L-3/T-1/MME **Date: 24/09/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **MME 321** (Crystal Defects, Deformation and Fracture)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **EIGHT** questions in this section. Answer any **SIX** questions.

The figures in the margin indicate full marks

1. (a) For an FCC crystal, determine the theoretical shear strength value in the closely packed plane. Lattice parameter is 0.40478 nm. **(10)**

   (b) Calculate the equilibrium number of vacancies per cubic meter for copper at 1000 C. The energy for vacancy formation is 0.9 eV/atom; the atomic weight and density (at 1000 C) for copper are 63.5 g/mol and 8.4 g/cm$^3$, respectively. **(7½)**

2. Let us assume that in a crystal containing $n_0$ atoms there are $n_v$ vacant lattice sites. Suppose that vacancies are created by movements of atoms from positions inside the crystal to positions on the surface of the crystal, in the manner for producing a Schottky defect. Ignoring vibrational entropy, derive an expression for equilibrium concentration of vacancies, in terms of $Q_v$ (energy required to produce one mole of vacancies, in cal/mol or Joules/mol). **(17½)**

3. (a) Using Schmid Law, build a concept on impact of orientation of slip planes with loading axis for continuation of deformation. Draw illustrations of different orientations of load axis and slip systems to enrich your argument. **(10)**

   (b) Consider a single crystal having simple cubic structure and cylindrical shape. Tensile load is applied along [010] direction. Will there be any shape change of the cylinder? Develop your reasoning considering the easiest slip system at room temperature. **(7½)**

4. (a) Can you obtain Shockley partials from the reaction below? **(5)**

$$\frac{a_0}{2}[110] \rightarrow \frac{a_0}{6}[2\bar{1}\bar{1}] + \frac{a_0}{6}[11\bar{2}]$$

   (b) How does stacking fault (layers of HCP in FCC structure) develop during deformation? **(5)**

   (c) Why is cross-slip easier in Al than to Cu? **(7½)**

Contd ..... P/2

**MME 321**

5. Design how jogs are created in edge dislocations. You should consider two edge dislocations (MN and OP) on two different slip planes, having Burgers vector $b_1$ and $b_2$ respectively. Condition: $b_1$ is normal to MN. Can jogs make rows of interstitials? **(10+7½)**

6. You are a materials consultant in a plain carbon steel cold-rolled sheet plant. Three materials engineers work under your supervision. You are responsible for developing new alloys by changing composition and rolling parameters. For this, you have devised a route: casting in a vacuum furnace, homogenizing at 800 °C, and cold rolling of 10 mm machined samples in a mini rolling mill having two rollers. After cold-rolling you carry out tensile test at different temperatures in a furnace-controlled UTM. During one such development work, one of your engineers came to you with a set of problems. **(17½)**

(a) Enhancement of the work-hardening rate was observed, leading to an increase in the UTS of the materials.

(b) Pre-straining the sample to a strain greater than the yield strain resulted in the removal of the yield point. However, if the sample rests before retesting, the yield point will return.

(c) Yield-point elongation occurred.

After carefully perusing their report, you're asked by your management to provide convincing remarks on the findings. What would be your probable explanations? Use illustrations if necessary.

7. For an FCC metal, draw stress-strain curves for the following conditions. Tensile tests were carried out at room temperature with a strain rate of $10^{-4}$ $S^{-1}$. **(17½)**

(a) Pure metal (Named: metal 'A') in rolled condition

(b) Solid solution with substitutional elements (solution-treated and quenched after rolling; named: alloy 'B')

(c) Alloy B aged to obtain GP zones

(d) Alloy B aged to peak hardness

(e) Alloy B over-aged

Now, support your plots using the categorising impacts of dislocation interactions and work hardening rate. Extend your discussion with derived relationship between particle strength and size.

8. Consider yourself as a junior materials engineer in a magnesium alloy development plant for automobiles. You, using thermodynamic modelling method CALPHAD, design alloys by changing compositions and adding different types of elements. Only

Contd ..... P/3

**MME 321**

**Contd.... for Q. No. 8**

substitutional type alloying is your specialisation. During your undergraduate studies, you learned about different types of solid solutions: interstitial, substitutional and self-interstitial for low carbon steels. Since you are working only substitutional types, you are thinking to modify the following well-known statement applicable for steels: **(17½)**

*"The relative strengthening potential for a given solute atom is determined by the nature of the stress field associated with the solute atom."*

(a) You considered Hume-Rothery size effect, and dilational misft strain energy.

