| Centre Number | | | | | | Candidate Number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Surname | | | | | | | | | | |
| Other Names | | | | | | | | | | |
| Candidate Signature | | | | | | | | | | |

| For Examiner's Use | |
|---|---|
| Examiner's Initials | |
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| TOTAL | |

General Certificate of Education
Advanced Level Examination
June 2012

# Applied Science SC11

## Unit 11 Controlling Chemical Processes

**Monday 11 June 2012 1.30 pm to 3.00 pm**

**For this paper you must have:**
- a pencil
- a ruler
- a calculator.

**Time allowed**
- 1 hour 30 minutes

**Instructions**
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.

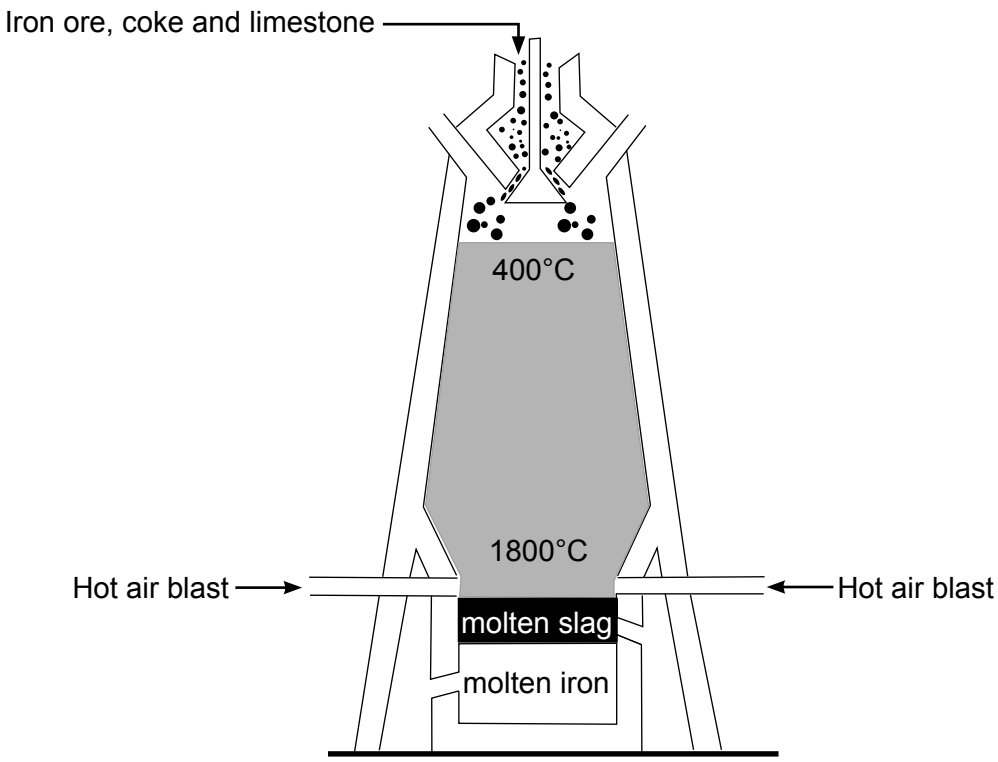
**Information**
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.
- You will be marked on your ability to
  - use good English
  - organise information clearly
  - use specialist vocabulary where appropriate.
- You are expected to use a calculator where appropriate.

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

**1** Metals are extracted industrially from their ores. Iron is produced in a blast furnace, as shown in **Figure 1**. Chemical engineers attempt to minimise costs while maintaining the purity of the product.

The raw materials used are iron ore (which contains iron oxide, $Fe_2O_3$), coke (mostly carbon) and limestone (calcium carbonate, $CaCO_3$).

**Figure 1**




**1 (a)** Costs involved in industrial processes can be classified as:

**capital costs, indirect costs, direct costs**

**1 (a) (i)** Classify each of the following as **one** of the above costs.

Construction of the furnace .....

Cost of iron ore .....

Salaries of sales force .....

*(3 marks)*

**1 (a) (ii)** Define the term *indirect cost.*

.....

.....

.....

.....

