



88116105

**CHEMISTRY  
STANDARD LEVEL  
PAPER 2**

Monday 7 November 2011 (afternoon)

1 hour 15 minutes

Candidate session number

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Examination code

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**INSTRUCTIONS TO CANDIDATES**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the boxes provided.



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**SECTION A**

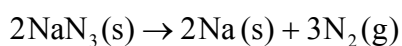
Answer *all* questions. Write your answers in the boxes provided.

1. Airbags are an important safety feature in vehicles. Sodium azide, potassium nitrate and silicon dioxide have been used in one design of airbag.



[Source: www.hilalairbag.net]

Sodium azide, a toxic compound, undergoes the following decomposition reaction under certain conditions.



Two students looked at data in a simulated computer-based experiment to determine the volume of nitrogen generated in an airbag.

- (a) Sodium azide involves ionic bonding, and metallic bonding is present in sodium. Describe ionic and metallic bonding. [2]

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(Question 1 continued)

(b) Using the simulation programme, the students entered the following data into the computer.

| Temperature ( $T$ ) / °C | Mass of $\text{NaN}_3(\text{s})$ ( $m$ ) / kg | Pressure ( $p$ ) / atm |
|--------------------------|---|------------------------|
| 25.00                    | 0.0650  | 1.08                   |

(i) State the number of significant figures for the temperature, mass and pressure data. [1]

|       |       |
|-------|-------|
| $T$ : | ..... |
| $m$ : | ..... |
| $p$ : | ..... |

(ii) Calculate the amount, in mol, of sodium azide present. [1]

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| ..... |
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(iii) Determine the volume of nitrogen gas, in  $\text{dm}^3$ , produced under these conditions based on this reaction. [4]

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Turn over

*(Question 1 continued)*

- (c) The chemistry of the airbag was found to involve three reactions. The first reaction involves the decomposition of sodium azide to form sodium and nitrogen. In the second reaction, potassium nitrate reacts with sodium.



- (i) Suggest why it is necessary for sodium to be removed by this reaction. [1]

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- (ii) The metal oxides from the second reaction then react with silicon dioxide to form a silicate in the third reaction.



Draw the structure of silicon dioxide and state the type of bonding present. [2]

Structure:

Bonding: .....

*(This question continues on the following page)*



(Question 1 continued)

(d) An airbag inflates very quickly.

(i) It takes just 0.0400 seconds to produce nitrogen gas in the simulation. Calculate the average rate of formation of nitrogen in (b) (iii) and state its units. [1]

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(ii) The students also discovered that a small increase in temperature (*e.g.* 10 °C) causes a large increase (*e.g.* doubling) in the rate of this reaction. State **one** reason for this. [1]

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2. Isotopes are atoms of the same element with different mass numbers. Two isotopes of cobalt are Co-59 and Co-60.

(a) Deduce the missing information and complete the following table. [2]

| Symbol              | $^{59}\text{Co}^{3+}$ | $^{60}\text{Co}$ |    |
|---------------------|-----------------------|------------------|----|
| Number of protons   | 27                    |                  | 53 |
| Number of neutrons  |                       | 33               | 72 |
| Number of electrons |                       | 27               | 53 |

(b) State why the Co-60 radioisotope is used in radiotherapy. [1]

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3. (a) Molten sodium chloride can be electrolysed using graphite electrodes.

(i) Draw the essential components of this electrolytic cell and identify the products that form at each electrode. [2]

Product formed at positive electrode (anode):  
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Product formed at negative electrode (cathode):  
.....

(ii) State the half-equations for the oxidation and reduction processes and deduce the overall cell reaction, including state symbols. [2]

Oxidation half-equation:  
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Reduction half-equation:  
.....

Overall cell reaction:  
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*(This question continues on the following page)*



(Question 3 continued)

- (b) Explain why solid sodium chloride does not conduct electricity. [1]

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- (c) Using another electrolysis reaction, aluminium can be extracted from its ore, bauxite, which contains  $\text{Al}_2\text{O}_3$ . State **one** reason why aluminium is often used instead of iron in many engineering applications. [1]

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4. (a) Define the term *average bond enthalpy*. [2]

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- (b) Deduce the balanced chemical equation for the complete combustion of butan-1-ol. [1]

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- (c) Determine the standard enthalpy change, in  $\text{kJ mol}^{-1}$ , for the complete combustion of butan-1-ol, using the information from Table 10 of the Data Booklet. [3]

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- (d) Based on the types of intermolecular force present, explain why butan-1-ol has a higher boiling point than butanal. [2]

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**SECTION B**

Answer **one** question. Write your answers in the boxes provided.