(b) You did not consider tetragonal distortion.

(c) Elastic strains are isotropic.

(d) Only hydrostatic components of the strain fields of dislocations were to be used.

After reviewing journal articles, classic textbooks on strengthening and consulting with your peers, you've modified the statement as below.

*"The relative strengthening potential for a given solute atom in magnesium matrix is determined by the interactions of only screw dislocations with the solute atom."*

Now, defend your statement based on the factors stated above.

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

The questions are of equal value.

9. The stress-strain diagrams of three different carbon steels are presented in Figure for Question No. 9. Considering the theory of instability, select the most appropriate one for a component to be manufactured by deep drawing process. With necessary schematic diagrams defend and explain your selection. Also explain which steel will be the most sensitive in deep drawing operation.

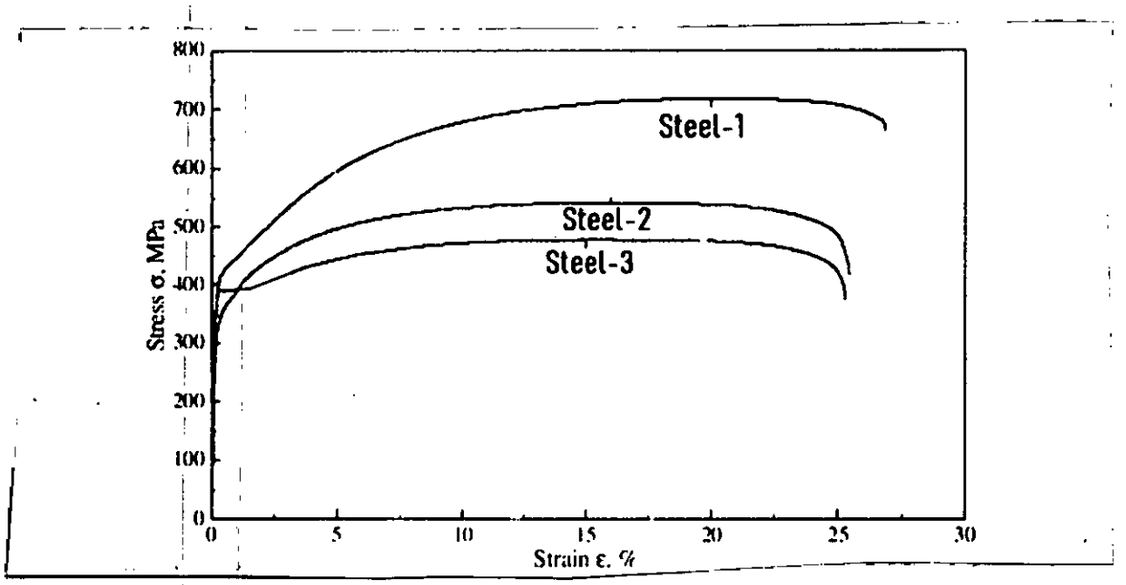


Figure for Question No. 9

Contd ..... P/4

**MME 321**

10. Do you think that happening of fast fracture is nothing but a competition between stress intensity factor of the loaded component and material toughness of the component? With necessary equation explain it. With the help of NDT cracks of variable sizes have been detected in a particular stock material of HSLA steel to be used for making a crank shaft. Among these cracks, the largest one was 2 mm and the stock material was still acceptable for the purpose. Suggest suitable changes in stock materials that might make the fast fracture process five times more difficult as per fracture mechanics concept.

11. Do you think that toughening of any brittle matrix with another brittle material is possible? Why? Suppose you are working as materials design engineer in a R & D section of an organization. You are advised to design a light-weight component to be used in moist and corrosive environment. In this regard, you are supplied with epoxy resin along with glass, carbon, and bamboo fibres as well as their particles. Suggest a suitable combination for making the toughest composite from the available materials. Defend your choice and with necessary schematic diagrams explain how this combination mutually works to ensure the service requirements.