*(2 marks)*

**1 (b)** Extraction methods can involve batch processes or continuous processes.

**1 (b) (i)** What is meant by a *batch process?*

.....

.....

.....

.....

*(2 marks)*

**1 (b) (ii)** Give **two** advantages, other than cost, of a continuous process compared with a batch process.

Advantage 1.....

.....

Advantage 2.....

.....

*(2 marks)*

**Question 1 continues on the next page**

**1 (c)** Iron oxide is reduced to iron in the blast furnace:

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

**1 (c) (i)** What is meant by *reduced*?

.....

.....

*(1 mark)*

**1 (c) (ii)** Calculate the relative molecular mass of iron oxide, $Fe_2O_3$.
(Relative atomic masses: Fe = 56, O = 16)

.....

$M_r$ iron oxide = .....

*(1 mark)*

**1 (c) (iii)** What mass of iron oxide would be required to produce 8 tonnes of iron? Assume there is a 100% yield. (1 tonne = 1000 kg)

.....

.....

.....

.....

.....

Mass of iron oxide = .....

*(3 marks)*

**1 (d)** Limestone is used in the blast furnace to remove impurities in the iron ore.

The first stage involves the conversion of limestone to calcium oxide:

$$CaCO_3 \longrightarrow CaO + CO_2$$

**1 (d) (i)** What type of reaction is this?

.....

*(1 mark)*

The calcium oxide then reacts with the main impurity silicon dioxide, $SiO_2$, to form calcium silicate, $CaSiO_3$:

$$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$$

**1 (d) (ii)** Give the oxidation state of silicon in silicon dioxide and in calcium silicate.

Silicon dioxide, $SiO_2$ .....

Calcium silicate, $CaSiO_3$.....

*(2 marks)*

**1 (d) (iii)** Calcium silicate is less dense than iron. Use **Figure 1** on page 2 to suggest the common name for calcium silicate.

.....

*(1 mark)*

**18**

**Turn over for the next question**

**2** Crude oil provides many useful hydrocarbons. Crude oil is a finite resource so industrial chemists have developed alternative sources of hydrocarbons.

Methane is produced in the reaction between carbon monoxide and hydrogen using a nickel catalyst. A dynamic equilibrium is established:

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g) \qquad \Delta H = -205\,kJ\,mol^{-1}$$

**2 (a)** Explain what is meant by a *dynamic equilibrium*.

.....

.....

.....

.....

*(2 marks)*

**2 (b) (i)** Write an expression for the equilibrium constant, $K_c$, for this reaction.

.....

.....

.....

.....

*(2 marks)*

**2 (b) (ii)** What is the unit of this equilibrium constant?

.....

.....

*(1 mark)*

**2 (c) (i)** What effect will decreasing the temperature have on the yield of methane?

State and use Le Chatelier's principle to explain your answer.

You will be assessed on the quality of written communication in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

*(5 marks)*

**2 (c) (ii)** Use Le Chatelier's principle to decide what effect increasing the pressure will have on the yield of methane.
Explain your answer.

Effect.....

.....

Explanation .....

.....

.....

.....

*(3 marks)*

**Question 2 continues on the next page**

**2 (d) (i)** Define the term *catalyst*.

.....

.....

.....

.....

*(2 marks)*

**2 (d) (ii)** What effect will the nickel catalyst have on the yield of methane? Explain why.

Effect.....

.....

Explanation .....

.....

.....

.....

*(3 marks)*

**18**

**3** Research chemists try to find innovative synthesis reactions that use low-cost starting materials and give good yields of the required substance.

Chloroethene (or vinyl chloride), $C_2H_3Cl$, is used to manufacture the polymer polyvinylchloride, PVC.

Chloroethene can be produced using the reaction of ethyne, $C_2H_2$, with hydrogen chloride:

$$HCl(g) + C_2H_2(g) \longrightarrow C_2H_3Cl(g)$$

ethyne — chloroethene

The product is very pure and the yield is high.

**3 (a)** Research chemists must consider the hazards of reactants and products. Ethyne is highly flammable and chloroethene is thought to cause cancer.
Suggest an appropriate safety precaution when using each substance.

