

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Level Examination



APPLIED SCIENCE
Unit 11 Controlling Chemical Processes

SC11

Thursday 14 June 2007 9.00 am to 10.30 am

For this paper you must have:

- a pencil and a ruler
- a calculator.

Time allowed: 1 hour 30 minutes

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.

Information

- The maximum mark for this paper is 80.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.

For Examiner's Use			
Question	Mark	Question	Mark
1		5	
2			
3			
4			
Total (Column 1) →			
Total (Column 2) →			
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Examiner's Initials			

Answer **all** questions in the spaces provided.

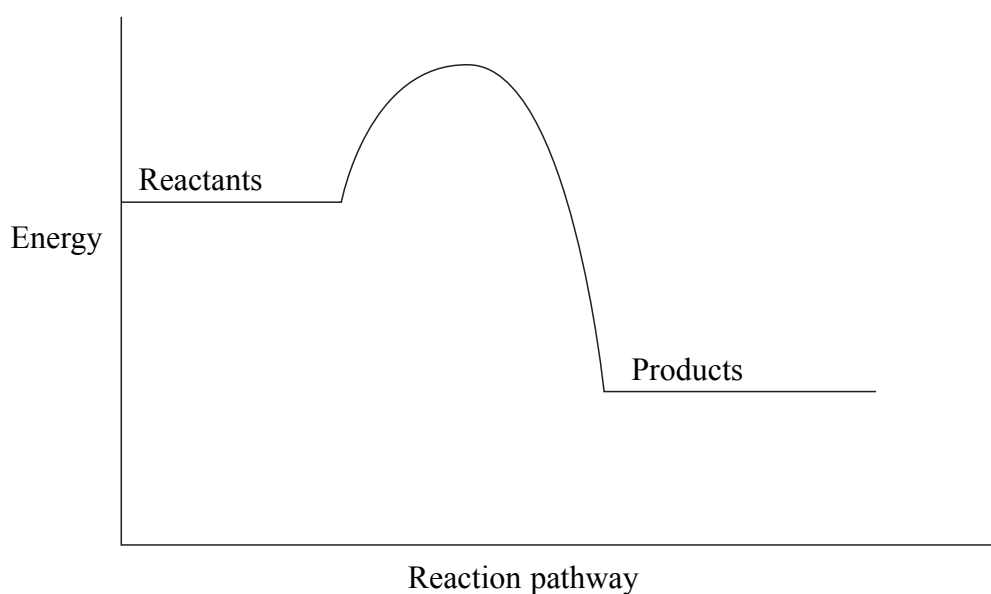
1 Catalysts play an important role in industrial chemical reactions.

(a) Define the term *catalyst*.

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(2 marks)

(b) The reaction profile for a reaction is shown below.



(i) State whether the reaction is exothermic or endothermic. Explain your answer.

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(1 mark)

(ii) On the diagram above sketch the reaction pathway for the same reaction when a catalyst is used.

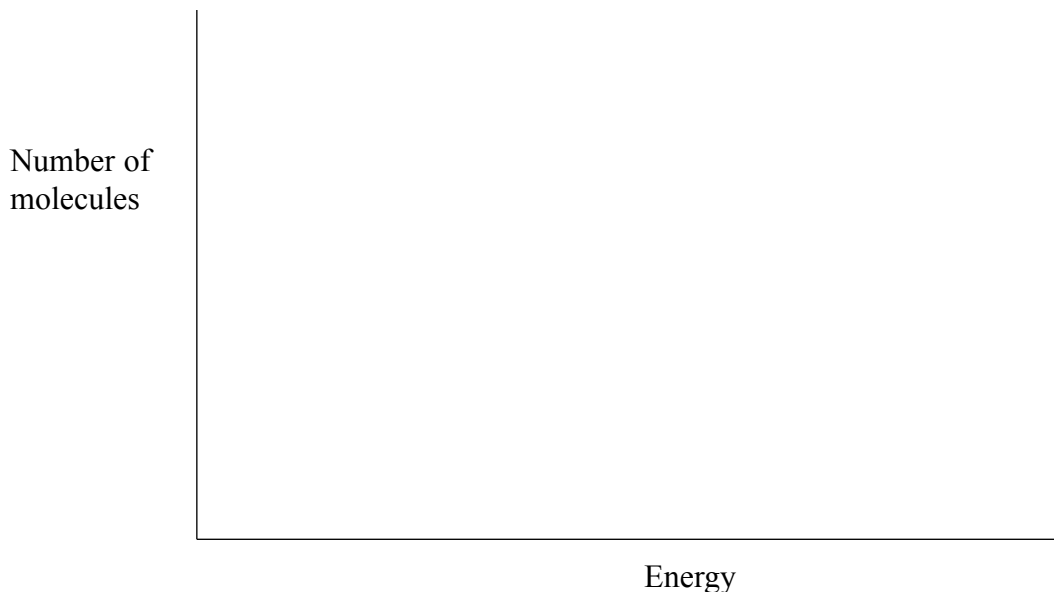
(2 marks)

(c) Define the term activation energy, E_a .

