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89.304 - IGNEOUS & METAMORPHIC PETROLOGY
THERMODYNAMICS

1. For the reaction kyanite \rightarrow andalusite (using the data in the table at the end of the problem set)
 - a. Calculate the enthalpy of formation of kyanite and andalusite at 466 K and 10^5 Pa (1 bar).

- b. Calculate the enthalpy of the reaction. Is the reaction exothermic or endothermic?

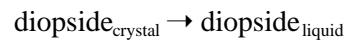
c. Calculate the entropies of kyanite and andalusite at 466 K and 10^5 Pa.

d. Calculate the entropy change for this reaction

e. Calculate the free-energy change for this reaction. From the free energy value what can you conclude about this reaction under these conditions of temperature and pressure?

- f. Calculate the change in free energy if the pressure is increased to 10^8 Pa At 466 K. Which mineral will be more stable under these new conditions? (Recall that $1 \text{ J} = 1 \text{ Pa m}^3$)

2. The melting of a pure mineral can be written as a simple reaction. For diopside it is



At 10^5 Pa (1 bar) diopside melts at 1665 K. If the S_{1665}° of crystalline and liquid diopside are 532.2 and $619.6 \text{ J mol}^{-1} \text{ K}$, respectively, and their volumes are, respectively, 0.06609×10^{-3} and $0.07609 \times 10^{-3} \text{ m}^3 \text{ mol}^{-1}$, calculate the melting point at 2 Gpa (20 kbar) using the Clapeyron equation. (Recall that $1 \text{ J} = 1 \text{ Pa m}^3$)

3. The mineral jadeite, which is known to occur in metamorphic rocks formed at high pressures, can be related to two common low-pressure minerals by the reaction



Use the data in the table at the end of the problem set to answer the following questions.

- a. Balance the reaction and calculate the free energy of the reaction at 298 K and 10^5 Pa. Comment on the feasibility of the reaction under these conditions.
- b. Repeat part (a), but for 600°C and 10^5 Pa.

c. Calculate the pressure increases that would be needed at 298 and 873 K to bring the reaction to equilibrium.

d. How does the slope of this univariant line compare with the slope obtained from the Clapeyron equation and the data for 298 K and 10^5 Pa?

Table of Thermodynamic Data

Mineral	Volume (m ³ mol ⁻¹) x 10 ⁻³	ΔH_f° (kJ mol ⁻¹)	S° (J mol ⁻¹ K ⁻¹)	ΔG_f° (kJ mol ⁻¹)	c_p° coefficients		
					a (J mol ⁻¹ K ⁻¹)	b x 10 ⁻³ (J mol ⁻¹ K ⁻²)	c x 10 ⁵ (J K mol ⁻¹)
Albite	0.10025	-3931.621	207.15	-3708.313	258.15	58.16	62.80
Andalusite	0.05153	-2576.783	92.88	-2429.176	172.84	26.33	51.85
Jadeite	0.0604	-3021.333	133.47	-2842.798	201.50	47.78	49.66
Kyanite	0.04409	-2581.097	83.68	-2430.720	173.19	28.52	53.90
Quartz	0.022688	-910.648	41.34	-856.239	46.94	34.31	11.30