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

| For Examiner's Use | |
|---|---|
| Examiner's Initials | |
| Question | Mark |
| 1 | |
| 2 | |
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| 10 | |
| TOTAL | |

General Certificate of Education
Advanced Subsidiary Examination
January 2010

# Chemistry CHEM2

## Unit 2 Chemistry in Action

**Thursday 21 January 2010 1.30 pm to 3.15 pm**

**For this paper you must have:**
- the Periodic Table/Data Sheet provided as an insert (enclosed)
- a calculator.

**Time allowed**
- 1 hour 45 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. **Answers written in margins or on blank pages will not be marked.**
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

**Information**
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

**Advice**
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

## SECTION A

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

**1** Hydrogen gas is used in the chemical industry.

**1** (a) Tungsten is extracted by passing hydrogen over heated tungsten oxide ($WO_3$).

**1** (a) (i) State the role of the hydrogen in this reaction.

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*(1 mark)*

**1** (a) (ii) Write an equation for this reaction.

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*(1 mark)*

**1** (a) (iii) State **one** risk of using hydrogen gas in metal extractions.

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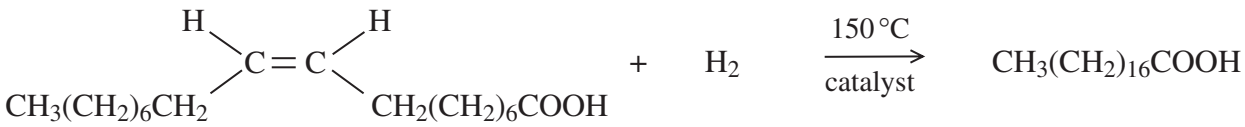
*(1 mark)*

**1** (b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.




oleic acid stearic acid

**1** (b) (i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

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*(1 mark)*

**1** (b) (ii) State the type of stereoisomerism shown by oleic acid.

.....

*(1 mark)*

**1** (c) Hydrogen reacts with nitrogen in the Haber Process. The equation for the equilibrium that is established is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

**1** (c) (i) State Le Chatelier's principle.

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*(1 mark)*

**1** (c) (ii) Use Le Chatelier's principle to explain why an increase in the total pressure of this equilibrium results in an increase in the equilibrium yield of ammonia.

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*(2 marks)*

**1** (d) Hydrogen reacts with oxygen in an exothermic reaction as shown by the following equation.

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -242\,\text{kJ mol}^{-1}$$

Use the information in the equation and the data in the following table to calculate a value for the bond enthalpy of the H–H bond.

| | O–H | O=O |
|---|---|---|
| Mean bond enthalpy / kJ mol$^{-1}$ | +463 | +496 |

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*(3 marks)*

*(Extra space)* .....

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11

**2** Hess's Law is used to calculate the enthalpy change in reactions for which it is difficult to determine a value experimentally.

**2** (a) State the meaning of the term *enthalpy change*.

.....

*(1 mark)*

**2** (b) State Hess's Law.

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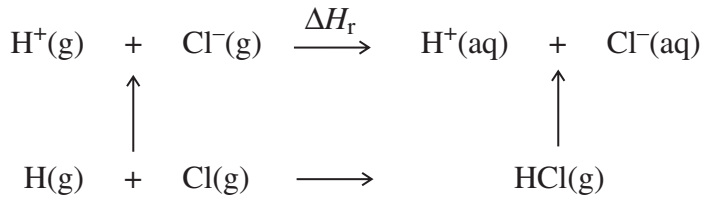
*(1 mark)*

**2** (c) Consider the following table of data and the scheme of reactions.

| Reaction | Enthalpy change / kJ mol$^{-1}$ |
|---|---|
| $HCl(g) \longrightarrow H^+(aq) + Cl^-(aq)$ | –75 |
| $H(g) + Cl(g) \longrightarrow HCl(g)$ | –432 |
| $H(g) + Cl(g) \longrightarrow H^+(g) + Cl^-(g)$ | +963 |




Use the data in the table, the scheme of reactions and Hess's Law to calculate a value for $\Delta H_r$

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*(3 marks)*

5

**3** For each of the following reactions, select from the list below, the **formula** of a sodium halide that would react as described.