.....

(2 marks)

- (d) (i) On the axes below sketch a curve to show the distribution of the molecular energies for the molecules in a gas.



(3 marks)

- (ii) On the energy axis, indicate the activation energy without a catalyst, E_a , and with a catalyst $E_a(\text{cat})$. (2 marks)
- (iii) Use the curve that you have drawn to explain how the use of a catalyst affects the rate of a chemical reaction.

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(2 marks)

Turn over for the next question

2 Hydrogen, chlorine and sodium hydroxide can be made at the same time from concentrated brine (sodium chloride solution).

(a) Name the process used.
(1 mark)

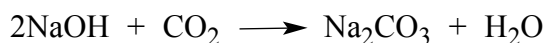
(b) Hydrogen is a highly flammable gas and chlorine is a poisonous gas.
For each of these gases, give **one** safety precaution that workers should take when working with them.

Hydrogen

Chlorine
(2 marks)

(c) One use of sodium hydroxide is in the manufacture of sodium carbonate, which is used in glass-making and as a water softener.

The reaction for the manufacture of sodium carbonate can be represented as follows:



In this reaction the yield of product is only 70% of the maximum possible.

(i) Calculate the relative formula masses of NaOH and Na₂CO₃.
(Relative atomic masses: Na = 23, O = 16, C = 12, H = 1)

M_r NaOH

M_r Na₂CO₃
(2 marks)

(ii) Use your answers in part (c)(i) and the equation for the reaction to calculate the mass of Na₂CO₃ that is made from 100 kg of NaOH when the yield is 70%.

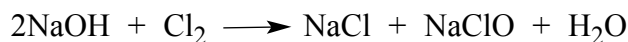
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(3 marks)

- (d) Sodium hydroxide also reacts with chlorine under different conditions to form two different products.

With cold, dilute sodium hydroxide:



NaClO is used as bleach.

With hot, concentrated sodium hydroxide:



NaClO₃ is used as a weed killer.

Given that the oxidation number of oxygen is -2 and that the oxidation number of sodium is +1, calculate the oxidation number of chlorine in:

NaClO

NaClO₃.

(2 marks)

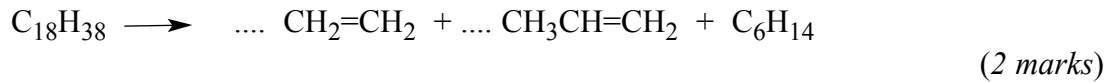
- (e) State **one** hazard associated with concentrated sodium hydroxide.

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(1 mark)

Turn over for the next question

- 3 Crude oil is a mixture of hydrocarbons. Some of these hydrocarbons are long chain molecules that only have a few uses. These hydrocarbons are cracked (broken down) at high temperatures to produce shorter chained products that are more useful. One of these products is ethene, $\text{CH}_2=\text{CH}_2$.

- (a) Balance the equation for the following cracking reaction.

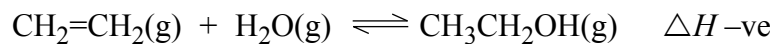


- (b) Give **one** direct and **one** indirect cost associated with cracking reactions.

Direct cost

Indirect cost (2 marks)

- (c) Ethene is used in the manufacture of ethanol, $\text{CH}_3\text{CH}_2\text{OH}$. Ethene and steam are passed over a heated catalyst.



The reaction is an example of a dynamic chemical equilibrium.

- (i) Explain the meaning of the term *dynamic equilibrium*.

.....
..... (2 marks)

- (ii) The reaction is a homogeneous equilibrium reaction. Explain the meaning of the term *homogeneous*.

.....
..... (2 marks)

- (iii) The reaction is exothermic. Suggest a use for the heat energy released in the reaction.

..... (1 mark)

- (iv) State and explain the effect on the yield of ethanol in the equilibrium reaction when the temperature is increased.

Effect on yield of ethanol

Explanation

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(3 marks)

- (d) The manufacture of ethanol from ethene and steam is an example of a continuous process.

- (i) Explain the difference between a continuous process and a batch process.

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(2 marks)

- (ii) Give **one** advantage and **one** disadvantage of each process.

	Continuous process	Batch process
Advantage
Disadvantage

(4 marks)

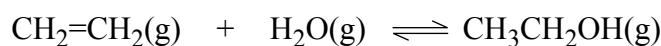
Question 3 continues on the next page

Turn over ►

- (e) The enthalpy change for reactions can be calculated using standard enthalpies of formation.

