Question Sheet 1, Atomic Diffusion

1. Estimate the steady–state flux of atomic hydrogen at 25 °C through a steel vessel of wall thickness 4 mm given that its inside surface is kept saturated with hydrogen at a concentration of 4.2 moles m^{-3}; the outside surface is exposed to the atmosphere. The diffusivity of hydrogen in α–iron is $D_0 = 0.1\,\text{mm}^2\,\text{s}^{-1}$, $Q = 13.4\,\text{kJ mol}^{-1}$.

   If the vessel contains 20 moles of hydrogen, estimate the hours taken to dissipate all of the hydrogen given that the vessel has a surface area of $2\,\text{m}^2$.

   Comment on why it is possible to store hydrogen gas in iron cylinders for much longer periods. How does dissolved hydrogen affect the mechanical properties of α–iron?

2. How is the carburising of steel carried out in commercial practice? Describe two components in automobiles or in bicycles which might be carburised, explain why they should be carburised.

   Mild steel containing 0.05 wt% carbon is carburised at 900 °C by maintaining its surface concentration at 1.5 wt% carbon. Calculate the time required to produce a hypereutectoid structure at a depth of 0.3 mm. The diffusivity of carbon in γ–iron is $D_0 = 2\,\text{mm}^2\,\text{s}^{-1}$, $Q = 84.1\,\text{kJ mol}^{-1}$.

3. The measured self–diffusion coefficients for two aluminium samples are given in the table below. Sample A is in an annealed condition whereas sample B is heavily cold–worked. Plot the data in an appropriate way, account for the observed behaviour and estimate the activation energy for lattice diffusion.

T / °C	50	100	150	200	250	300	350	400
D_A / $\text{nm}^2\,\text{s}^{-1}$	4×10^{-7}	2×10^{-4}	5×10^{-3}	5×10^{-2}	1.1	19	210	1620
D_B / $\text{nm}^2\,\text{s}^{-1}$	5×10^{-5}	3×10^{-3}	5×10^{-2}	0.4	3	25	220	1630

4. $M0$ in the metallography series is a eutectoid steel which was heat treated in a furnace containing air at 1200 °C for 20 min following by cooling to ambient temperature in air. Examine and explain the change in microstructure from the surface to the centre of the sample. You may need to use a phase diagram to help with interpretation.

   How could you prevent the decarburisation of steels during elevated temperature heat treatment?

Numerical answers to AQ1; full answers will be distributed with AQ3.

1. flux = 4.7×10^{-7} moles $m^{-2}\,s^{-1}$, time = 5910 h.

2. About 8 min

3. $Q_{lattice} \simeq 140$ kJ mole^{-1}

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