First Semester Examination
2020/2021 Academic Session

February 2021

KIT 257 – Materials Chemistry
[Kimia Bahan]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **NINE (9)** pages of printed material before you begin the examination.

Instructions:

Part A: Answer **ALL** questions.

Part B: Answer any **TWO (2)** questions.

Answer each question on a new page.

If a candidate answers more than five questions, only the answers to the first five questions in the answer sheet will be graded.

Part A: Answer **ALL** questions.

1. (a) Determine the indices for planes a, b and c as well as directions A, B and C as shown in Fig. 1.

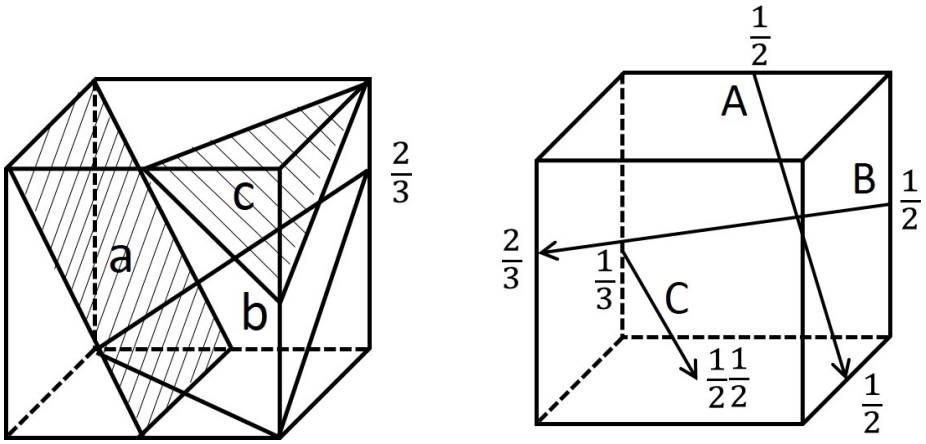

Fig. 1: Unit cells

(9 marks)

(b) Draw a cubic unit cell and sketch the following within the cell:

(i) Planes of $(30\bar{1})$ and (211)

(ii) Directions of $[\bar{3}11]$ and $[4\bar{2}1]$

(6 marks)

(c) Define family of planes.

(1 mark)

(d) Aluminium and iron have face centered cubic (FCC) and body centered cubic (BCC) structures, respectively. Explain why aluminium is more ductile than iron.

(4 marks)

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2. (a) Consider the ternary phase diagram of stainless steel at 900 °C as shown in Fig. 2. State the phase and mass fraction of A. If 2.5 kg of stainless steel is melted at 900 °C, determine the mass (in kg) of Fe, Ni and Cr formed.

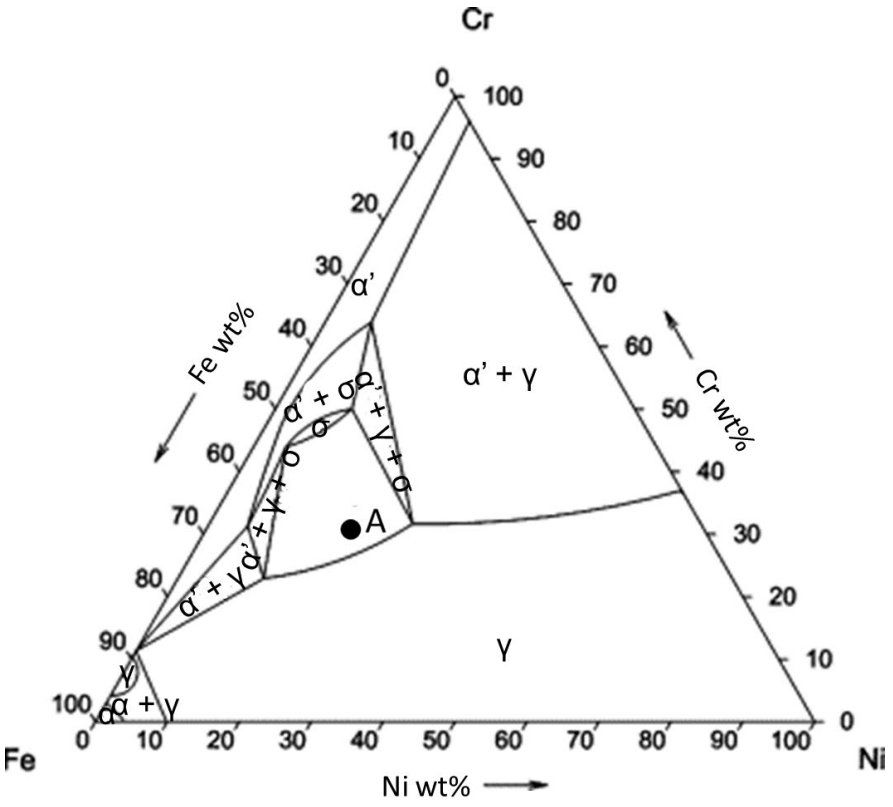

Fig. 2: Ternary phase diagram of stainless steel at 900 °C

(8 marks)

(b) As much as 5.0 kg of austenite containing 0.65 wt % of C is cooled to below 727 °C. Based on the Fe-C phase diagram shown in Fig. 3,

(i) explain the term pro-eutectoid phase. Write the equilibrium reaction at the eutectoid temperature.