5. (a) Deduce the balanced chemical equation for the reaction between sodium and sulfur. State the electron arrangements of the reactants and product, and explain whether sulfur is oxidized or reduced. [4]

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- (b) Describe the acid-base character of the oxides of the period 3 elements, Na to Cl. For the compounds sodium oxide and phosphorus(V) oxide, state the balanced chemical equations for the reaction of each oxide with water. [4]

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(Question 5 continued)

(c) Phosphorus tribromide ( $\text{PBr}_3$ ) is used to manufacture alprazolam, a drug used to treat anxiety disorders. Methanal ( $\text{HCHO}$ ) is used as a disinfectant.

(i) For each of the species  $\text{PBr}_3$  and  $\text{HCHO}$ :

- deduce the Lewis structure.
- predict the shape and bond angle.

[6]

| $\text{PBr}_3$   | $\text{HCHO}$    |
|------------------|------------------|
| Lewis structure: | Lewis structure: |
| Shape:           | Shape:           |
| .....            | .....            |
| Bond angle:      | Bond angle:      |
| .....            | .....            |

(ii) Explain why  $\text{PBr}_3$  is a polar molecule.

[2]

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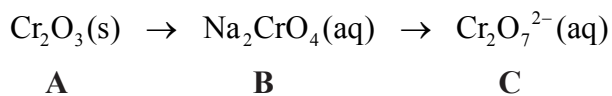
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(Question 5 continued)

(d) Consider the following reaction sequence:



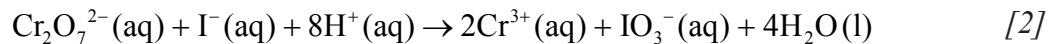
(i) State the name of **A**. [1]

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(ii) Describe the redox behaviour of chromium with reference to oxidation numbers in the conversion of **B** to **C**. [1]

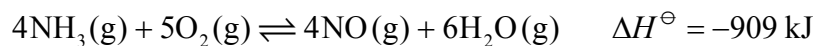
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(iii) Define the term *oxidizing agent* and identify the oxidizing agent in the following reaction.



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6. (a) Consider the following equilibrium:



(i) Deduce the equilibrium constant expression,  $K_c$ , for the reaction. [1]

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(ii) Predict the direction in which the equilibrium will shift when the following changes occur. [4]

The volume increases.  
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The temperature decreases.  
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H<sub>2</sub>O(g) is removed from the system.  
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A catalyst is added to the reaction mixture.  
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(b) Define the term *activation energy*,  $E_a$ . [1]

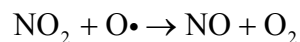
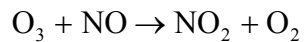
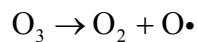
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(Question 6 continued)

- (c) Nitrogen monoxide, NO, is involved in the decomposition of ozone according to the following mechanism.



State and explain whether or not NO is acting as a catalyst.

[2]

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- (d) (i) Define the term *endothermic reaction*.

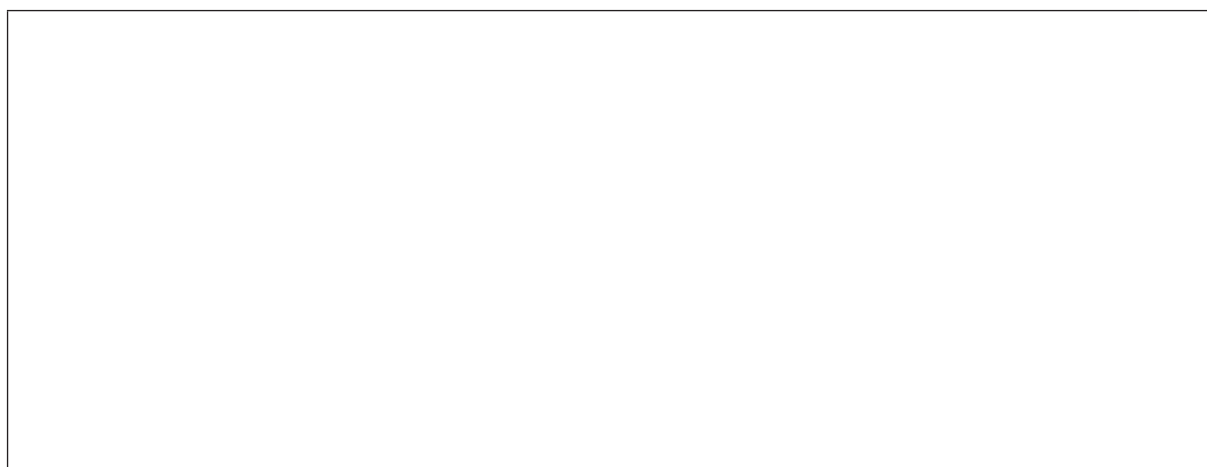
[1]

