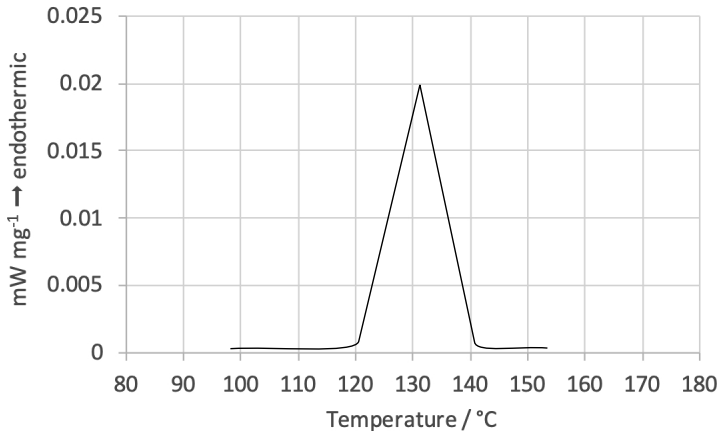
Question 1

(i) Barium titanate can exist in both the cubic and tetragonal crystal structures. Explain why the tetragonal form exhibits piezoelectricity whereas its cubic form does not. [20%]

(ii) The transformation from cubic to tetragonal $BaTiO_3$ occurs when the former is cooled below the Curie temperature of 120 °C. Describe how the change can be verified experimentally based on measurements made at ambient temperature. [20%]

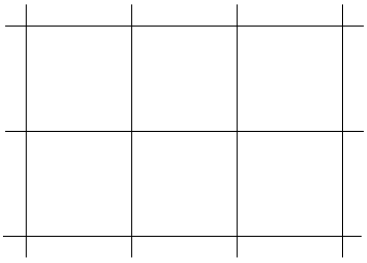
(iii) The figure shows a differential scanning calorimeter experiment in which the sample of tetragonal $BaTiO_3$ was heated at $25\,\mathrm{K\,min^{-1}}$. Using the figure, work out the enthalpy change ΔH when the transformation to the cubic form was completed, giving your answer in units of $\mathrm{J\,g^{-1}}$. State also the sign of ΔH for the tetragonal→cubic transformation. [50%]



(iv) Explain why the transformation appears to extend over a range of temperatures rather than a sharp peak at the Curie temperature. [10%]

Question 2

(i) The diagram below shows a lattice. Count the number of sites N available and calculate how many configurations are possible by placing 4 identical atoms on this lattice. Show the steps in your calculation. [20%]



(ii) Explain why the configurational entropy of mixing cannot ever be negative. [20%]

(iii) The heat capacity of gold is a function of temperature as follows:

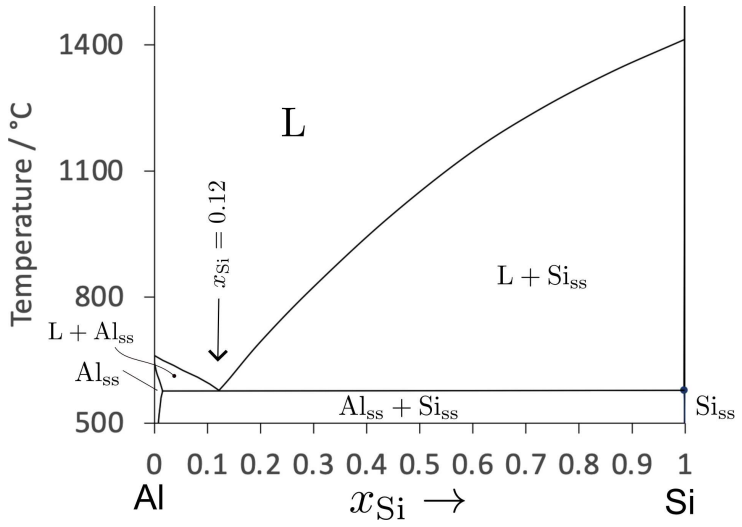
$$C_{\mathrm{P}} = 21.05 + 0.02T \qquad \mathrm{J\,mol^{-1}K^{-1}} \qquad \text{for } 100 < T < 300\,\mathrm{K}$$

There are no phase or magnetic transitions in gold over the stated temperature range. Showing the steps in your method, calculate the enthalpy and entropy change when the sample is heated from 100 to 300 K. [40%]

(iv) What are the concentrations of Fe, Mn, Cu, Ni, W that on mixing to form a single solid solution, would give the maximum configurational-entropy of mixing? [20%]

Question 3

(i) Using the Al-Si phase diagram, calculate the amount of liquid existing just above the eutectic temperature for an alloy containing $x = 0.3$ mole fraction of silicon. You may assume that density effects can be neglected and that aluminium has a zero solubility in silicon. The eutectic composition is indicated as $x_{\mathrm{Si}} = 0.12$. [30%]



(ii) Describe the microstructure obtained in this alloy as it is cooled below the eutectic temperature. Mention the fractions of eutectic and pro-eutectic phases. [10%]

(iii) Al-Si alloys of eutectic composition are used extensively to make large engine-blocks for internal combustion engines. Give two reasons why this is the case. [30%]

(iv) Describe three kinds of information that can be obtained from a phase diagram. [30%]