Second Semester Examination
2020/2021 Academic Session

July 2021

KIE458 – Selected Topics in Industrial Chemistry

Duration : 2 hours

Please check that this examination paper consists of **SIX (6)** pages of printed material before you begin the examination.

Answer **ALL** questions from **Part A** and **ONE (1)** question from **Part B**.

Answer each question on a new page.

You may answer the questions either in English or in Bahasa Malaysia.

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

…2/-

Part A
Answer **ALL** questions.

1. (a) A researcher conducting a heterogeneous catalytic study for the reduction of p-nitrophenol to p-aminophenol using silver (Ag) supported porous silicon catalysts decided to fabricate porous silicon from a piece of silicon wafer. Compare the benefits of fabricating the porous silicon for this purpose, using the metal assisted etching method over the double cell electrochemical method.

(10 marks)

(b) The quantum confinement effect is one of the characteristics of porous silicon. It causes a change in the optical and electrical properties of bulk silicon. It is exhibited by quantum dots.

(i) With the aid of illustrations, compare the band gap theory of bulk silicon and quantum dots.

(ii) Explain the changes in the optical properties of quantum dots.

(10 marks)

(c) Describe the divalent mechanism for the anodic etching of porous silicon

(5 marks)

2. (a) ViscoLigno and LignoPEX are two drilling additives developed at the School of Chemical Sciences, Universiti Sains Malaysia. Each has its unique functions. Describe **FIVE** similarities and **FIVE** differences between these two products.

(10 marks)

(b) Below are the rheometer readings for the mud formulations used in three different well conditions. Based on these readings, suggest the suitable additive(s) *i.e.* ViscoLigno or/and LignoPEX, that can be used to improve the performance of the mud formulation in its respective well.

		Well A		Well B		Well C	
Equipment	Parameter	Readings		Readings		Readings	
Rolling oven	200 °C	Before	After	Before	After	Before	After
Fann Viscometer	600	54	44	32	13	44	40
	300	42	29	23	8	34	32
	200	32	21	19	6	29	27
	100	26	16	14	4	23	20
	6	12	7	8	1	11	10
	3	10	4	6	1	7	7
pH		10	9	10	9	10	9
API Filter Press	30 min	7 ml	10 ml	13 ml	26 ml	12 ml	25 ml
	60 min	9 ml	13 ml	23 ml	28 ml	20 ml	27 ml

(10 marks)

(c) Mud balance is one of the most important equipment for mud engineers in the field.

(i) State the function of mud balance.

(ii) Explain how the mud engineer adjusts the properties of the mud based on the result obtained.

(5 marks)

3. (a) Discuss the main difference between a fuel cell and a battery.

(4 marks)

(b) The following reactions are involved in a fuel cell (Reaction 1) and a nickel metal hydride battery (Reaction 2), respectively. You would like to identify which cells can perform more work per unit mass.

Reaction 1: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $E_{cell} = 1.23$ V

Reaction 2: $MH(s) + NiO(OH)(s) \rightarrow M(s) + Ni(OH)_2(s)$ $E_{cell} = 1.40$ V

(i) In each cell, determine the moles of electrons transferred and ΔG.

(ii) Evaluate which cells can perform more work (W_{max}) per unit mass.

(iii) Explain your answer in (ii).

[Faraday constant: 96458 C mol^{-1} e; atomic masses for H: 1.008 g mol^{-1}, O: 16.00 g mol^{-1}, Ni: 58.69 g mol^{-1}, M: 72.06 g mol^{-1}. Note: For simplicity, ignore the masses of cell components that do not appear in the cell as reactants, including electrode, electrolyte, cell casing, etc]

(8 marks)

(c) A company employed a solid oxide fuel cell (SOFC) for large scale and continuous power generation at 500 °C, using syn gas ($CO + H_2$) as a fuel for the process.

(i) Explain in detail why polymer electrolyte membrane fuel cell (PEMFC) is not suitable for the same application.

(ii) Compare the half-reactions that happen on the cathode and anode of SOFC with those in PEMFC if only H_2 is used as a fuel.

(8 marks)

(d) Mass transport is one of the main barriers in solid-solid interactions. For instance, the interaction of $LiNH_2$ and LiH requires high temperature for dehydrogenation to occur.

$$LiNH_2(s) + LiH(s) \leftrightarrow Li_2NH(s) + H_2(g)$$

(i) Propose one approach that can be used to reduce such barrier.

(ii) Explain how this approach helps to reduce the barrier.

(5 marks)

Part B
Choose **ONE(1)** question.

4. (a) In a laboratory, a piece of Boron - doped silicon wafer was immersed in an electrolyte containing HF. The wafer was then subjected to a Xe light source to fabricate porous silicon.

(i) Name the possible methods the scientist could have used in the preparation of the porous silicon.

(ii) Briefly describe the conditions of the photon energy source which could promote continuous porosification and dissolution of the porous silicon layer respectively.

(8 marks)

(b) (i) Describe any chemistry-based experiment/testing/procedure that you had performed before.

(ii) Propose how you are going to perform the same experiment /testing/procedure using the Taguchi Orthogonal Array L_9 (4 factors and 3 levels).

(8 marks)

(c) Conventionally, hydrogen is produced in large scale via methane steam reforming, followed by water gas shift reaction. Upon production, a mixture of gaseous products is obtained. In order to obtain high purity hydrogen gas, a separation process is needed.

(i) Write the equations involved in the hydrogen production process as described above.

(ii) Propose a separation technology.

(iii) Briefly explain the working principle of the separation technology mentioned in (ii).

(9 marks)

5. (a) Compound semiconductors and extrinsic semiconductors are two different categories of semiconductors.

(i) With examples, distinguish the difference between compound and extrinsic semiconductors.

(ii) Briefly explain with an example how a compound semiconductor can be an extrinsic semiconductor.

(8 marks)

(b) Sketch the following:

(i) gas density for volatile oil (density vs P)
(ii) phase diagram for wet gas (P vs T)
(iii) phase diagram for black oil (P vs T)

(9 marks)

(c) Ethylene oxide is an important feedstock in many chemical syntheses and is produced in large volumes. Two possible routes for the manufacturing of ethylene oxide (C_2H_4O) are (1) two-step process involving epoxidation of ethylene to form chorohydrin as intermediate and followed by interaction with $Ca(OH)_2$, (2) direct oxidation of ethylene using silver as catalyst. You are in-charge of the manufacturing process in the company. As an industrial chemist that understands the green chemistry principles,

(i) compare which route is greener.
(ii) Explain your answer in detail.

Route 1: $C_2H_4 + Cl_2 + H_2O \longrightarrow HOCH_2CH_2Cl + HCl$

$2HOCH_2CH_2Cl + Ca(OH)_2 \longrightarrow 2C_2H_4O + CaCl_2 + H_2O$

Route 2: $C_2H_4 + ½\ O_2 \xrightarrow[\text{Ag catalyst}]{} C_2H_4O$

(8 marks)