Use the following enthalpy of formation data to calculate the enthalpy change for the reaction which makes ethanol from ethene.

	CH ₂ =CH ₂ (g)	H ₂ O(g)	CH ₃ CH ₂ OH(g)
Standard enthalpy of formation $\Delta H_f/\text{kJ mol}^{-1}$	+52.3	-242	-235



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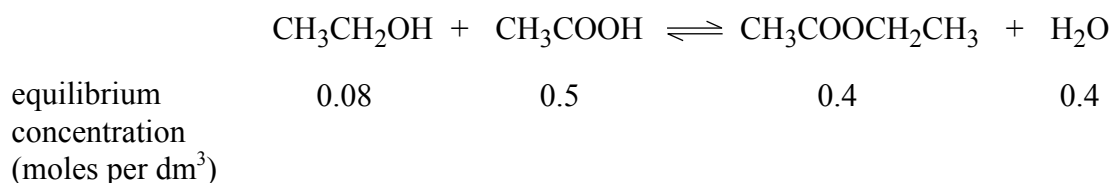
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(4 marks)

- (f) Ethanol is used to make ethyl ethanoate, which is used widely as a solvent. The reaction is an equilibrium reaction.

Some ethanol and ethanoic acid were mixed and allowed to reach equilibrium. The equation for the reaction and the concentrations of the reactants and products at equilibrium are shown below.



- (i) Write an expression for the equilibrium constant, K_c , for this reaction and use the data to calculate the value of K_c .

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(4 marks)

- (ii) Suggest **one** change in the conditions of the equilibrium that would change the value of K_c .

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(1 mark)

27

Turn over for the next question

Turn over ▶

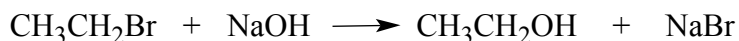
4 The measurement of the rate of a reaction can be used to find the order of reaction.

(a) Explain what is meant by the term *rate of reaction*.

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(2 marks)

(b) Ethanol can be made by the reaction of bromoethane with sodium hydroxide solution:



The rate of this reaction can be determined by measuring the change in concentration of sodium hydroxide.

The concentration of sodium hydroxide can be calculated from its pH value or by titration with an acid.

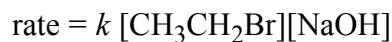
Outline a method that you could use to show that the order of reaction with respect to sodium hydroxide is first order.

Show how you would use the results to find the order.

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(7 marks)

- (c) The rate equation for the reaction is:



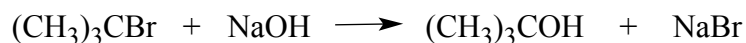
What effect will doubling the concentration of both $\text{CH}_3\text{CH}_2\text{Br}$ and NaOH have on the rate of the reaction? Explain your answer.

Effect on rate

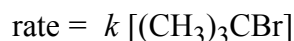
Explanation

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(2 marks)

- (d) In a different reaction involving $(\text{CH}_3)_3\text{CBr}$:



the rate equation for the reaction is:



- (i) State the overall order for this reaction.
(1 mark)

- (ii) What will be the effect of doubling the concentration of NaOH on the rate of this reaction? Explain your answer.

Effect on rate

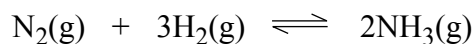
Explanation

(2 marks)

Turn over for the next question

Turn over ▶

- 5 Ammonia is manufactured from nitrogen and hydrogen in an equilibrium reaction.



The pressure normally used in this reaction is over 200 atmospheres.
Chemical engineers have developed a new catalyst for this reaction which allows the ammonia plant to be run at about 100 atmospheres pressure.
This makes the manufacturing process less expensive.

- (a) Give an example of **one** capital cost and **one** direct cost that is reduced by operating the plant at a lower pressure.

Capital cost

Direct cost

(2 marks)

- (b) What effect will using a lower pressure have on the yield of ammonia in this equilibrium reaction? Explain your answer.

Effect

Explanation

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(3 marks)

- (c) What effect will using a higher pressure have on the rate of reaction in this equilibrium reaction? Explain your answer.

Effect

Explanation

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(3 marks)

- (d) What effect would using a different catalyst have on the yield of ammonia in this equilibrium reaction? Explain your answer.

Effect

Explanation

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(3 marks)

- (e) Ammonia is used to make ammonium nitrate, NH_4NO_3 , which is used as a nitrogenous fertiliser.

Calculate the percentage mass of nitrogen in ammonium nitrate.

(Relative atomic masses: O=16, N=14, H=1)

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(3 marks)

END OF QUESTIONS

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