Ethyne.....

.....

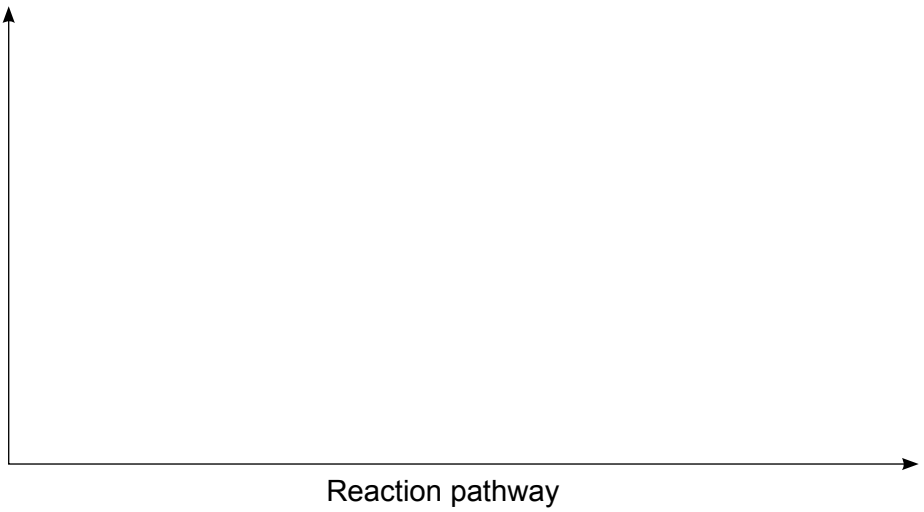
Chloroethene .....

.....

*(2 marks)*

**3 (b)** The reaction for the production of chloroethene from ethyne is exothermic.

On the axes, sketch the reaction profile for the production of chloroethene.
Add the correct label to the vertical (y) axis.




*(4 marks)*

**Question 3 continues on the next page**

**3 (c)** Use the mean bond enthalpy data in **Table 1** to calculate the enthalpy change when one mole of chloroethene is produced from ethyne:

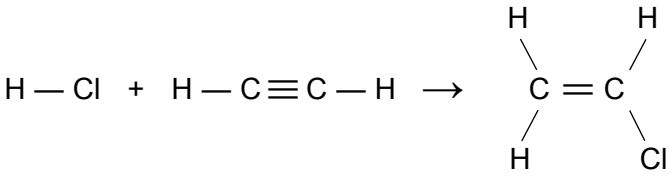


**Table 1**

| | C−Cl | C=C | C≡C | H−Cl | C−H |
|---|---|---|---|---|---|
| Mean bond enthalpy/kJ mol$^{-1}$ | 346 | 612 | 838 | 432 | 413 |

.....

.....

.....

.....

.....

.....

.....

Enthalpy change = .....

*(4 marks)*

**3 (d)** Enthalpy changes can also be calculated using enthalpy of combustion or enthalpy of formation data.
Define the term *enthalpy of combustion*.

.....

.....

.....

.....

*(2 marks)*

**3 (e)** Research chemists have tried to find new methods to manufacture chloroethene. One of the new methods uses ethene and tetrachloromethane as the starting materials:

$$4C_2H_4 + CCl_4 \longrightarrow 4C_2H_3Cl + CH_4$$

ethene + tetrachloromethane ⟶ chloroethene + methane

Use the enthalpy of combustion data in **Table 2** to calculate the enthalpy change when one mole of chloroethene is formed from ethene. You may assume that the combustion products for reactants and products in the above equation are the same.

**Table 2**

| | $C_2H_4$ | $CCl_4$ | $C_2H_3Cl$ | $CH_4$ |
|---|---|---|---|---|
| Enthalpy of combustion/kJ $mol^{-1}$ | −1410.8 | −359.9 | –1162.5 | –890.3 |

.....

.....

.....

.....

.....

.....

.....

.....

.....

Enthalpy change = .....

