Question			Answer	Marks	AO	Guidance
14	(a)		When $t = 0$, $82 = \theta_0 e^0$ so $\theta_0 = 82$	B1	3.3	
			$t = 5$, $27 = \theta_0 e^{-5k}$	M1	3.3	Forming an equation for k and attempt to solve
			giving $k = \left[-\frac{1}{5} \ln\left(\frac{27}{82}\right) \right] = 0.222$ to 3 sf	A1	1.1b	Allow for exact value or evaluated to at least 2 s.f.
				[3]		
14	(b)		The model predicts that temperature tends to zero but if the quantity of water is small the water will warm up so it will not cool the object to zero.	E1	3.5b	Must imply to the model tends to zero and this does not match the real situation.
				[1]		
14	(c)		$\ln\theta = \ln\left(\theta_0 e^{-kt}\right) = \ln\theta_0 + \ln\left(e^{-kt}\right)$	M1	2.1	Taking logs and attempting to use laws of logs Do not award for values of a and b obtained directly from the data and the natural log form of the model.
			$\ln\theta = \ln 82 - 0.222t = [4.41 - 0.222t]$	A1	2.1	FT their values for θ_0 and k Accept as part of equation or a and b clearly stated
				[2]		
14	(d)		When $t = 0, \ln\theta = 3.4$ giving $\theta = 29.96$ so 30.0° C to 3 sf	B1	3.4	Accept 30° www Must be evaluated
			$\theta = 29.96e^{-0.08t}$ $\frac{d\theta}{dt} = 29.96 \times -0.08e^{-0.08t}$	M1	3.4	Attempt to differentiate their exponential expression for θ
				A1	3.4	Any form eg $e^{3.4} \times -0.08e^{-0.08t}$ or $-0.08e^{3.4-0.08t}$
			When $t = 0$ $\frac{d\theta}{dt} = -2.3968$ [object is cooling by 2.4°per minute]	A1	3.4	Allow for correct negative value for $\frac{d\theta}{dt}$ or a clear statement that the rate of cooling is 2.4° per minute. Accept $= -0.08e^{3.4}$
				[4]		

			Alternative method When $t = 0$, $\ln\theta = 3.4$ giving $\theta = 29.96$ so 30.0° C to 3 sf	**B1**	**3.4**	Accept 30° www	
			Differentiate $\ln\theta = 3.4 - 0.08t$ w.r.t t $\frac{1}{\theta}\frac{d\theta}{dt} = -0.08$	**M1**		Uses implicit differentiation w.r.t t	
			$\frac{d\theta}{dt} = -0.08\theta$	**A1**		Correct derivative	
			When $t = 0$, $\theta = 29.96$ so $\frac{d\theta}{dt} = -2.3968$ object is cooling by 2.4°per minute	**A1**		Allow for correct negative value for $\frac{d\theta}{dt}$ or a clear statement that the rate of cooling is 2.4°per minute	
				[4]			
14	**(e)**		Solve simultaneously $\ln\theta = 3.4 - 0.08t$ $\ln\theta = \ln 82 - 0.222t$	**M1**	**3.1b**	Attempting to find the intersection of their (c) and the given line	Could be BC
			gives $t = 7.089$ $t = 7.1$ [7 minutes and 5 seconds]	**A1**	**3.4**	Accept awrt 7.0, 7.1 or 7.2	
			$\ln\theta = 2.8328$ gives $\theta =$ 17° C	**A1**	**3.4**	Must be the value for θ	
			Alternative method $82e^{-0.222t} = 30e^{-0.08t}$ $\frac{82}{30} = e^{0.142t}$	**M1**		Equate their expressions for temperature and attempts to solve for t	
			$t = 7.08$ [7 minutes and 5 seconds]	**A1**		Accept awrt 7.0, 7.1 or 7.2	
			$\theta = 17$ °C	**A1**		Cao	
				[3]			