(ii) determine the mass (in kg) of ferrite and cementite formed.

(iii) determine the mass (in kg) of perlite and pro-eutectoid phase formed.

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(iv) draw the microstructures of hypoeutectoid and hypereutectoid. Discuss the differences.

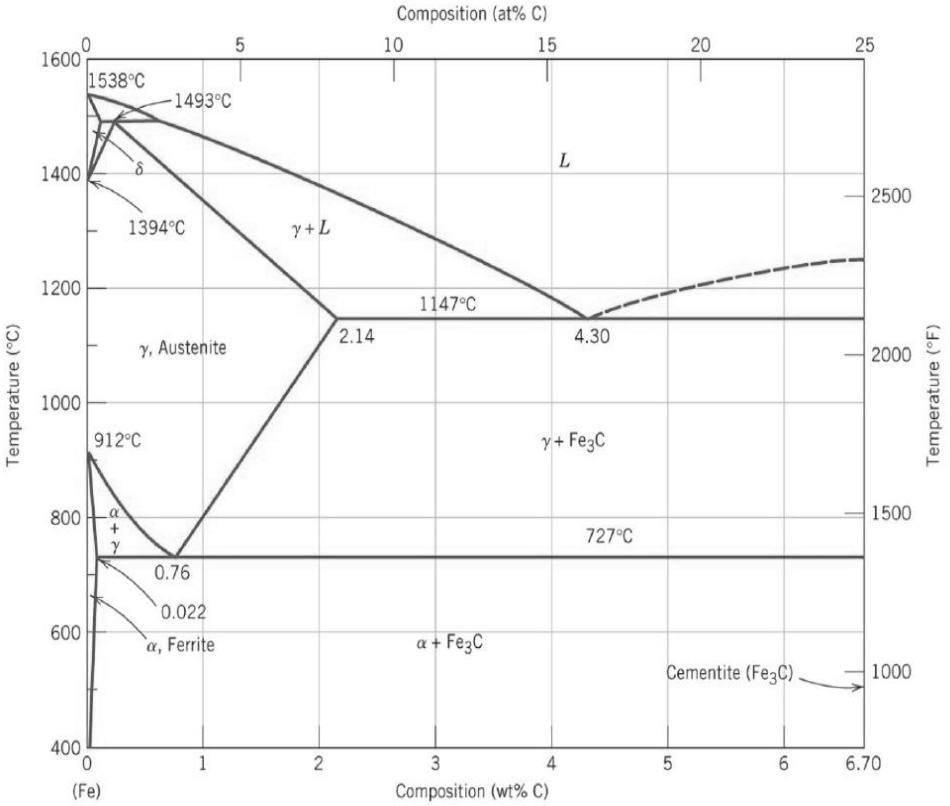

Fig. 3: The phase diagram of Fe-C metal

(12 marks)

3. (a) Describe the difference between thermoplastic and thermosetting polymers.

(4 marks)

(b) An alternating copolymer is known to have a number average molecular weight of 100,000 g mol^{-1} and a degree of polymerization of 2210. If one of the repeating units is vinyl chloride (62.49 g mol^{-1}), determine which monomer is another repeating unit. Explain your answer.

[Styrene: 104.15 g mol^{-1}; Tetrafluoroethylene: 100.02 g mol^{-1}; Ethylene: 28.05 g mol^{-1}; Propylene: 42.08 g mol^{-1}]

(6 marks)

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(c) Fig. 4 shows the dimension of a hollow (open end) carbon steel pipeline.

