Question	Scheme	Marks	AOs
10 (a)	$\dfrac{\mathrm{d}r}{\mathrm{d}t} \propto \pm\dfrac{1}{r^2}$ or $\dfrac{\mathrm{d}r}{\mathrm{d}t} = \pm\dfrac{k}{r^2}$ (for k or a numerical k)	M1	3.3
	$\int r^2\,\mathrm{d}r = \int \pm k\,\mathrm{d}t \Rightarrow \ldots$ (for k or a numerical k)	M1	2.1
	$\dfrac{1}{3}r^3 = \pm kt\ \{+c\}$	A1	1.1b
	$t=0, r=5$ and $t=4, r=3$ gives $\dfrac{1}{3}r^3 = -\dfrac{49}{6}t + \dfrac{125}{3}$, where r, in mm, is the radius {of the mint} and t, in minutes, is the time from when it {the mint} was placed in the mouth OR $t=0, r=5$ and $t=240, r=3$ gives $\dfrac{1}{3}r^3 = -\dfrac{49}{360}t + \dfrac{125}{3}$, where r, in mm, is the radius {of the mint} and t, in seconds, is the time from when it {the mint} was placed in the mouth	M1 A1	3.1a 1.1b
		(5)	
(b)	$r=0 \Rightarrow 0 = -\dfrac{49}{6}t + \dfrac{125}{3} \Rightarrow 0 = -49t + 250 \Rightarrow t = \ldots$	M1	3.4
	time = 5 minutes 6 seconds	A1	1.1b
		(2)	
(c)	Suggests a suitable limitation of the model. E.g. • Model does not consider how the mint is sucked • Model does not consider whether the mint is bitten • Model is limited for times up to 5 minutes 6 seconds, o.e. • Not valid for times greater than 5 minutes 6 seconds, o.e. • Mint may not retain the shape of a sphere (or have uniform radius) as it is being sucked • The model indicates that the radius of the mint is negative after it dissolves • Model does not consider the temperature in the mouth • Model does not consider rate of saliva production • Mint could be swallowed before it dissolves in the mouth	B1	3.5b
		(1)	
			(8 marks)

Notes for Question 10	
(a)	
M1:	Translates the description of the model into mathematics. See scheme.
M1:	Separates the variables of their differential equation which is in the form $\frac{\mathrm{d}r}{\mathrm{d}t} = \mathrm{f}(r)$ and some attempt at integration. (e.g. attempts to integrate at least one side). e.g. $\int r^2 \,\mathrm{d}r = \int \pm k \,\mathrm{d}t$ and some attempt at integration. Condone the lack of integral signs
Note:	You can imply the M1 mark for $r^2 dr = -k\,\mathrm{d}t \Rightarrow \frac{1}{3}r^3 = -kt$
Note:	A numerical value of k (e.g. $k = \pm 1$) is allowed for the first two M marks
A1:	Correct integration to give $\frac{1}{3}r^3 = \pm kt$ with or without a constant of integration, c
M1:	For a complete process of using the boundary conditions to find both their unknown constants and finds an equation linking r and t So applies either • $t = 0,\ r = 5$ and $t = 4,\ r = 3,$ or • $t = 0,\ r = 5$ and $t = 240,\ r = 3,$ ***on their integrated equation*** to find their constants k and c ***and*** obtains an equation linking r and t
A1:	Correct equation, with variables r and t fully defined including correct reference to units. • $\frac{1}{3}r^3 = -\frac{49}{6}t + \frac{125}{3}$, {or an equivalent equation,} where r, in mm, is the radius {of the mint} and t, in minutes, is the time from when it {the mint} was placed in the mouth • $\frac{1}{3}r^3 = -\frac{49}{360}t + \frac{125}{3}$, {or an equivalent equation,} where r, in mm, is the radius {of the mint} and t, in seconds, is the time from when it {the mint} was placed in the mouth
Note:	Allow correct equations such as • in minutes, $r = \sqrt[3]{\frac{250 - 49t}{2}}$, $r^3 = -\frac{49}{2}t + 125$ or $t = \frac{250 - 2r^3}{49}$ • in seconds, $r = \sqrt[3]{\frac{15000 - 49t}{120}}$, $r^3 = -\frac{49}{120}t + 125$ or $t = \frac{15000 - 120r^3}{49}$
Note:	t defined as "the time from the start" is not sufficient for the final A1
(b)	
M1:	Sets $r = 0$ in their part (a) equation which links r with t and rearranges to make $t = ...$
A1:	5 minutes 6 seconds cao (**Note:** 306 seconds with no reference to 5 minutes 6 seconds is A0)
Note:	Give M0 if their equation would solve to give a negative time or a negative time is found
Note:	You can mark part (a) and part (b) together
(c)	
B1:	See scheme
Note:	Do not accept by itself • mint may not dissolve at a constant rate • rate of decrease of mint must be constant • $0 \le t < \frac{250}{49}$, $r \ge 0$; without any written explanation • reference to a mint having $r > 5$