8	**(a)**		20 (minutes) 97.2 (grams) **[2]**	**B1** **B1**	**3.3** **3.4**	Obtain $t = 20$ Obtain $m = 97.2$	Allow [19.9, 20.1] from setting up and using exponential model Allow [97.1, 97.3] from setting up and using exponential model
8	**(b)**	**(i)**	$160e^{-0.055t} = 80$	**B1**	**3.4**	Equate given model to 80	soi, so could be $e^{-0.055t} = 0.5$

Question			Answer	Marks	AO	Guidance	
			$e^{-0.055t} = 0.5$ $-0.055t = \ln 0.5$	**M1**	**3.4**	Attempt correct process to find value of t, as far as dealing with exponential term	Rearrange to $e^{-0.055t} = k$, and hence obtain $-0.055t = \ln k$ If introducing logs straight away then need to get as far as $\ln 160 - 0.055t = \ln$(their 80)
			$t = 12.6$ (minutes)	**A1** **[3]**	**1.1**	Obtain $t = 12.6$, or better	If more sig fig given, then allow answers which round to 12.60 (the more accurate answer is 12.602676..)
8	**(b)**	**(ii)**	$\frac{dm}{dt} = -8.8e^{-0.055t}$	**B1**	**3.4**	Correct derivative soi	Allow unsimplified No need to see $\frac{dm}{dt} =$
			$-8.8e^{-0.055 \times 15}$	**M1**	**3.4**	Substitute $t = 15$ into their derivative	Must be of the form $ke^{-0.055t}$, with $k \neq 160$ Possibly still with k unsimplified Substitution sufficient, no need to evaluate for M1
			$= -3.86$, hence rate of decay is 3.86 grams/minute	**A1** **[3]**	**1.1**	Units required, and positive answer	Must follow correct derivative ie negative coefficient No need to see –3.86 first, but A0 if clear error Accept 3.9 grams/minute Accept g/m for grams/minute

Question			Answer	Marks	AO	Guidance	
8	(c)		For A, $\frac{\mathrm{d}m}{\mathrm{d}t} = -63.9\mathrm{e}^{-0.0511t}$ Rate of decrease at $t = 15$ is 29.7 g/min hence A decaying at a faster rate	B1	3.4	State A, with clear comparison	Insufficient to just say that A has a greater initial mass – needs to consider decay factor as well Allow solutions that identify that B is decaying faster, with supporting evidence eg after 10 minutes, B's mass is 92.3g which is 58% of initial mass whereas A is 60% of initial mass so B decaying faster eg A's half-life is 13.6 so B is decaying faster eg change initial mass in model B to 1250 then when $t = 10$ B's mass would be 721g which is less than 750 hence decaying faster eg compare coefficients of t (for A, coeff is – 0.0511); B's is of a greater magnitude hence decaying faster For either solution, the conclusion and the supporting evidence must be consistent Numerical supporting evidence must be correct, allowing for slight inaccuracies from using different numbers of sig fig (see appendix)

Question			Answer	Marks	AO	Guidance	
				[1]			

APPENDIX

Supporting Evidence for Q8(c)

When comparing % remaining or percentage lost in t minutes. Substance B is shown to be decreasing at a faster rate.

Choose t = 15

Substance A

time	0	10	20	50	15
mass (exact)	1250	750	450	97.200	580.948
mass (k=-0.0511)	1250	750	450	97.115	580.796
mass (k=-0.051)	1250	750	450	97.602	581.667

Percentage decreased at t =	0	10	20	50	15
Exact k value	0%	40%	64%	92.22%	53.52%
k=-0.0511	0%	40%	64%	92.23%	53.54%
k=-0.051	0%	40%	64%	92.19%	53.47%

Percentage remaining at t =	0	10	20	50	15
Exact k value	100%	60%	36%	7.78%	46.48%
k=-0.0511	100%	60%	36%	7.77%	46.46%
k=-0.051	100%	60%	36%	7.81%	46.53%

Substance B

time	0	10	20	50	15
mass (exact)	160.00	92.312	53.259	10.228	70.118

Percentage decreased at t =	0	10	20	50	15
Exact k value	0%	42.31%	66.71%	93.61%	56.18%

Percentage remaining at t =	0	10	20	50	15
Exact k value	100%	57.69%	33.29%	6.39%	43.82%

When comparing RATE of decrease at t minutes. Substance A is shown to be decreasing at a faster rate.

Substance A

time	0	10	20	50	15
dm/dt (exact)	-63.853	-38.312	-22.987	-4.965	-29.676
dm/dt (k=-0.0511)	-63.875	-38.318	-22.987	-4.963	-29.679
dm/dt (k=-0.051)	-63.750	-38.282	-22.988	-4.978	-29.665

Substance B

time	0	10	20	50	15
dm/dt (exact)	-8.800	-5.077	-2.929	-0.563	-3.856