Section B. Statistical Mechanics and Thermodynamics

1. **Putting Pressure on** ^3He

   Usually it is true that the entropy S of a solid is lower than that of the corresponding liquid. He^3 represents a counter example. Above 0.1 K to a good approximation *liquid* He^3 may be treated as a Fermi gas so S is proportional to the temperature. *Solid* He^3 which is stable at higher pressure, may be regarded as a regular lattice of non-interacting nuclear spins, with a constant nonzero spin entropy down to very low temperatures. The nuclei have spin 1/2.

   DATA:

$$
\begin{aligned}
S_{\text{liq}} &= S_{\text{solid}} \text{ at } 0.32 \text{ K}, \\
P_{\text{melt}} &= 31.0 \text{ atm at } 0.32 \text{ K}, \\
P_{\text{melt}} &= 33.0 \text{ atm at } 0.72 \text{ K}.
\end{aligned}
$$

   The volume change on melting is temperature independent at the low temperatures considered here.

   (a) Give an expression for the constant entropy of N atoms of *solid* He^3 in terms of fundamental constants.

   (b) Sketch the phase boundary between liquid and solid He^3 in the $P-T$ plane.

   (c) Evaluate P_{melt} at $T = 0$ K, assuming the above-described approximations remain valid there. Give P_{melt} to the nearest 0.1 atm. Explain how you obtain this result.