12. In the ideal condition, the fatigue fracture surface in **tag I** is featureless. With necessary diagrams explain under what conditions striation marks like **stage II** might be formed from start of the fatigue loading? The fatigue crack markings shown in the Figure for Question No. 12 were found on the fracture surface of a cyclically loaded component with the maximum stress 300 MPa and the minimum stress zero. What will happen on the geomorphologies of the striation marks at points, 1, 2 and 3 if the initial maximum stress is increased to 400 MPa?

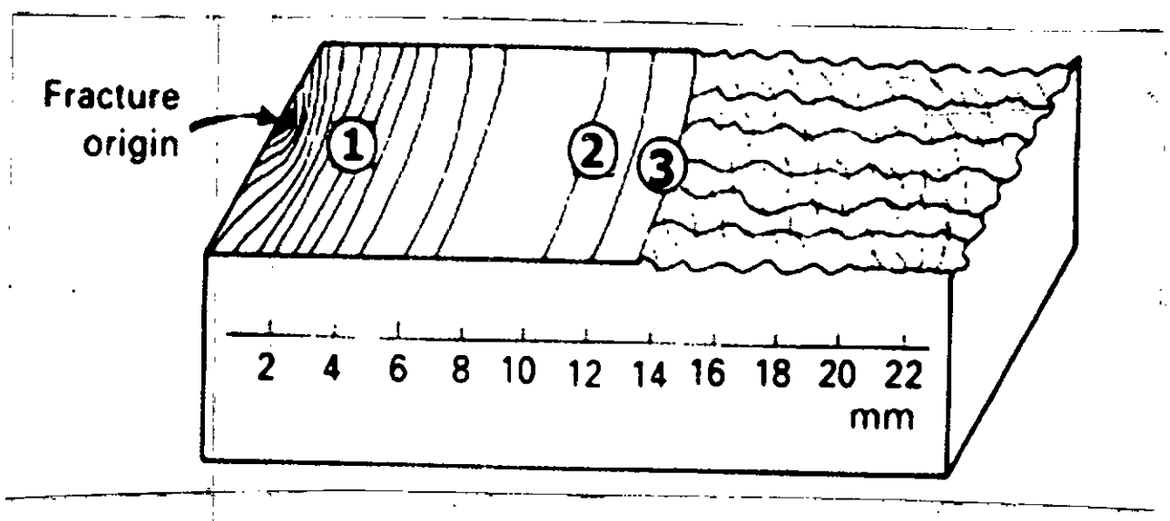


Figure for Question No. 12

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**L-3/T-1/MME** **Date: 29/09/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **MME 325** (Corrosion and Degradation of Materials)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) 'Gaseous oxidation is analogous to aqueous galvanic corrosion or an electrolytic cell.' --Justify with necessary diagram. **(8)**

   (b) Establish the criteria how oxidation resistance is improved by doping in case of n-type and p-type oxides. **(22)**

   (c) How is total polarization quantified in case of anodic dissolution and cathodic reduction? **(5)**

2. (a) With schematic diagrams, prove that the required amount of oxidizer concentration to cause passivation is greater than that required to maintain passivity. Which special precaution shall be taken to maintain passivity? **(25)**

   (b) Analyse the velocity effect on the electrolyte on the corrosion rate of an active-passive metal corroding under diffusion control. Hence prove that smaller the Ic, the easier a metal will be passivated by an increase in velocity. **(10)**

3. (a) Figure 1 show galvanic coupling between two corroding metals M and N (M is noble and N is active) of equal area. Write the conventional notations at eight points indicated by 1-8 arrowheads that best describe the galvanic coupling. Analyse the changes of the followings: **(20)**

   i) Corrosion of M before and after coupling
   ii) Corrosion of N before and after coupling
   iii) $H_2$ gas evolution from the surface of M before and after coupling
   iv) $H_2$ gas evolution from the surface of N before and after coupling

   (b) Does 'Noble metal alloying' concept support classic corrosion theory? Give reasoning to your answer. How will you apply the concept in industrial exposure condition? **(15)**

Contd ..... P/2

**MME 325**

4. (a) Explain important design rules that should be followed for corrosion prevention of materials. **(13)**

(b) Consider the system shown in Figure 2 and show that anodic protection is much more efficient than cathodic protection in acid solutions. **(15)**

(c) Compare and contrast anodic protection to cathodic protection system. **(7)**

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Economy loss due to indirect loss occur by corrosion is more difficult to assess- why? **(6)**