NaF NaCl NaBr NaI

Each **formula** may be selected once, more than once or not at all.

**3** (a) This sodium halide is a white solid that reacts with concentrated sulfuric acid to give a brown gas.

Formula of sodium halide .....

*(1 mark)*

**3** (b) When a solution of this sodium halide is mixed with silver nitrate solution, no precipitate is formed.

Formula of sodium halide .....

*(1 mark)*

**3** (c) When this solid sodium halide reacts with concentrated sulfuric acid, the reaction mixture remains white and steamy fumes are given off.

Formula of sodium halide .....

*(1 mark)*

**3** (d) A colourless aqueous solution of this sodium halide reacts with orange bromine water to give a dark brown solution.

Formula of sodium halide .....

*(1 mark)*

**4**

**Turn over for the next question**

**4** Group 2 metals and their compounds are used commercially in a variety of processes and applications.

**4** (a) State a use of magnesium hydroxide in medicine.

.....

*(1 mark)*

**4** (b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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*(3 marks)*

*(Extra space)* .....

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**4** (c) Strontium metal is used in the manufacture of alloys.

**4** (c) (i) Explain why strontium has a higher melting point than barium.

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*(2 marks)*

*(Extra space)* .....

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**4** (c) (ii) Write an equation for the reaction of strontium with water.

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*(1 mark)*

**4** (d) Magnesium can be used in the extraction of titanium.

**4** (d) (i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

*(1 mark)*

**4** (d) (ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

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*(1 mark)*

**9**

**Turn over for the next question**

**5** Nitric acid is manufactured from ammonia in a process that involves several stages.

**5** (a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905\,kJ\,mol^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

**5** (a) (i) In terms of redox, state what happens to the ammonia in the forward reaction.

.....

*(1 mark)*

**5** (a) (ii) Suggest a reason why the catalyst must be hot.

.....

*(1 mark)*

**5** (a) (iii) Suggest a reason why the catalyst remains hot during the reaction.

.....

*(1 mark)*

**5** (a) (iv) State how a catalyst increases the rate of a reaction.

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.....

*(2 marks)*

**5** (b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113\,kJ\,mol^{-1}$$

Explain why the equilibrium mixture is cooled during this stage of the process.

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*(2 marks)*

**5** (c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$$2NO_2(g) + H_2O(l) \longrightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$$

Give the oxidation state of nitrogen in each of the following.

$NO_2$ .....

$NO_3^-$ .....

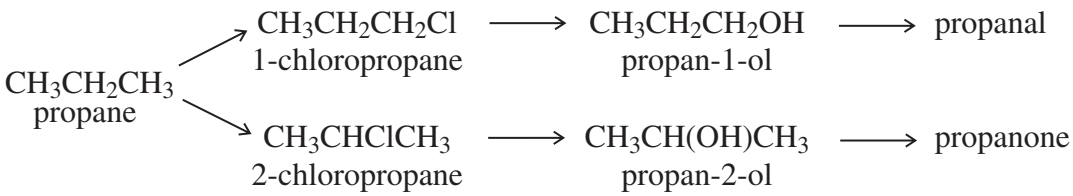
$HNO_2$ .....

*(3 marks)*

**10**

**Turn over for the next question**

**6** Consider the following scheme of reactions.




**6** (a) State the type of structural isomerism shown by propanal and propanone.

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*(1 mark)*

**6** (b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent .....

Observation with propanal .....

Observation with propanone .....

*(3 marks)*

**6** (c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 $cm^{-1}$.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

*(1 mark)*

**6** (d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

**6** (d) (i) Name the type of mechanism in the reaction of chlorine with methane.

.....

*(1 mark)*

**6** (d) (ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula $C_3H_7$

.....

