temperature and specific temperature change. [1]

M Use balance/scales to measure mass of blocks. [1]

M Stir water (so that metal is in thermal equilibrium). [1]

Method of analysis (2 marks)

A Plot a graph of *E* against *m*. Do not allow log–log graphs. [1]

A *a* = gradient and *b* = *y*-intercept; must be consistent with suggested graph. [1]

Safety considerations (1 mark)

S Precaution linked to hot heater/water, e.g. use gloves **or** use tongs for hot blocks. Do not allow goggles. [1]

Additional detail (4 marks)

D Relevant points might include [4]

1 Method to ensure that e.m.f. of the power supply is constant/current in heater is constant, e.g. adjust variable power supply/variable resistor to ensure p.d./current is constant
2 Keep the starting temperature of water/metal constant
3 Wait for water and metal temperatures to equalise
4 Add insulation to sides of beaker/lid (to prevent energy losses)
5 Use of timer and equation, e.g. $E = Pt = ItV$ for candidate's method
6 Use large temperature change to reduce percentage uncertainty
7 Relationship is valid if the graph is a straight line that does not pass through the origin

Do not allow vague computer methods.

Question	Answer	Marks
4	**Defining the problem**	
	P is the independent variable and θ is the dependent variable, or vary *P* and measure θ. (Allow θ is the independent variable and *P* is the dependent variable.)	**1**
	keep density of salt solution constant or keep σ <u>constant</u>	**1**
	Methods of data collection	
	labelled diagram of workable experiment including: • sealed container e.g. bell jar, sealed conical flask • tube connected to pump (for changing pressure) or other workable method • salt solution, labelled	**1**
	workable method to heat salt solution within the sealed container, e.g. hot plate/(electrical) heater	**1**
	description of pressure gauge or manometer to measure *P*	**1**
	use of a thermometer to measure θ **or** labelled thermometer (in salt solution) in diagram	**1**
	Method of analysis	
	plot a graph of lg θ against lg *P* (or ln θ against ln *P*)	**1**
	q = gradient	**1**
	$k = 10^{y\text{-intercept}}/\sigma$ (for ln θ against ln *P*: $k = e^{y\text{-intercept}}/\sigma$)	**1**

Question	Answer	Marks
	Additional detail including safety considerations	**Max. 6**
	D1 safety precaution relating to pressure, e.g. safety screen	
	D2 use of (protective) gloves to handle hot salt solution/beaker/flask	
	D3 density of salt solution or ρ given by m/V	
	D4 measuring cylinder to measure volume **and** difference in top pan balance/scales readings to measure mass of salt solution	
	D5 slowly/gradually increase/decrease the temperature/pressure	
	D6 measure P and θ when salt solution starts to boil	
	D7 $\lg\theta = q\lg P + \lg k\sigma$	
	D8 relationship valid if a straight line	
	D9 identification of when (salt solution) starts to boil, e.g. wait until (vapour) bubbles are on the surface or surface moves or temperature remains constant (for heating methods)	
	D10 recheck that density of salt solution is constant/add water to keep density constant/take multiple solutions from a large volume	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>5(a)</td><td>gradient = q
and
y-intercept = lg p</td><td>1</td></tr>
<tr><td>5(b)</td><td><table><tr><th>R / 10^3 Ω</th><th>lg (R / 10^3 Ω)</th></tr><tr><td>9.4 or 9.40</td><td>0.97 or 0.973</td></tr><tr><td>5.9 or 5.88</td><td>0.77 or 0.771 or 0.769</td></tr><tr><td>3.9 or 3.92</td><td>0.59 or 0.591 or 0.593</td></tr><tr><td>2.5 or 2.54</td><td>0.40 or 0.398 or 0.405</td></tr><tr><td>1.7 or 1.71</td><td>0.23 or 0.230 or 0.233</td></tr><tr><td>1.1 or 1.08</td><td>0.04 or 0.041 or 0.033</td></tr></table></td><td></td></tr>
<tr><td></td><td>Values of R as above.</td><td>1</td></tr>
<tr><td></td><td>Values of lg R as above.</td><td>1</td></tr>
<tr><td></td><td>Uncertainties in R from (±0.9 to ±1.2) to (±0.02 to ±0.03)
and
row 2 between ±0.40 and ±0.50
and
row 4 between ±0.09 and ±0.10.</td><td>1</td></tr>
<tr><td></td><td>Uncertainties in lg R consistent with uncertainties in R e.g. from ±0.05 to ±0.01.</td><td>1</td></tr>
<tr><td>5(c)(i)</td><td>Six points plotted correctly.
Must be accurate to the nearest half a small square. Diameter of points must be less than half a small square.</td><td>1</td></tr>
<tr><td></td><td>Error bars in lg R plotted correctly.
All error bars must be plotted. Length of bar must be accurate to less than half a small square and symmetrical.</td><td>1</td></tr>
</table>

Question	Answer	Marks
5(c)(ii)	Line of best fit drawn. Upper end of line should pass between (2.500, 0.70) and (2.502, 0.70) **and** lower end of line should pass between (2.528, 0.30) and (2.532, 0.30). Do not accept line from first to last point.	**1**
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	**1**
5(c)(iii)	Gradient determined with clear substitution of data points from the line of best fit into $\Delta y / \Delta x$. Distance between data points must be greater than half the length of the drawn line. Gradient must be negative.	**1**
	uncertainty = gradient of line of best fit – gradient of worst acceptable line **or** uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)	**1**
5(c)(iv)	*y*-intercept determined by substitution of correct point from the line of best fit into $y = mx + c$.	**1**
5(d)	*p* determined from *y*-intercept. $p\ (= 10^{y\text{-intercept}}) = 10^{\mathbf{(c)(iv)}}$	**1**
	q = answer to **(c)(iii) and** given to 2 or 3 significant figures.	**1**

Question	Answer	Marks
5(e)	*T* determined from **(d) or (c)(iii) and (c)(iv)** with correct substitution shown. $T=\sqrt[q]{\frac{R}{p}}=\sqrt[q]{\frac{15}{p}}$ **or** $\lg T=\frac{\lg 15-\lg p}{q}=\frac{1.176-\lg p}{q}$ $\lg T=\frac{\lg 15-y\text{-intercept}}{\text{gradient}}=\frac{1.176-\mathbf{(c)(iv)}}{\mathbf{(c)(iii)}}$ $T=10^{\left(\frac{1.176-\mathbf{(c)(iv)}}{\mathbf{(c)(iii)}}\right)}$	**1**