(b) In your opinion which cell is the most detrimental for a corrosive system among three main types of cells? Justify your answer. How is Zn coating of galvanized steel sheet corroded in a dilute HCl solution? **(6+5=11)**

(c) Calculate the emf of the cell $Cu;Cu^{2+};Ni^{2+};Ni$ at 25°C and write the spontaneous reaction of the cell. What is the polarity and which electrode is anode? The standard potential of $Cu^{+} + 2e \rightarrow Cu$ and $Ni^{2} + 2e \rightarrow Ni$ are 0.337 and -0.250 volt respectively. Given R = 8.314 j/deg-mol and F = 96,500 C/eq. **(8)**

6. (a) Why does corrosion of water filled steel tanks take place below the water line? **(8)**

(b) Design engineer specifies the materials detailed to be used in equipment. Explain the aspects he/she should consider to prepare a specification of materials for making equipment in point of view of galvanic corrosion. **(15)**

(c) Yellow brass tubes (65% copper) in air compressor showed leaking in cooling water after 8 years of service. The cooling water was chlorinated well-water. The water was re-circulated. A visual examination showed a thick layer of porous brittle copper on the inside surface. A plug type deposit had penetrated deep in the well of the tube. At many points the wall of the tube was completely damaged. What type of corrosion occurs in this case? Justify you answer and also suggest possible remedy of this damage. **(12)**

Contd ..... P/3

## MME 325

7. (a) How does graphitization by graphitic corrosion differ from graphitization of cast iron? Explain the mechanism of graphitic corrosion in cast iron. **(3+7=10)**

(b) A seawater pumping plant had been designed to provide seawater for cooling purpose to a thermal power plant (TPP), a turbo-blower station (TBS) and other plants in a steel mill. The average pH was 8.0. The casing material was stainless steel (304SS). After three years of operation, the inside of the casing was examined. The surface was found to be covered by a thin dark brown layer of uniform thickness over the surface. Removal of the layer showed a large number of pits on the weld metal. Explain how pits were formed in the casing and what remedial measures should be taken to reduce the corrosion. **(20)**

(c) Why is fatigue life of a material drastically reduced in a corrosive environment? **(5)**

8. (a) What would happen if austenitic stainless steel is held at the sensitizing temperature for, say 1800 h? Would it be still susceptible to intergranular attack? Justify your answer. **(10)**

(b) State the main points of disagreement and agreement between the theory of wear oxidation and oxidation-wear. **(10)**

(c) What would happen if hydrogen is adsorbed on an active metal surface? Outline the main difference between hydrogen attack and blistering caused by hydrogen. **(15)**

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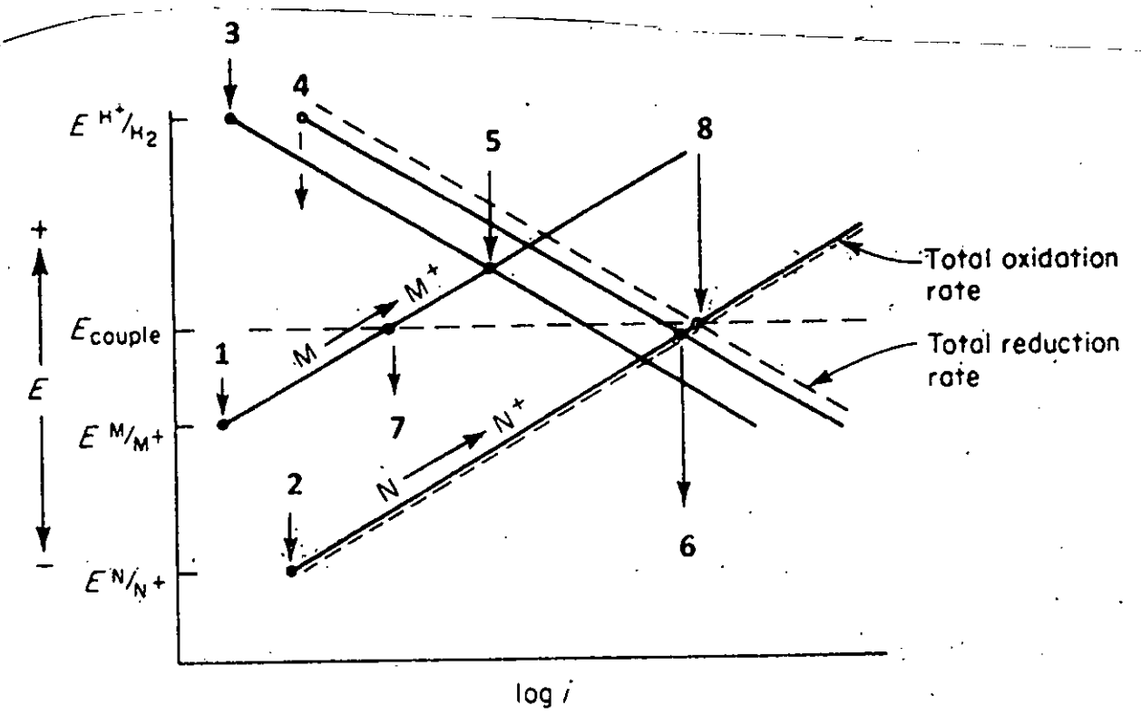


