6.	This question is about storing vaccines	Mark
(a)	Process 1: $Si(OCH_2CH_3)_4 + 4\ H_2O \rightarrow Si(OH)_4 + 4\ CH_3CH_2OH$ Process 2: $Si(OH)_4 \rightarrow SiO_2 + 2\ H_2O$ *One mark for each correct equation.*	☑ ☑
(b)	Process 3 = Process 5 – (6 × Process 6) + (6 × Process 4) = [−100.3 + (6 × −56.7) – (6 × −61.5)] kJ mol^{-1} = −71.5 kJ mol^{-1} *Answer must be negative for mark.*	☑
(c)	Using the relation between Gibbs free energy and the equilibrium constant, $$\Delta G^{\ominus} = \Delta H^{\ominus} - T\,\Delta S^{\ominus} = -RT\ln K_{\mathrm{eq}}$$ and $$\ln K_{\mathrm{eq}} = \ln\frac{1}{[\mathrm{Si(OH)_4}]} = -\ln[\mathrm{Si(OH)_4}]$$ we can rearrange for $$\ln[\mathrm{Si(OH)_4}] = \frac{\Delta H^{\ominus} - T\,\Delta S^{\ominus}}{RT} = \frac{\Delta H^{\ominus}}{RT} - \frac{\Delta S^{\ominus}}{R}$$ Comparing to the relation $$\ln[\mathrm{Si(OH)_4}] = -\frac{1680}{T} - 0.605$$ we identify $\Delta H^{\ominus}$ = −1680 K × 8.314 J K^{-1} mol^{-1} = 14.0 kJ mol^{-1} $\Delta S^{\ominus}$ = 0.605 × 8.314 J K^{-1} mol^{-1} = 5.03 J K^{-1} mol^{-1} *Both correct answers score all three marks. First mark for the dependence of $ln([Si(OH)_4])$ on enthalpy and entropy. Second mark for $\Delta H^{\ominus}$ and third mark for $\Delta S^{\ominus}$.*	☑ ☑ ☑
(d)	$A = c - 1 = 0.56744$	☑
(e)	For $t = 1\ \mu s$, $f_1 = -0.143809\ \mathrm{nm^{-1}}$ and for $t = 2\ \mu s$, $f_2 = -0.140792\ \mathrm{nm^{-1}}$. $$a = \frac{f_2 - f_1}{2-1} = 3.017 \times 10^{-3}\ \mathrm{nm^{-1}\mu s^{-1}}$$ $$b = a \times 1 - f_1 = 0.146826\ \mathrm{nm^{-1}}$$ *One mark for correctly calculating each of a and b.*	☑ ☑

(f) Let $r_1^{-1} = x_1$ and $r_2^{-1} = x_2$. Rearranging the equation for b gives

$$x_2 = \frac{b - x_1}{A}$$

Substituting this into the equation for a gives

$$\left(1 + \frac{1}{A}\right) x_1^2 - \frac{2\,b}{A} x_1 + \left(\frac{b^2}{A} - \frac{2\,a}{\Gamma}\right) = 0.$$

The first root gives $x_1 = 0.00526\ \mathrm{nm}^{-1}$ and hence $x_2 = \frac{b - x_1}{A} = 0.249\ \mathrm{nm}^{-1}$, which corresponds to $r_1 = 190\ \mathrm{nm}$ and $r_2 = 4.01\ \mathrm{nm}$.

The second root gives $x_1 = 0.182\ \mathrm{nm}^{-1}$ and hence $x_2 = \frac{b - x_1}{A} = -0.0621\ \mathrm{nm}^{-1}$, which corresponds to an unphysical $r_2 < 0$ and is therefore discarded. ☑

Hence the final answer is $r_1 = 190\ \mathrm{nm}$ and $r_2 = 4.01\ \mathrm{nm}$. ☑

Alternative solution: can equivalently rearrange for ☑

$$x_1 = b - A x_2$$

which leads to the quadratic

$$(A^2 + A) x_2^2 - 2Abx_2 + \left(b^2 - \frac{2a}{\Gamma}\right) = 0.$$

This gives rise to the same values of x_1 and x_2 as above.

Correct r_1 and r_2 scores all three marks. One mark for deriving the quadratic equation for x_1 (or equivalently x_2), one mark for each correctly calculated radius (full marks for r_1 in the range 180-200 nm and for r_2 in the range 3.95-4.05 nm.

Error carried forward can be given. One mark to be awarded for each radius consistent with the equation for $x_{1,2}$ given above, evaluated with the values of A, a, and b the student has used. The suggested values of A = 0.5, a = 0.0025 and b = 0.125 give r_1 = 249 nm and r_2 = 4.13 nm.

Total out of 12 **12**