Answer Sheet 1

The terminology used here is as in the lecture notes.

1. Consider equilibrium between two phases α and γ in a binary alloy. Since the compositions of these phases are not identical, $x^{\alpha\gamma} \neq x^{\gamma\alpha}$, it follows that concentration gradients exist and yet there will be no diffusion since the phases are at equilibrium.
2. Given that $G = \mu_A(1-x) + \mu_B x$, it follows that $\frac{\partial G}{\partial x} = \mu_B - \mu_A$.
3. Coiling and uncoiling of molecular chains, vibration of side groups, rotation about covalent bonds.
4. In ordered crystals, A atoms prefer to be next to B atoms: the enthalpy of ordering ΔH_O is negative. However, there is a decrease in entropy on ordering so $-T\Delta S_O$ is positive. The latter term dominates at high temperatures, making ΔG_O positive and hence favouring disorder (random distribution of atoms).
5. An ideal solution is one in which the atoms are randomly mixed at all temperatures. The probability of finding an A atom next to a B atom (or *vice versa*) in an equiatomic ideal solution is $p_{AB} = 2x(1-x) = 0.5$ since x is the probability of finding a B atom and $x(1-x)$ is that of finding an A atom next to a B atom.
6. The task is to calculate the equilibrium carbon concentration at any point given a fixed manganese concentration gradient in austenite. The activity (a) of carbon will tend to become uniform:

$$\ln\{a_C^0\} = \ln\{a_C^{Mn}\}$$
$$\ln\{\Gamma_C^0\} + \ln\{x_C^0\} = \ln\{\Gamma_C^{Mn}\} + \ln\{x_C^{Mn}\}$$

where a_C^0 is the activity of carbon at zero Mn, a_C^{Mn} is the activity of carbon at a finite Mn concentration, x_C^0 and x_C^{Mn} are the corresponding mole fractions of carbon, Γ_C^0 and Γ_C^{Mn} are the corresponding activity coefficients. The activity coefficients can be expanded as follows (Kirkaldy and Baganis, Metall. Trans. 9A, 1978, 495):

$$\ln\{\Gamma_C\} = 8.1 \times x_C - 5 \times x_{Mn}$$

where x_{Mn} is the concentration of manganese. It follows that

$$(8.1 \times x_C^0) + \ln\{x_C^0\} = (8.1 \times x_C^{Mn} - 5 \times x_{Mn}) + \ln\{x_C^{Mn}\}$$
$$\ln\{x_C^0\} - \ln\{x_C^{Mn}\} = (8.1 \times [x_C^{Mn} - x_C^0] - 5 \times x_{Mn})$$

Writing $[x_C^0 - x_C^{Mn}] = \Delta x$, we get

$$\ln\left\{1 + \frac{\Delta x}{x_C^{Mn}}\right\} = -8.1 \times \Delta x - 5 \times x_{Mn}$$

which for small Δx becomes

$$x_C^0 - x_C^{Mn} \equiv \Delta x = \frac{-5x_{Mn}}{8.1 + \frac{1}{x_C^{Mn}}}$$

Suppose we have 1 wt% C and the manganese concentration ranges from 0–5 wt%. 1 wt% C is about 0.05 mole fraction of carbon. Setting $x_C^{Mn} \simeq 0.05$, $x_{Mn} \simeq 0.05$ (since we have 5 wt% Mn), we see that $\Delta x = 0.0089$ or 0.18 wt%. The carbon concentration in the Mn–rich region will therefore be higher by about 0.18 wt%.