Figure 1 for question No. 3(a)

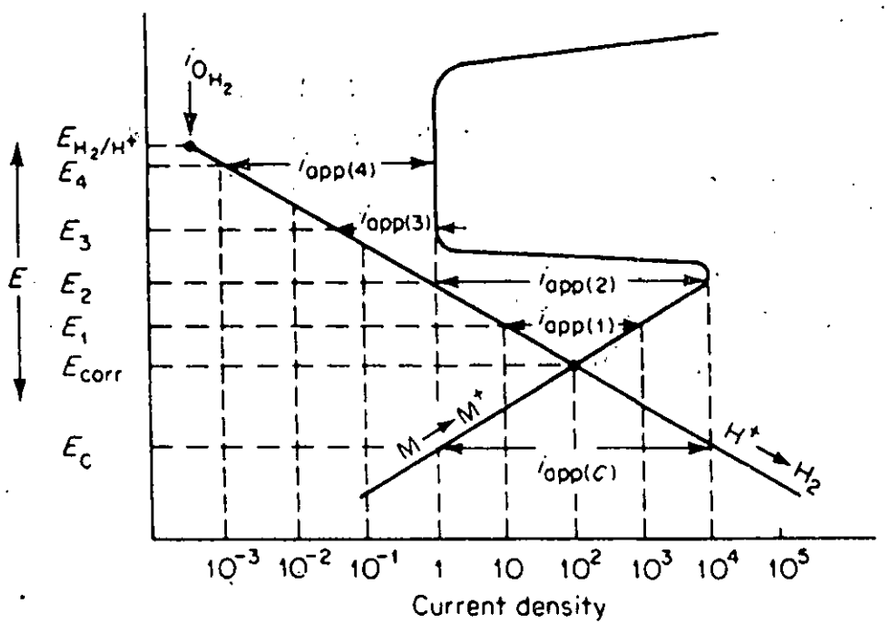


Figure 2 for question No. 4(b)

L-3/T-1/MME **Date: 19/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **MME 341** (Refractories and Furnaces)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) Give a neat sketch and analyze the working principles of a rotary regenerator. **(17)**

   (b With the help of appropriate diagrams, explain in details how waste heat recovery from the flue gas improves the furnace efficiency in terms of fuel savings. **(18)**

2. (a) Compare the main design features between converters and crucible furnaces. **(15)**

   (b) List various type of crucible furnaces and compare their working principles, efficiency and applications using free hand neat sketches. **(20)**

3. (a) Analyze how heat is generated and transferred to load inside a flame fired furnace. Indicate the parameters that affect both the heat generation and transfer processes. **(20)**

   (b) Make a comparison between recuperators and regenerators. **(10)**

   (c) For electric resistance furnaces, which type of heating elements would you chose– (i) straight or (ii) coiled. Give your reason. **(5)**

4. (a) Using the following data, draw up a heat balance for a steel ingot soaking pit for a twenty hours test period during which 130 tons of ingots were heated from 20°C to 1220°C. **(20)**

   Data

   Mean temperature of:

   - Air after recuperator = 620°C
   - Blast furnace gas (fuel) after recuperator = 450°C
   - Flue gas after soaking pit = 1050°C
   - Flue gas after Air recuperator = 770°C
   - Average Blast Furnace gas consumption = 2805 $m^3$/hr
   - Air/fuel gas ratio = 0.8
   - Flue gas/fuel gas ratio = 1.65
   - Net calorific value of B.F. gas = 860 kcal/$m^3$
   - Mean specific heats (kcal/$m^3$ °C) are as follows:
   - Air = 0.301
   - Blast Furnace gas = 0.310
   - Flue gas = 0.358