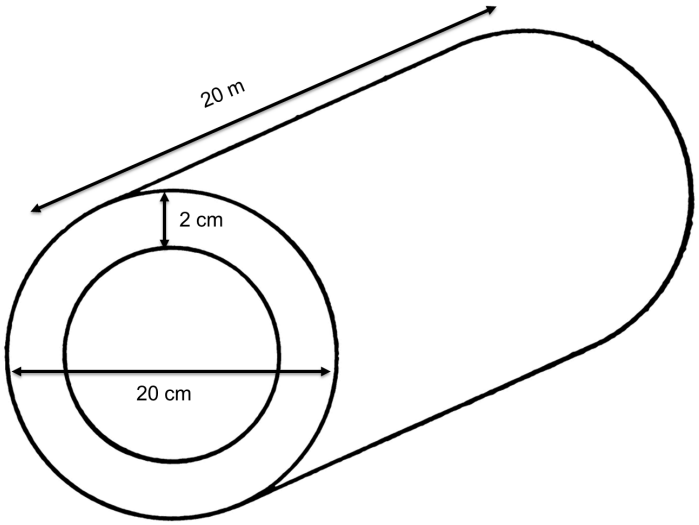

Fig. 4: The dimension of carbon steel pipeline

The carbon steel pipeline is used to transport sour crude oil that contains 3.14% (31,400 ppm) of corrosive hydrogen sulfide, H_2S. After 3 months, it is removed for maintenance check. It is observed that the carbon steel pipeline produced a weight loss of 5.2 g. By using Faraday's law, predict the corrosion rate (mmpy) of carbon steel pipeline.

[Molar mass of Fe is 55.85 g mol^{-1}, valency of Fe is 2, Faraday constant is 96 500 C mol^{-1}, density of Fe is 7.85 g cm^{-3} and circumference formula is $2\pi r$]

(10 marks)

Part B: Answer any **TWO (2)** questions.

4. (a) Given the following information about ceramics:

Ceramics	Ions	Atomic Mass ($g\ mol^{-1}$)	Ionic Radius (nm)	Electronegativity (χ_p)
X	Cation	9.01	0.045	1.57
	Anion	32.07	0.184	2.58
Y	Cation	24.31	0.072	1.31
	Anion	16.00	0.140	3.44

(i) Identify the ceramic that exhibits primarily covalent bonding. Explain your answer.

(ii) Determine the density of both ceramics in the unit of $g\ cm^{-3}$.

(iii) Explain the main reason that causes huge difference in the densities of both ceramics.

(12 marks)

(b) A copper wire is stretched with a stress of 70 MPa at 20 °C. If the length is held constant, suggest a temperature in which the wire has to be heated to reduce the stress to 35 MPa. Explain.

[Modulus of elasticity for copper is 100 GPa and linear coefficient is 20 x 10^{-6} $°C^{-1}$]

(8 marks)

5. (a) Aluminium has a FCC structure and an atomic radius of 0.143 nm.

(i) Calculate its planar density in (100), (110) and (111) planes.

(ii) Explain which plane would be the most possible slip plane when shear stress is applied.

(8 marks)

(b) Rank the following samples in order of increasing self-diffusion coefficients and justify your answer.

Sample A: Aluminium single crystal.

Sample B: Polycrystalline aluminium with average grain size of 5 μm.

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Sample C: Polycrystalline aluminium with average grain size of 10 μm.

(4 marks)

(c) Explain the functions of matrix and reinforcement phase in a composite material.

(4 marks)

(d) Briefly discuss the factors that influence the mechanical properties of a fiber reinforced composite.

(4 marks)

6. (a) Define the term 'Schottky defect' and 'Frenkel defect', respectively.

(2 marks)

(b) Suppose that CaO is added as an impurity to Li_2O, determine

(i) the kind of vacancies expected to form, if the Ca^{2+} substitutes for Li^{+}.

(ii) the amount of these vacancies created for every Ca^{2+} added.

(4 marks)

(c) As much as 10^{17} cm^{-3} of boron atoms is added to high-purity silicon as shown in Fig. 5.

(i) Explain if this material is n-type or p-type.

(ii) Predict if the material has electrical conductivity at 300 K. $|e|$ is equal to 1.6×10^{-19} C