*(4 marks)*

**6** (e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise $M_r$ values can be used to prove that the sample contains both of these gases.

| Atom | Precise relative atomic mass |
|---|---|
| $^{12}C$ | 12.00000 |
| $^{1}H$ | 1.00794 |
| $^{16}O$ | 15.99491 |

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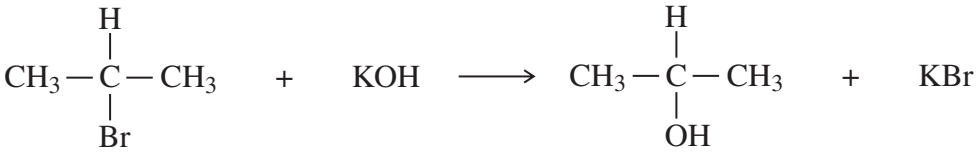
*(2 marks)*

**12**

**Turn over ▶**

**7** (a) Consider the following reaction.



**7** (a) (i) Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

*(3 marks)*

**7** (a) (ii) Name the haloalkane in this reaction.

.....

*(1 mark)*

**7** (a) (iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

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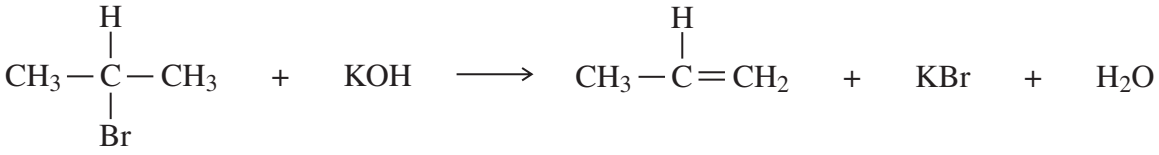
*(1 mark)*

**7** (b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

*(4 marks)*

**7** (c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

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*(1 mark)*

**7** (d) Alkenes can be polymerised to produce poly(alkenes).

**7** (d) (i) State the type of polymerisation that alkenes undergo.

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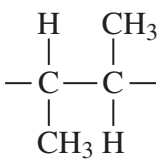
*(1 mark)*

**7** (d) (ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene .....

*(1 mark)*

**12**

**Turn over ▶**

**8** Copper is extracted from the ore chalcopyrite ($CuFeS_2$) in a three-stage process.

**8** (a) In the first stage of this extraction, the chalcopyrite is heated with silicon dioxide and oxygen.

**8** (a) (i) Balance the following equation for this first stage in which copper(I) sulfide is formed.

……$CuFeS_2$ + ……$SiO_2$ + ……$O_2$ $\longrightarrow$ $Cu_2S$ + ……$FeSiO_3$ + ……$SO_2$

*(1 mark)*

**8** (a) (ii) Give **one** environmental reason why the $SO_2$ gas formed in this reaction is not allowed to escape into the atmosphere.

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*(1 mark)*

**8** (a) (iii) State **one** use for the sulfur dioxide formed in this reaction.

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*(1 mark)*

**8** (b) In the second stage of this extraction, the copper(I) sulfide is converted into copper(II) oxide. This occurs by roasting the sulfide with oxygen at high temperature. Write an equation for this reaction.

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*(1 mark)*

**8** (c) In the third stage of this extraction, copper(II) oxide is reduced to copper by its reaction with carbon. Write an equation for this reaction.

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*(1 mark)*

**8** (d) Scrap iron can be used to extract copper from dilute aqueous solutions containing copper(II) ions.

**8** (d) (i) Explain why this is a low-cost method of extracting copper.

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*(1 mark)*

**8** (d) (ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

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*(1 mark)*

**7**

**Turn over for the next question**

## SECTION B

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

**9** There are **four** isomeric alcohols with the molecular formula $C_4H_{10}O$

**9** (a) Two of these are butan-l-ol ($CH_3CH_2CH_2CH_2OH$) and butan-2-ol.
The other two isomers are alcohol **X** and alcohol **Y**.

Draw the displayed formula for butan-2-ol.

Alcohol **X** does not react with acidified potassium dichromate(VI) solution.
Give the structure of alcohol **X**.

Name the fourth isomer, alcohol **Y**.

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*(3 marks)*

*(Extra space)* .....