Contd ..... P/2

**MME 341**

**Contd... for Q. No. 4(a)**

Steel = 0.180 (kal/kg °C)

(All volumes are measured at 1 atm, 20°C)

Scale formation = 1.5% (by weight)

Scale formation reaction is expressed as: $3Fe + 2O_2 = Fe_3O_4, \Delta H_{20^\circ C} = -266841$ kcal

Atomic weight of iron = 56

Calculate the thermal efficiency of the air recuperator and Blast Furnace gas recuperator using the above data.

(b) During continuous casting of steel, liquid steel passes through some shaped refractory parts. Name each of those individual shaped parts. Mention the types of refractories that are used in those parts. Outline the main types of interactions that occur between steel and refractories of those different parts during continuous casting of steel. **(15)**

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. (a) Ductile material can be distinguished from brittle material through their differential behaviour under thermal stress— justify this statement. Suggest three ways to enhance thermal shock resistance of brittle ceramic material. **(20)**

(b) Illustrate the factors working behind different types of spalling of refractories in service. **(15)**

6. (a) Select a refractory for glass melting furnace and justify your choice. Compare fusion cast refractories with insulating refractories. **(7+10=17)**

(b) Why does a clay, once having been fired at an elevated temperature, loses its hydroplasticity? Describe the changes occurring during firing of a fireclay brick. **(18)**

7. (a) Illustrate the effect of baking and vitrifying on kaolin. Explain the principle of oil-fired burners. **(12+8=20)**

(b) How does a shuttle kiln operate? With help of heat balance diagram, explain kiln efficiency and draw the heat balance diagrams of a recuperative kiln with 70% and 100% efficiency. **(15)**

8. (a) With the help of appropriate diagram, elaborate how waste heat recovery from the flue gas improves the furnace efficiency in terms of fuel saving. **(10)**

(b) What additives are used during manufacturing dolomite refractories? Explain with reasons behind adding them in different steps. **(20)**

(c) Draw the equilibrium phase diagram of $Al_2O_3$–$SiO_2$ system. **(5)**

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L-3/T-1/MME **Date: 25/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **MME 351** (Principles of ore dressing and extractive metallurgy)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

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**SECTION – A**

There are **FOUR** questions in this section. Answer any **THREE**.

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1. (a) Why is ore dressing important before metal extraction? **(10)**

   (b) In a ball mill, with the help of a diagram describe the zone/s where there is size reduction and the zone/s where there is not size reduction. **(25)**

2. (a) Given that the coefficient of friction in one jaw crusher is $\mu = 0.5$ and another is 0.2, indicate a range of angles between the jaws that will allow the particle to be gripped and crushed in both cases. Which jaw crusher is likely to produce larger size particles and why? **(20)**

   (b) What can be done to overcome the harmful effects of batch grinding? **(15)**

3. (a) A pulp consists of galena and quartz suspended in water, the pulp contains 30 percent galena, 40 percent quartz and 30 percent water by weight. Specific gravity of galena is 7.5 and of quartz is 2.7. Calculate.

   (i) pulp dilution **(5)**

   (ii) pulp density **(5)**

   (iii) percent of solids **(5)**

   (b) Explain the working principle of a hydrocyclone. **(20)**

4. (a) Describe a classification process that helps separate magnetic from non-magnetic and weakly magnetic minerals. **(20)**

   (b) In the froth floatation process, what is the function of a collector? **(15)**

Contd ..... P/2

**MME 351**

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. The gases from a roasting furnace were analyzed and found to contain (percent): **(35)**

$CO_2 - 1.8$, $SO_2 - 7.2$, $H_2O - 0.6$, $N_2 - 80.1$, $O_2 - 10.3$

The ore before roasting contained 10 percent Cu, 34 Fe, 14 $SiO_2$, 42 S. Four-fifths of the sulphur is removed by the operation and 50 tons of ore is charged per day. The Fuel is coal containing 76 percent carbon. The ore and fuel are separate, but the resulting gases mix.

