ME 214 MID-TERM EXAM
November 2004

Question 1

(a) On an oblique representation of a cubic unit cell, sketch [101] and [012] What are the indices of the plane containing these?

Remember that (hkl) denotes a PLANE and [uvw] denotes a direction
The condition that a direction [uvw] lies in (is parallel to) a plane (hkl) is hu +kv+lw =0.

(b) It is possible to cool aluminum very quickly so that the number of vacancies present in equilibrium at high temperature is "frozen in". If the equilibrium fraction of lattice sites that are vacant at 600 °C is 10^{-5}, and the equilibrium fraction vacant at room temperature is $3x10^{-15}$, calculate the percentage change in density of the quenched aluminium resulting from the excess vacancies.
Ignore the $3x10^{-15}$ as irrelevant:

When vacancies are introduced into a material the mass (=number of atoms*mass per atom) is unchanged but the volume (= volume per atomic site*number of sites) changes because the number of sites (= number of atoms + number of vacancies) changes.

Therefore "new" density = mass/volume = mass/ (original volume*$(1+ 10^{-5})$)
= original density / $(1+ 10^{-5})$ = original density $(1 -10^{-5})$

Therefore percentage change is 10^{-5} * 100 = 0.001%

Question 2

(a) Calculate the diffusion coefficient (D) for the diffusion of
(i) Fe in α-Fe (ferrite) at 600 °C and
(ii) C in α-Fe (ferrite) at 600 °C.
Briefly explain the difference between the values.
$D = D_0 \exp(-Q/RT)$ D_0 and Q from table in text, R from front cover – remember T in K.

(i) $D = D_0 \exp(-Q/RT) = 2.8*10^{-4} \exp(-251000/(8.31*873)) = 2.64*10^{-19}$

(ii) $D = D_0 \exp(-Q/RT) = 6.2*10^{-7} \exp(-80000/(8.31*873)) = 1.0*10^{-11}$

The difference arises since C dissolves interstitially in Fe the probability of an adjacent interstital site being vacant is practically 1.

The fact that there is considerable lattice strain locally also helps.

An Fe atom must move into an adjacent vacancy in order to diffuse and hence the activation energy involves both the probability that an atom will acquire the energy to make the jump and also the probability that there is a vacant site nearby.

(b) During carburising, carbon is diffused into austenite (f.c.c. Fe) from an environment of constant carbon concentration.
If the required depth of carburisation is achieved at 900 °C in 10 hours, what time would be required at 950 °C?

Using $x^2/(Dt)^{1/2}$ = constant,
for a constant depth of carburisation Dt = constant

Remember that this is for C diffusing in austenite (f.c.c.Fe) D_{950} can be calculated using $D = D_0 \exp(-Q/RT)$ (D_0 and Q from table in text, R from front cover – remember T in K.) D_{900} is actually given in the table in the text or can be calculated. t_{900} is given and t_{950} is required.
$D_{900} / D_{950} = t_{950} / 10 = \exp(-Q/RT_{900}) / \exp(-Q/RT_{950})$

$$\ln t_{950} - \ln 10 = (-Q/R)*[1/1173 - 1/1223)] = (-Q/R)*(3.48*10^{-5})$$

$$= 0.619$$

from which t_{950} = 5.4 hrs.

Question 3

(a) The non-destructive testing department assures you that they can detect any through thickness cracks greater that 7 mm in a 2024 -T3 component. The dimensions of the component are 900 mm long 200 mm wide and 5 mm thick. In service a tensile load is applied parallel to the long axis.

Determine what you believe to be the maximum load that should be applied to the component, giving reasons for your decision.

Use $K = \sigma (\pi a)$ ½ for a central through thickness crack and $K = 1.12 \sigma (\pi a)$ ½ for a through thickness edge crack. K_{1c} and σ_{ys} are given in notes and the text for 2024 –T3 Al.
K_{1c} = 44 MPa $m^{1/2}$ and σ_{ys} = 345 MPa

For central crack $44 = \sigma (\pi *0.0035)^{½}$ from which σ = 420 MPa ($>\sigma_{ys}$!!)

For edge crack $44 = 1.12 \sigma (\pi *0.007)^{½}$ from which σ = 265 MPa ($>0.5*\sigma_{ys}$!!)

Normally choose $\sigma_{ys}/2$ = 172 MPa which gives 172 kN as load

(b) High-temperature creep tests were performed on a nickel alloy and the results were to be used to predict long-term low-temperature performance. The steady state creep rate at 800 °C was found to be 0.8 % per hour and the steady state creep rate at 750 °C was found to be 0.04 % per hour. The stress applied was constant and was the same for each test.

What is the activation energy for creep in this alloy?

Use steady state creep rate = constant*exp (-Q/RT) for constant stress.

m= m

0.8% = constant*exp (-Q/R(800 + 273)) = constant*exp (-Q/R*1073) (1)

0.04% = constant*exp (-Q/R(750 + 273)) = constant*exp (-Q/R*1023) (2)

Divide (1) by (2)

0.8/0.04 = 20 = exp [(1/1023 – 1/1073) * Q/R]

[(1/1023 – 1/1073) * Q/R] = ln 20 = 2.996

from which Q = 547 kJ/mol

Question 4
(a) What phases are present, what are the compositions of those phases and what would be the amounts in 100 kg of alloy for:
(i) Mg 50 wt% Pb slowly cooled from 700 °C to just above the eutectic temperature,
(ii) Mg 50 wt% Pb slowly cooled from 700 °C to just below the eutectic temperature.

(b) Mg 50 wt% Pb is slowly cooled from 700 °C to just below the eutectic temperature. What is the ratio of the amount of proeutectic α to eutectic α.

using the Mg Pb phase diagram from the test

(a) (i) For a 50% Pb alloy at 700 °C +
Phases present α + L
Compositions C_α = 41% Pb, C_L = 67% Pb
Amounts m_α = (67-50)/(67-41) = .654 → 65.4 kg α, 34.6 kg L

(ii) For a 50% Pb alloy at 700 °C -
Phases present α + Mg_2Pb
Compositions C_α = 41% Pb, C_{Mg2Pb} = 81% Pb
Amounts m_α = (81-50)/(81-41) = .775 → 77.5 kg α, 22.5 kg Mg_2Pb

(b) From above total α = 77.5 kg and proeutectic (primary) α = 65.4 kg
therefore the amount of α in the eutectic is 77.5 – 65.4 = 12.1 kg
so that the ratio is 65.4/12.1 = 5.4.