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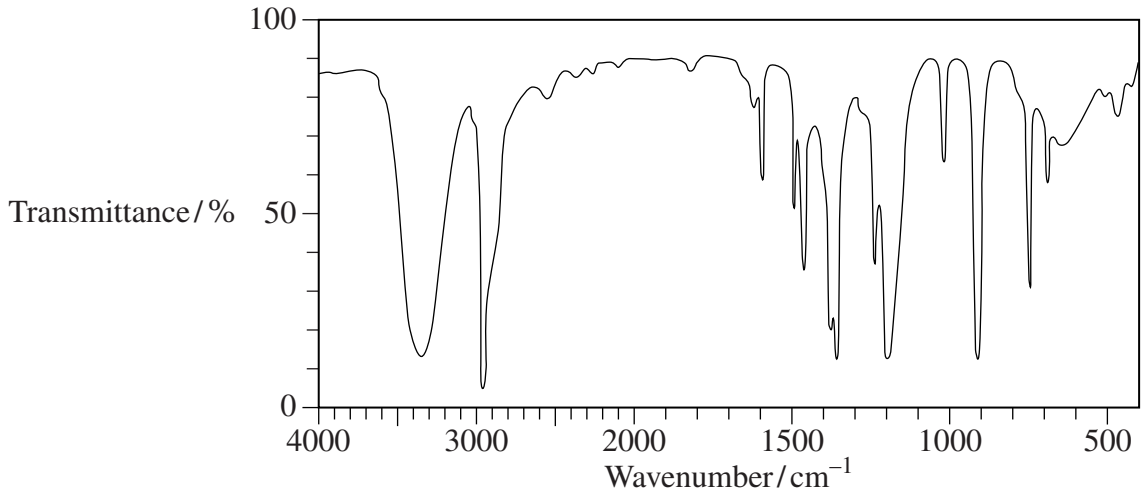
**9** (b) The infrared spectrum of one of these isomeric alcohols is given below.




Identify **one** feature of the infrared spectrum which supports the fact that this is an alcohol. You may find it helpful to refer to **Table 1** on the Data Sheet.

Explain how infrared spectroscopy can be used to identify this isomeric alcohol.

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*(3 marks)*

*(Extra space)* .....

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**Question 9 continues on the next page**

**9** (c) British scientists have used bacteria to ferment glucose and produce the biofuel butan-l-ol.

Write an equation for the fermentation of glucose ($C_6H_{12}O_6$) to form butan-l-ol, carbon dioxide and water only.

State **one** condition necessary to ensure the complete combustion of a fuel in air.

Write an equation for the complete combustion of butan-l-ol and state why it can be described as a *biofuel*.

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*(4 marks)*

*(Extra space)* .....

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**9** (d) Butan-l-ol reacts with acidified potassium dichromate(VI) solution to produce two organic compounds.

State the class of alcohols to which butan-l-ol belongs.

Draw the displayed formula for **both** of the organic products.

State the type of reaction that occurs and the change in colour of the potassium dichromate(VI) solution.

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*(5 marks)*

*(Extra space)* .....

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**15**

**Turn over for the next question**

**10** (a) When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.

$$Cl_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

Give the formula of the species responsible for the pale green colour in the solution of chlorine in water.

Use Le Chatelier's principle to explain why the green colour disappears when sodium hydroxide solution is added to this solution.

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*(3 marks)*

*(Extra space)* .....

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**10** (b) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

In terms of electrons, state the meaning of the term *reducing agent*.

Deduce the half-equation for the conversion of chlorine into chloride ions.

Explain why iodide ions are stronger reducing agents than chloride ions.

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*(4 marks)*

*(Extra space)* .....

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**Question 10 continues on the next page**

**10** (c) When chlorine reacts with water in bright sunlight, only two products are formed. One of these products is a colourless, odourless gas and the other is an acidic solution that reacts with silver nitrate solution to give a white precipitate.

Write an equation for the reaction of chlorine with water in bright sunlight.

Name the white precipitate and state what you would observe when an excess of aqueous ammonia is added to it.

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*(3 marks)*

*(Extra space)* .....

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**10** (d) The reaction of chlorine with ethene is similar to that of bromine with ethene.

Name and outline a mechanism for the reaction of chlorine with ethene to form 1,2-dichloroethane, as shown by the following equation.

$$H_2C{=}CH_2 + Cl_2 \longrightarrow ClCH_2CH_2Cl$$

*(5 marks)*

**15**

**END OF QUESTIONS**

**There are no questions printed on this page**

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**ANSWER IN THE SPACES PROVIDED**