Required :

a. The weight of roasted ore, per day, assuming it to contain only $Cu_2S$, FeS, $Fe_2O_3$ and $SiO_2$

b. The amount of fuel used, expressed as percentage of the ore.

c. The percentage of excess air used over that theoretically required for combustion and roasting.

d. The ratio of air required theoretically for roasting to that required theoretically for combustion of the fuel.

6. (a) Draw neat sketches and explain the situation that can arise when a mineral surface dissolves in a leaching reagent. Identify the kinetic steps in each case and explain how the leaching reaction can be accelerated. **(20)**

(b) Explain with a suitable phase diagram, the principles of zone refining. **(15)**

7. (a) Explain with appropriate chemical reactions, the purification of leach liquors by the ion exchange methods. **(20)**

(b) How can the pregnant solution be separated from the residue? How can the losses be minimized? **(15)**

8. (a) Consider the relative activity of metals with respect to hydrogen and explain why all metals are not amenable to electrowinning from aqueous solution. **(20)**

(b) What are the harmful impurities in electrical grade copper and how they are eliminated during copper electrorefining? **(15)**

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L-3/T-1/MME **Date : 15/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub : **MME 449** (Ferrous Production Metallurgy)

Full Marks : 280 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) You have iron ore and charcoal at your place. You need to produce iron in very small scale from it. But there is no scope for the installation of a blast furnace structure at your place. Suggest and explain a method how you can produce iron from ore and charcoal. **(16)**

   (b) Both the direct reduction and indirect reduction of iron oxides take place in a blast furnace during production of liquid iron. Which reduction you think the most dominant? Justify your answer. **(16⅔)**

   (c) At 900°C, equilibrium concentration of CO is 30% for the reduction of $Fe_3O_4$ to FeO and 60% for the reduction of FeO to Fe. Calculate the moles of CO required for complete reduction of 1 mole of $Fe_3O_4$ and FeO. Show both the reduction reactions. **(14)**

2. (a) How does Si enter into liquid iron from iron ore charge materials? Write down the methods that can be followed for the production of low Si content pig iron. **(20⅔)**

   (b) "The most favourable melting condition- gangue of an ore contains a $SiO_2/Al_2O_3$ ratio 2.5-4/1" – explain this assertion with suitable diagram. **(10)**

   (c) A blast furnace is using hematite ore for the production of pig iron having 4.5%C. The volume of CO and $CO_2$ in top gas is 28% and 16% respectively. The blast required for the production of per ton product iron is 1500 $Nm^3$. Carbon in coke used for the production of iron is 88%. From these data, calculate coke rate. **(16)**

3. (a) Show the zone in the blast furnace with the relevant reactions where maximum ore reduction occurs and form iron droplets. Why is dead man's zone important in a blast furnace? **(10+5)**

   (b) How will you utilize the blast furnace gases in increasing the furnace efficiency? **(6⅔)**

Contd ..... P/2

**MME 449**

**Contd ... Q. No. 3**

(c) Iron ore contains 61% Fe and 4.5% $SiO_2$; final slag basicity measured ($CaO/SiO_2$ ratio) 1.2; 68 percent of the coke is burned in the tuyeres and 35 percent ash is released above the tuyere level and is incorporated in the bosh slag. The final product pig iron contains 93% Fe and 0.2% Si. Two types of coke are used (i) coke consumption = 550 kg/THM; coke ash = 7% with $SiO_2$ = 40% in ash and (ii) coke consumption = 630 kg/THM; coke ash = 16% with $SiO_2$ = 50% in ash. Calculate the basicity of the bosh slag for both the cokes. Which basicity is favourable for the formation of slag at the bosh zone? **(25)**

4. (a) Compare the alternative routes of liquid iron production techniques other than blast furnace. Among them choose an appropriate technique for Bangladesh by considering the resources available in the country. Justify your choice. **(12+6)**

(b) The productivity of a DRI plant mainly depends on the reduction rate of iron ore. By considering all rate controlling steps, explain how you will increase the reduction rate as well as the productivity. **(16⅔)**

(c) A blast furnace produces per day 620 tons of pig iron containing 4.5% C. The coke and $CaCO_3$ consumption for per ton pig iron are 720 kg and 220 kg, respectively. Coke used in the furnace contains 93% C. The blast furnace gas analysis shows $CO_2$-10%, CO-28%, $N_2$-59%, $H_2O$-3%. Calculate (i) the volume of gas made per day and (b) the volume of he blast supplied per day. **(12)**

## SECTION – B

There are **FOUR** questions in this section. Answer **Q. No. 5** and any **TWO** from the rest.

