Ollscoil *na* hÉireann, Gaillimh
National University of Ireland, Galway

SUMMER EXAMINATIONS 1999

FIRST YEAR ENGINEERING

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Time allowed: Three Hours
Answer Five questions

Answer five questions of which not more than two may be chosen from any one section. All questions carry equal marks.

Section A

1. Explain what is meant by *each* of the following terms:

- Function of State
- Average Bond Dissociation Energy
- Entropy

Methanol (CH_3OH) is an industrially important material which is produced using the following high temperature, high pressure reaction:

$$CO(g) + 2H_2(g) \longrightarrow CH_3OH(g)$$

A company wishes to explore the possibility of manufacturing methanol using an alternative process:

$$CH_4(g) + \tfrac{1}{2} O_2(g) \longrightarrow CH_3OH(g)$$

(a) Use the data provided below to determine $\Delta H°$, $\Delta S°$ and $\Delta G°$ for both processes, and the temperature at which each becomes spontaneous.

(b) Are the calculated entropy changes in line with what you would expect for each reaction? Explain your answer.

(c) Which process in thermodynamically preferred? Explain your answer.

	$\Delta H°_f$ (kJ mol^{-1})	$S°$ (J mol^{-1} K^{-1})
$CO(g)$	–110.5	197.6
$CH_3OH(g)$	–200.7	239.7
$CH_4(g)$	–74.8	186.1
$O_2(g)$	–	205.0
$H_2(g)$	–	130.6

2 (a) Nitric oxide (NO) is an important pollutant in air and is formed by the high temperature reaction of nitrogen and oxygen in the engine of a car:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

At 2000°C the equilibrium constant for the reaction is 0.1. If the initial concentrations of N_2 and O_2 are 0.81 mol l^{-1} determine the equilibrium concentrations of NO, N_2 and O_2.

(b) Sodium carbonate is an important industrial chemical and is manufactured using the two-step Solvay process:

$$CO_2(g) + H_2O + NH_3(g) + NaCl \longrightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O$$

(i) What weight of NH_4Cl would be produced in processing $1m^3$ of $CO_2(g)$ at STP? ($1m^3$ = 1000 litres).

(ii) What volume of NH_3 (g) at STP would be required to process this amount of CO_2?

(iii) What weight of Na_2CO_3 would be produced from this amount of CO_2?

3. Draw a phase diagram for water (triple point: 0.01°C and 0.006 atm) and use it to answer the following questions:

(i) What happens when a sample of ice at –5°C is heated to 120°C at 1 atm?

(ii) What happens when steam at 200° is cooled to –20° at 2 atm?

(iii) Explain how a pressure cooler works.

(iv) A compound X has a triple point at 6.0atm and 4°C but gives a phase diagram which is otherwise very similar to that of water. If samples of solid X and ice are heated at 1 atm pressure, what differences in behavior would you observe?
Include a sketch of the phase diagram of X in your answer.

(v) Based on your phase diagram for water, explain why changes in pressure have a major effect on its boiling point but little effect on its melting point.

4. (i) Explain what is meant by a micelle, and how it relates to the way a soap or a detergent works.

(ii) Outline the factors that effect the rate of a reaction and use an activation energy (transition state) diagram to explain how any two of them achieve this.

(iii) Use diagrams to explain the difference between a $2p_x$ and a 3s orbital.

(iv) Explain how the Bohr picture of the atom accounts for the phenomenon of spectra.

Section B

5. Give an account of how the refractory material periclase (MgO) can be manufactured using seawater as a source of magnesium.

6. Describe in detail all three types of **intramolecular** bond, giving examples of each type and listing them in order of increasing strength. What type of **intramolecular** bonding occurs in each of the following:

$$H_2O(l),\ \ CO_2(s),\ \ N_2(l),\ \ O_2(g)$$

7. Magnesium metal can be manufactured by the electrolysis of molten magnesium chloride.

(i) Draw a simple diagram showing how this might be done and write down equations for the reactions occurring at the two electrodes and for the overall reaction.

(ii) The electrolysis is a redox reaction. Explain what is meant by this term and identify what is being reduced and what oxidised. Does this make sense in terms of the electronic structure of the atoms involved? Explain your answer.

(iii) What mass of magnesium and what volume of chlorine gas (STP) would be produced by a current of 10A flowing for 50 minutes? (1F = 96, 500C)

Section C

8. In the case of each of the following functional groups:

alcohol, carboxylic acid, alkane, aldehyde

(a) Draw the structure of a molecule containing the functional group.

(b) Give **one** typical reaction for each of these molecules.

(c) Suggest a method by which each molecule might be prepared.

(d) Provide a simple mechanism for **any two** of the reactions you have outlined in (b) and (c).

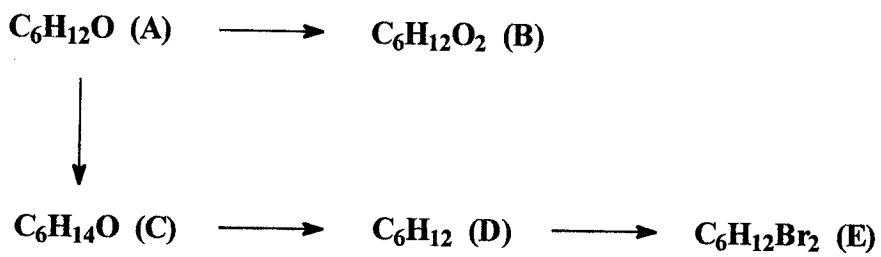
9. (i) Draw structures for the five structural isomers of C_6H_{14} (hexane) and provide a systematic name for **one** of them.

(ii) Explain, with respect to the reaction of chlorine gas and methane gas, what is meant by a photochemical free-radical substitution reaction.

(iii) Explain how hybridization accounts for the structure of ethene.

(iv) Explain, using an example, what is meant by a Grignard reaction.

10.



A: This molecule contains a straight chain of carbon atoms with a functional group at one end. It gives a yellow precipitate with 2,4-dinitrophenylhydrazone.

B: This turns blue litmus red.

C: This produces hydrogen gas when sodium metal is added.

(i) Provide structures for compounds (A) to (E). The functional group should be named and clearly labeled in each case.

(ii) Suggest reagents which could be used to carry out each of these transformations.

(iii) Provide a simple mechanism for the conversion of (C) to (D).