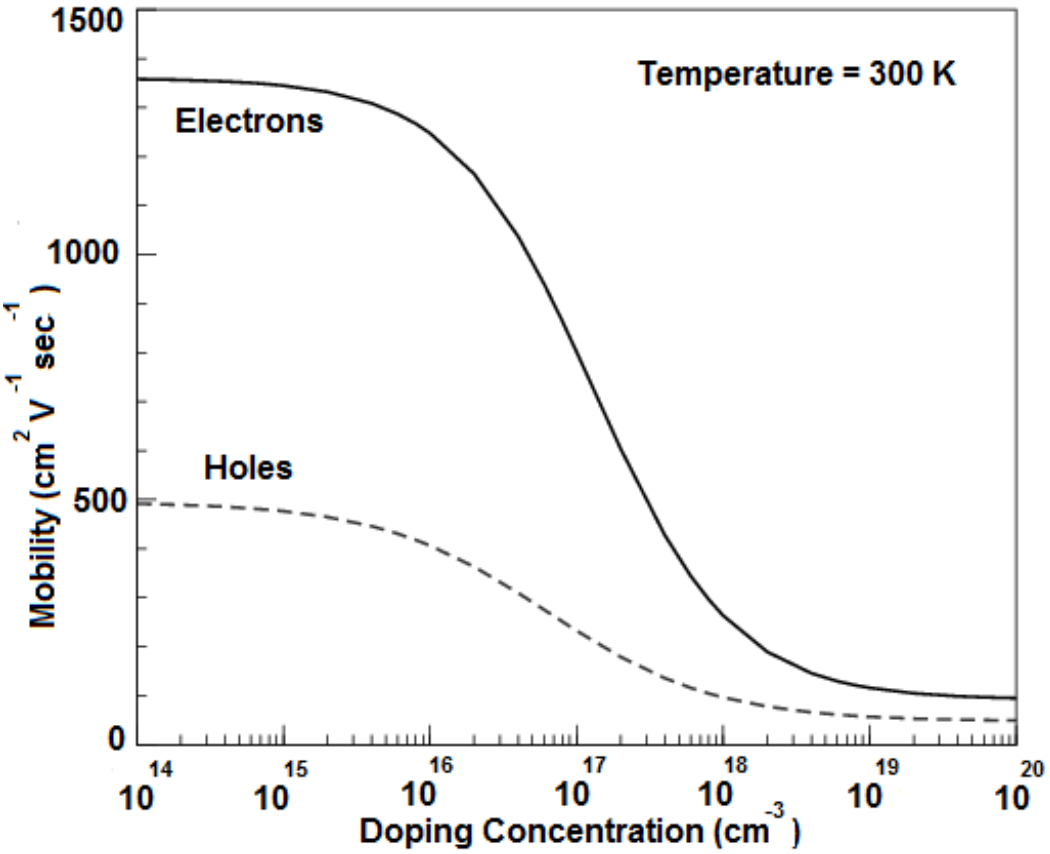

Fig. 5: Mobility versus doping concentration of boron atoms

(8 marks)

(d) Differentiate between diamagnetism and paramagnetism materials.

(6 marks)

7. (a) Fig. 6 shows a tensile stress-strain behaviour of cylindrical stainless steel SS318 with a diameter of 9.0 mm and initial length of 310 mm. Discuss the difference in the mechanical properties of SS318 to that of SS316 in terms of their; ultimate tensile strength, Young's Modulus and yield strength at strain offset of 0.002. The ultimate tensile strength, Young's Modulus and yield strength at strain 0.002 offset of SS316 with similar dimensions are 45 MPa, 10 GPa and 27 MPa, respectively. Then, predict the maximum load that can be sustained by stainless steel SS318.

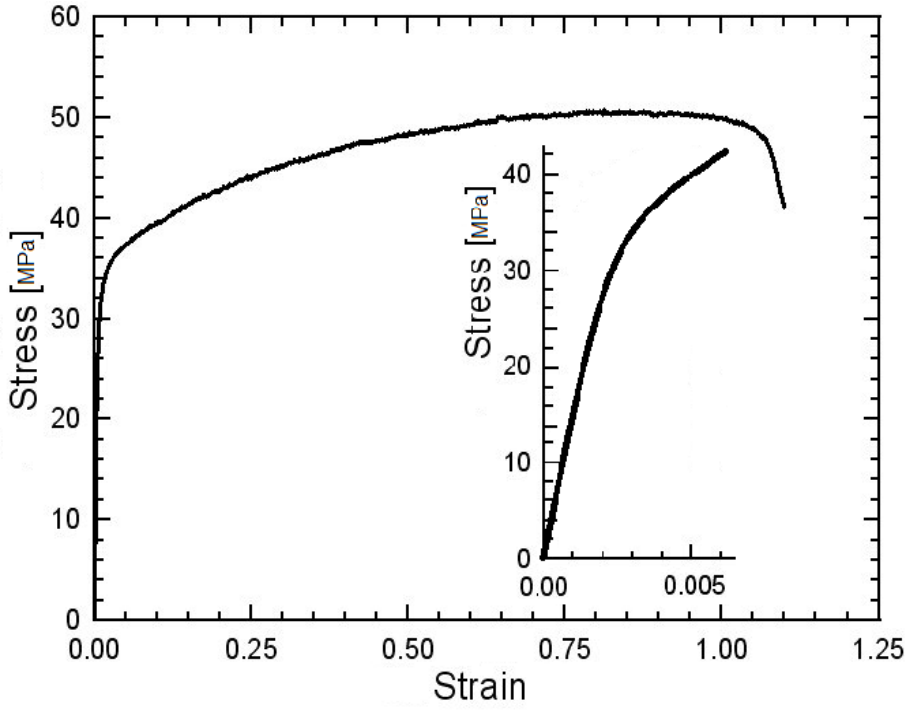

Fig. 6: The tensile stress-strain curve of cylindrical stainless steel SS318

(10 marks)

(b) Briefly discuss the differences between phosphorescence and fluorescence

(6 marks)

(c) Define ferroelectric and piezoelectric materials.

(4 marks)

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