*(5 marks)*

17

**Turn over for the next question**

**4** Alcohols are useful as solvents.
An analytical chemist working for a solvent manufacturer has been asked to study the rate of reaction of 1-bromopropane with sodium hydroxide:

| | | | | | | |
|---|---|---|---|---|---|---|
| $CH_3CH_2CH_2Br$ | + | NaOH | $\longrightarrow$ | $CH_3CH_2CH_2OH$ | + | NaBr |
| 1-bromopropane | + | sodium hydroxide | $\longrightarrow$ | propan-1-ol | + | sodium bromide |

**4 (a)** The rate of this reaction can be determined by measuring the change in concentration of sodium hydroxide. Sodium hydroxide is an alkali.

**4 (a) (i)** The analytical chemist uses titration and not a pH meter to measure the change in concentration of sodium hydroxide.
List the apparatus the chemist uses.

.....

.....

.....

.....

.....

.....

*(3 marks)*

**4 (a) (ii)** 100 $cm^3$ of 1-bromopropane at the required temperature is added to 100 $cm^3$ of 2.0 $mol\,dm^{-3}$ sodium hydroxide which is also at the required temperature.
The reactants are stirred continuously throughout the experiment.
At set time intervals, small samples of the reaction mixture are removed and analysed by titration.

Describe how the reaction mixture would be analysed.
You will be assessed on the quality of written communication in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

*(5 marks)*

**Question 4 continues on the next page**

**4 (a) (iii)** The reaction taking place in a sample must be stopped before analysis of the sample can take place. Explain why the reaction in the sample must be stopped.

.....

.....

*(1 mark)*

**4 (a) (iv)** It is not possible to repeat each titration without starting the whole experiment again. Explain why.

.....

.....

*(1 mark)*

**4 (a) (v)** Why would repeat results be desirable?

.....

.....

*(1 mark)*

**4 (b)** If the rate of any reaction is to be measured, the temperature must be controlled. Use ideas about particle kinetic theory and activation energy to explain why an increase in temperature increases the rate of a reaction.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

*(5 marks)*

**16**

**5** Industrial chemists must consider both the rate of a reaction and the position of any equilibrium that may be established if they are to produce a good yield of product in a reasonable time.
The rate equation for a reaction can only be determined by carrying out experiments in which the rate of reaction is measured.

**5 (a)** Define the term *rate of reaction*.

.....

.....

.....

.....

*(2 marks)*

**5 (b)** The reaction between iodine and propanone is:

$$CH_3COCH_3 + I_2 \longrightarrow CH_3COCH_2I + H^+ + I^-$$

propanone iodine hydrogen ion

Experiments have shown that the reaction between iodine and propanone is first order with respect to propanone, first order with respect to hydrogen ions, and zero order with respect to all other reactants and products.
Use the information given to answer the following questions.

**5 (b) (i)** What would happen to the rate of reaction if the concentration of hydrogen ions was halved?

.....

*(1 mark)*

**5 (b) (ii)** What is the overall order of the reaction?

.....

*(1 mark)*

**5 (b) (iii)** Write the rate equation for this reaction.

.....

*(3 marks)*

**5 (c)** State what *zero order* means.

.....

.....

*(1 mark)*

**Question 5 continues on the next page**

**5 (d)** Another reaction that forms a substance **Z** was studied:

$$2X + Y \rightleftharpoons Z$$

The expression for the equilibrium constant is:

$$K_c = \frac{[Z]}{[X]^2[Y]}$$

For the above reaction, assume the following values:

$K_c = 1.7 \times 10^{-4}\,mol^{-2}dm^6$
$[X] = 0.23\ mol\,dm^{-3}$ at equilibrium
Number of moles of Z = 0.52 at equilibrium
Volume of reaction vessel = $0.4\,dm^3$

**5 (d) (i)** Calculate the concentration of **Z** at equilibrium.

.....

Concentration = .....$mol\,dm^{-3}$
*(1 mark)*

**5 (d) (ii)** Calculate the concentration of **Y** at equilibrium.
You can use $[Z] = 2.7\ mol\,dm^{-3}$ if you were unable to answer part (d)(i). This is not the correct answer to part (d)(i).

.....

.....

.....

Concentration = .....$mol\,dm^{-3}$
*(2 marks)*

11

**END OF QUESTIONS**