5. (a) Explain the role of slag in the steelmaking process. Analyse the importance of slag basicity, slag viscosity and oxygen potential of slag in controlling the kinetics of the steelmaking process. **(16)**

(b) Explain how a Kaldo process or a Rotor process different from the LD process. Why didn't these processes find their use in the modern world? **(10)**

(c) What is meant by the term "secondary" metallurgy? Examine how inclusion control and inclusion engineering help in controlling the quality of steel. **(10)**

(d) Why do steelmakers nowadays prefer liquid iron pre-treatments? Explain how would one pre-treat liquid iron for silicon removal. **(10)**

(e) The kinetic data for the gasification of char by ore in given in Fig. 1. Determine the kinetic parameter E using any one method of the differential approach. **(10)**

Contd ..... P/3

## MME 449

6. (a) Analyse the comparative advantages and disadvantages of EAF and IF steelmaking. **(16)**

   (b) Using schematic diagram, explain the refining reactions that occur in the LD process. **(28)**

7. (a) Relate degree of deoxidation and final carbon content of the bath with the resultant structure of the solidified ingot. **(16)**

   (b) A bubble of nitrogen gas of diameter 0.5 mm, at a pressure of 1.5 atm, is rising through a stagnant melt of steel of composition 0.4% C, 0.5% Mn and temperature 1625 °C. Assuming mass transfer in the melt to be rate controlling, and Higbie's theory to be applicable, calculate the rate of transfer of nitrogen from gas to melt. Given data: Diffusivity of N in liquid steel at 1625 °C is $3.85 \times 10^{-9}$ $m^2/s$, for the reaction $(1/2)N_2 = [N]$, $\log K_N = (-581/T) + 2.937$, and the interaction parameters: $e_N^N = 0$, $e_N^C = 0.13$, $e_N^{Mn} = -0.02$. **(28)**

8. (a) Examine the kinetics of C-O reaction and analyse the influence of temperature and carbon boil on carbon reduction and the overall quality of steelmaking process. **(28)**

   (b) Analyse the technological and economic advantages of continuous casting process over ingot casting process. **(16)**

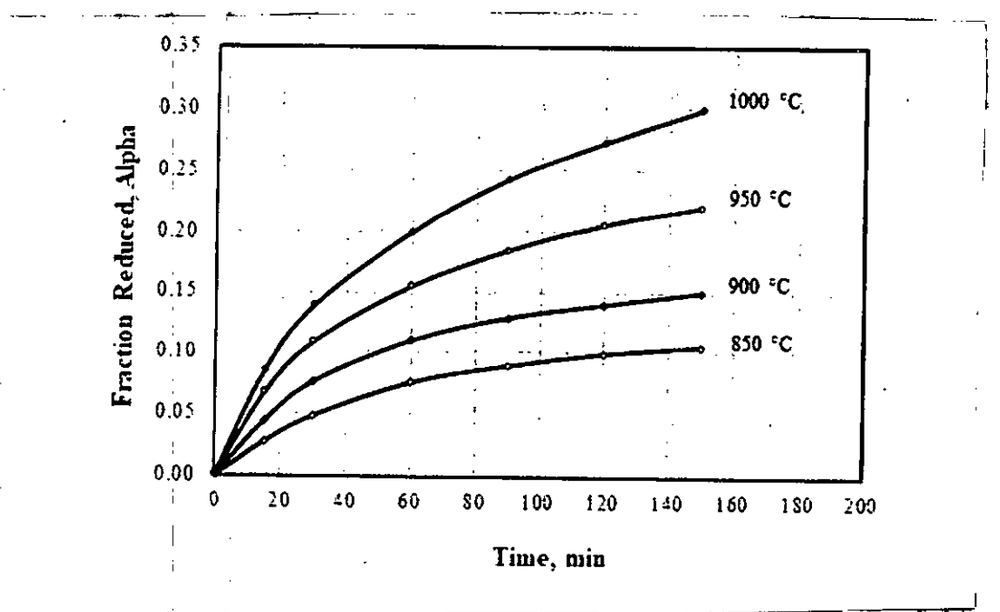


Fig. 1 for Question 5(e)