88116105

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

0	0							

Monday 7 November 2011 (afternoon)

1 hour 15 minutes

Examination code

8	8	1	1	–	6	1	0	5

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.

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.

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

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]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

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

Temperature (T) / °C	**Mass of NaN_3(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]*

. . . . . .

. . . . . .

(iii) Determine the volume of nitrogen gas, in dm^3, produced under these conditions based on this reaction. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(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.

$$2KNO_3(s) + 10Na(s) \rightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$$

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

. . . . . .

. . . . . .

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

$$K_2O(s) + Na_2O(s) + SiO_2(s) \rightarrow Na_2K_2SiO_4(s)$$

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]*

. . . . . .
. . . . . .
. . . . . .

(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]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

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	$^{59}Co^{3+}$	^{60}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]*

. . . . . .

. . . . . .

. . . . . .

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):

. . . . . .

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:

. . . . . .

Reduction half-equation:

. . . . . .

Overall cell reaction:

. . . . . .

(This question continues on the following page)

(Question 3 continued)

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

. . . . . .

. . . . . .

(c) Using another electrolysis reaction, aluminium can be extracted from its ore, bauxite, which contains Al_2O_3. State **one** reason why aluminium is often used instead of iron in many engineering applications. *[1]*

. . . . . .

. . . . . .

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

. . . . . .
. . . . . .
. . . . . .
. . . . . .

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

. . . . . .
. . . . . .

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

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

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

. . . . . .
. . . . . .
. . . . . .
. . . . . .

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]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(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]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 5 continued)

(c) Phosphorus tribromide (PBr_3) is used to manufacture alprazolam, a drug used to treat anxiety disorders. Methanal (HCHO) is used as a disinfectant.

(i) For each of the species PBr_3 and HCHO:
- deduce the Lewis structure.
- predict the shape and bond angle. *[6]*

PBr_3	**HCHO**
Lewis structure: Shape: . . . . . . Bond angle:	Lewis structure: Shape: . . . . . . Bond angle: . . . . .

(ii) Explain why PBr_3 is a polar molecule. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 5 continued)

(d) Consider the following reaction sequence:

$$\underset{\textbf{A}}{Cr_2O_3(s)} \rightarrow \underset{\textbf{B}}{Na_2CrO_4(aq)} \rightarrow \underset{\textbf{C}}{Cr_2O_7^{2-}(aq)}$$

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

. . . . . .

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

. . . . . .

. . . . . .

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

$$Cr_2O_7^{2-}(aq) + I^-(aq) + 8H^+(aq) \rightarrow 2Cr^{3+}(aq) + IO_3^-(aq) + 4H_2O(l) \quad \textit{[2]}$$

. . . . . .

. . . . . .

. . . . . .

. . . . . .

6. (a) Consider the following equilibrium:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^{\ominus} = -909 \text{ kJ}$$

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

. . . . . .

. . . . . .

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

The volume increases.

. . . . . .

The temperature decreases.

. . . . . .

$H_2O(g)$ is removed from the system.

. . . . . .

A catalyst is added to the reaction mixture.

. . . . . .

(b) Define the term *activation energy*, E_a. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 6 continued)

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

$$O_3 \rightarrow O_2 + O\bullet$$

$$O_3 + NO \rightarrow NO_2 + O_2$$

$$NO_2 + O\bullet \rightarrow NO + O_2$$

Overall: $2O_3 \rightarrow 3O_2$

State and explain whether or not NO is acting as a catalyst. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(d) (i) Define the term *endothermic reaction*. *[1]*

. . . . . .

. . . . . .

(ii) Sketch the Maxwell-Boltzmann energy distribution curve for a reaction with and without a catalyst, and label both axes. *[3]*

(This question continues on the following page)

(Question 6 continued)

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

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92.6 \text{ kJ}$$

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

. . . . . .

. . . . . .

(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]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

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

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

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

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) Consider the following reactions.

$(CH_3)_2CH(CH_2)_3OH \longrightarrow (CH_3)_2CH(CH_2)_2CHO$

X **Y**

$\downarrow$

$(CH_3)_2CH(CH_2)_2COOH$

Z

(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**: . . . . . .
. . . . . .

(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]*

. . . . . .
. . . . . .

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

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(c) $(CH_3)_3CCl$ reacts with OH^- to form a tertiary alcohol. Explain the reaction mechanism by using curly arrows to represent the movement of electron pairs. *[4]*

(This question continues on the following page)

(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_2 and 0.089 g H_2O.

Precipitation Reaction with $AgNO_3$ (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]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

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

. . . . . .
. . . . . .

(This question continues on the following page)

(Question 7 continued)

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

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.