INSTRUCTIONS TO CANDIDATES

1. Answer Question **ONE** and any other **TWO** questions
2. Use of sketch diagrams where necessary and brief illustrations are encouraged.
3. Read the instructions on the answer booklet keenly and adhere to them.
Instructions to candidates:
a) Answer question **one** (30 marks) and **any other two** (20 marks each)
b) The following are useful constants and formulae
   (i) Planck's constant, \( h = 6.63 \times 10^{-34} \text{ J.s} \)
   (ii) mass of an electron, \( M_e = 9.11 \times 10^{-31} \text{ kg} \)
   (iii) Boltzmann's constant, \( K_B = 1.38 \times 10^{-23} \text{ J K}^{-1} \)
   (iv) s.h.c of water \( = 4.19 \text{ J g}^{-1} \text{ K}^{-1} \)

**Question one (30 marks)**

a) Explain the importance of heat in diffusion \((4\text{marks})\)
b) Using an appropriate graph, explain the solidification process of a composite material. \((4\text{marks})\)
c) i. Define the term free energy \((1\text{mark})\)
   ii. What are the similarities/differences between Gibbs and Helmholtz free energies \((3\text{marks})\)
d) State the factors that affect diffusion in solids \((4\text{marks})\)
e) State Fick's laws in words and symbols, state the meaning of each term in the symbol. \((4\text{marks})\)
f) What properties makes for a good oxide film \((3\text{marks})\)
g) Define sintering \((1\text{mark})\)

h) With the aid of a diagram derive Fick's second law, hence or otherwise show that Fick's first law is just a simplified format of the second law when applied to a steady state. \((6\text{marks})\)

**Question Two (20 marks)**

a) What is diffusion \((1\text{mark})\)
b) State and give an example of each of the sintering products \((6\text{marks})\)
c) State Gibbs phase rule. Using the phase rule calculate the number of degrees of freedom for a binary system. \((3\text{marks})\)
d) Explain the physical meaning of the equation \( \Delta(\gamma A) = \Delta \gamma A + \gamma \Delta A \), when considering a sintering process \((2\text{marks})\)

e) On a well labelled diagram show the graphs of oxidation rates of a metal by their equations. \((4\text{marks})\)
f) Briefly explain corrosion classification techniques. \((4\text{marks})\)

**Question Three (20 marks)**

a) (i) What is an Ellingham diagram \((2\text{marks})\)
    (ii) State three uses of the Ellingham diagram \((3\text{marks})\)

b) (i) Consider the following two oxidation reactions:
2M+O₂ → 2MO
N+O₂ → NO₂

where M and N are metals. Draw and explain the Ellingham diagram for the variation of $\Delta G$ with T for the resultant reaction. (6 marks)

c) i. State the Pilling-Bedworth ratio expression (1 mark)
    ii. What deductions can be made from this expression (3 marks)

d) i. State the property that determines categorization of sintering. (1 mark)
    ii. State the four categories of sintering (4 marks)

**Question Four (20 marks)**

a) A sheet of BCC Fe 1.0 mm thick is exposed to a carburizing gas on one side and a decarburizing gas on the other at 725°C. After reaching steady state, the Fe membrane is quenched to room temperature, and the C concentrations at each side of the membrane are 0.012 and 0.075 wt%. Calculate the diffusion coefficient if the diffusion flux is $1.4 \times 10^{-8}$ kg/m$^2$-sec. (6 marks)

b) After a combustion process in a cylinder, the pressure is 1200kPa and the temperature is 350°C. The gases expand to 140kPa with a reversible and adiabatic process. Calculate the work done by the gases assuming they can be approximated by air with constant specifics heats. (6 marks)

c) State the factors that determine the limits of solubility. (8 marks)