2B28 Statistical Thermodynamics Problem Sheet 1 (2005)
Answers should be handed in on Monday 31 January 2005

1 (a) Give the Kelvin and the Clausius statements of the Second Law of Thermodynamics.

(b) Show that if the Clausius statement is untrue, then the Kelvin statement is also untrue.

(c) One litre of water is heated from 10^{o}C to 90^{o}C by placing it in contact with a large reservoir at 90^{o}C. Calculate the entropy changes of:

(i) the water;
(ii) the reservoir;
(iii) the universe.

(d) One litre of water is heated from 10^{o}C to 90^{o}C by operating a *reversible heat engine* between it and a reservoir at 90^{o}C. Calculate the entropy changes of:

(i) the water;
(ii) the reservoir;
(iii) the universe.

(e) Explain briefly why the answers to c (iii) and d (iii) differ.

2. State Boltzmann's definition of entropy, explaining the symbols used, and the conditions under which the definition is valid.

Brass is an alloy of 70% copper and 30% zinc. If all the lattice sites are occupied by an atom, determine the configurational entropy of the system when the total number of atoms (N) is (i) 50 and (ii) 500. What are the corresponding values of the entropy for an alloy of 50% copper and 50% zinc?

You may use Stirling's formula for large N: $\ln N! = N \ln N - N$

3. A Schottky defect is formed when an atom leaves a perfect crystal and migrates to the surface. If the energy of formation of a single defect is ε, derive an expression for the concentration of defects at a temperature T.

For what concentration of defects does the entropy of the crystal reach (i) its maximum value, and (ii) its minimum value?

According to one theory, melting occurs when a substance contains 0.01% of vacancy defects. Consider whether this theory can satisfactorily explain the temperatures T_m at which Cu and Pt melt, given that:

for Cu, ε = 1.07 eV and T_m = 1356 K;

for Pt, $\varepsilon = 1.3$ eV and $T_m = 2046$ K.

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