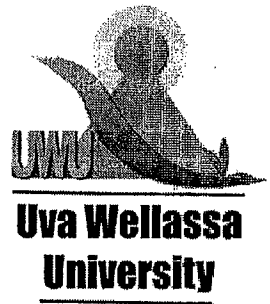


Uva Wellassa University, Sri Lanka
End Semester Examination – February 2012
SCT 331-3 Materials Chemistry I
Time: Three (03) hours



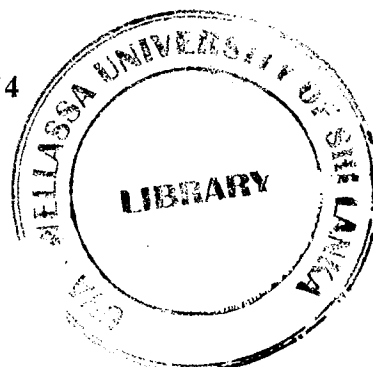
Total Five (05) questions

Answer all questions

Calculators are allowed

All symbols carry standard meanings. You may use standard symbols without definition

1.
 - i. Explain the uses of an isothermal transformation diagram? (4 marks)
 - ii. In addition to coarse pearlite, what other types of structures may form in the coarse pearlite region? (6 marks)
 - iii. Name the four regions in the region of transformation? (10 marks)
 - iv. Consider transformation products: bainite or martensite
 - a. Which has more ductility?
 - b. Which has greater hardness? (10 marks)
 - v. Draw an isothermal transformation diagram for an iron – carbon alloy of eutectoid composition. (10 marks)
 - vi. On the same diagram drawn in part (v), sketch and label the time – temperature paths to produce the following microstructures:
 - a. 100% coarse pearlite
 - b. 100% tempered martensite
 - c. 50% coarse pearlite, 25% bainite and 25% martensite
 - d. 50% bainite, 25% martensite and 25% austenite
 - e. 50% fine pearlite and 50% austenite (60 marks)
2.
 - i. State two limitations of isothermal transformation diagrams? (4 marks)
 - ii. List three special types of tempering? (6 marks)



- iii. What is the special quenching method used to produce 100% bainite? (10 marks)
- iv. Explain the difference between *general quenching and tempering* with *martempering*? (10 marks)
- v. Consider the I-T diagram given with the question paper
- Plot three lines to show three different microstructures.
 - Compare the properties of these three different types of microstructures. (70 marks)

3. Part A

- (i) Plot the family of P-V curves of CO₂ accordance to van der Waals equation. Identify the van der Waals loop and show a method of correcting this effect (no mathematical derivations are required). (25 marks)
- (ii) The critical constants of CO₂ is given as P_c = 73.843 bar, V_c = 0.094 (L.mol⁻¹) and T_c = 304.14 K.
Calculate the compressibility factor and the van der Waals parameters of CO₂.
Briefly explain the answer you received for compressibility factor. (25 marks)

Part B

- (i) Maxwell Boltzmann distribution of speeds of gas molecules is given by the following equation: $F(u)du = \left(\frac{m}{2\pi k_b T}\right)^{3/2} u^2 e^{-mu^2/2k_b T} du$.
Identify all terms therein. Plot the distribution of the velocity of a given gas according the Maxwell Boltzmann distribution.

State the physical meaning of following expressions:

a. $\int_{v_1}^{v_2} uF(u).du$

b. $\int_0^{\infty} F(u).du$

c. $\int_0^{\infty} uF(u).du$

d. $\int_0^{\infty} u^2 F(u).du$

(25 marks)

(ii) Define following terms:

(a). collision frequency (b). collision cross section (c). mean free path.

Write mathematical expressions for each of these parameters. (25 marks)

4. Part A

(i) State the two assumptions made in the collision theory in deriving an expression for the rate of a reaction. Differentiate the meaning of collision cross section and reactive collision cross section. (25 marks)

(ii) According to the collision theory the rate of a reaction

$$A_g + B_g \rightarrow \text{products is given as rate} = \sigma_0 \left(\frac{8k_b T}{\pi \mu} \right)^{1/2} \exp \left(-\frac{\epsilon_a}{k_b T} \right) N_A N_B.$$

Based on this expression,

Write an expression for rate constant of the reaction.

Write an expression for the pre-exponential factor of the Arrhenius model.

How the Arrhenius pre-exponential factor depends on temperature. (25 marks)

Part B

(i) What is the major assumption made in transition state theory?

Prove that for a reaction, $A_g + B_g \rightarrow \text{products}$, the rate constant is given by

$$k = \frac{k_b T}{h} K^\ddagger. \quad (10 \text{ marks})$$

(ii) Use the thermodynamics approach to prove that

$$k = \frac{k_b T}{h} e^{\Delta S^\ddagger / R} e^{-E_a / RT}.$$

Following general thermodynamic relationships were given:

$$RT \ln K = -\Delta G^\circ; \quad \frac{d \ln K}{dT} = \frac{\Delta U}{RT^2}. \quad (40 \text{ marks})$$



5.

(i)

State Fick's second law of diffusion. Define all terms therein.
State all assumptions made.

(20 marks)

(ii)

It is desired to diffuse indium into pure silicon such that the In concentration at a depth of 3×10^{-4} cm from the surface will be one-half of the surface concentration.

How long should the silicon be in contact with indium at 1600K in order to accomplish this diffusion? ($D = 8 \times 10^{-12}$ cm²/s)

(40 marks)

(iii)

To increase its corrosion resistance, chromium (Cr) is diffused into steel at 980°C. If during diffusion the surface concentration of chromium remains constant at 100%, how long will it take (in days) to achieve a Cr concentration of 1.8% at a depth of 0.002 cm below the steel surface?

($D_0 = 0.54$ cm²/s; $E_A = 286$ kJ/mol).

(40 marks)