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- (ii) Sketch the Maxwell-Boltzmann energy distribution curve for a reaction with and without a catalyst, and label both axes.

[3]



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(Question 6 continued)

- (e) Nitrogen reacts with hydrogen to form ammonia in the Haber process, according to the following equilibrium.



- (i) Define the term *rate of reaction*. [1]

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- (ii) A high pressure such as 1000 atm and a low temperature such as 300 K can produce a high yield of ammonia. Discuss how these conditions compare with the actual conditions of pressure and temperature used in the Haber process. [4]

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- (f) Iron, used as the catalyst in the Haber process, has a specific heat capacity of  $0.4490 \text{ J g}^{-1} \text{ K}^{-1}$ . If 245.0 kJ of heat is supplied to 8.500 kg of iron, initially at a temperature of  $15.25^\circ\text{C}$ , determine its final temperature in K. [3]

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7. (a) One example of a homologous series is the alcohols. Describe **two** features of a homologous series. [2]

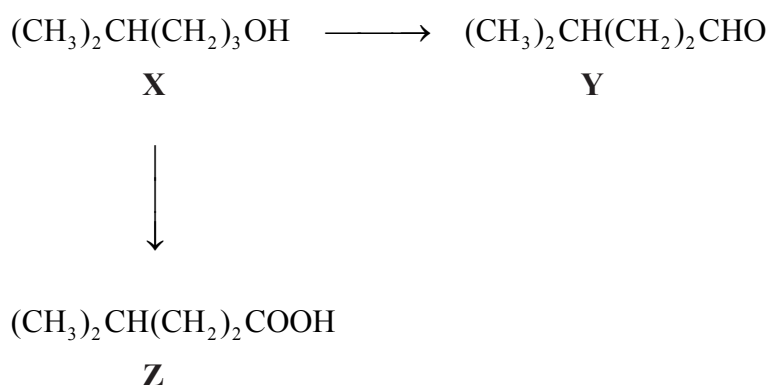
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- (b) Consider the following reactions.



- (i) The IUPAC name of **X** is 4-methylpentan-1-ol. State the IUPAC names of **Y** and **Z**. [2]

**Y:** .....

**Z:** .....

- (ii) State the reagents and reaction conditions used to convert **X** to **Y** and **X** to **Z**. [2]

**X to Y:** .....

.....

**X to Z:** .....

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(This question continues on the following page)





(Question 7 continued)

(iii) **Z** is an example of a weak acid. State what is meant by the term *weak acid*. [1]

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(iv) Discuss the volatility of **Y** compared to **Z**. [2]

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(c)  $(\text{CH}_3)_3\text{CCl}$  reacts with  $\text{OH}^-$  to form a tertiary alcohol. Explain the reaction mechanism by using curly arrows to represent the movement of electron pairs. [4]

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(Question 7 continued)

- (d) An important environmental consideration is the appropriate disposal of cleaning solvents. An environmental waste treatment company analysed a cleaning solvent, **J**, and found it to contain the elements carbon, hydrogen and chlorine only. The chemical composition of **J** was determined using different analytical chemistry techniques.

*Combustion Reaction:*

Combustion of 1.30 g of **J** gave 0.872 g CO<sub>2</sub> and 0.089 g H<sub>2</sub>O.

*Precipitation Reaction with AgNO<sub>3</sub> (aq):*

0.535 g of **J** gave 1.75 g AgCl precipitate.

- (i) Determine the percentage by mass of carbon and hydrogen in **J**, using the combustion data. [3]

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- (ii) Determine the percentage by mass of chlorine in **J**, using the precipitation data. [1]

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(Question 7 continued)

(iii) The molar mass was determined to be  $131.38 \text{ g mol}^{-1}$ . Deduce the molecular formula of **J**. [3]

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Answers written on this page  
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