22096117

International Baccalaureate®
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CHEMISTRY
STANDARD LEVEL
PAPER 2

Monday 18 May 2009 (afternoon)

1 hour 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

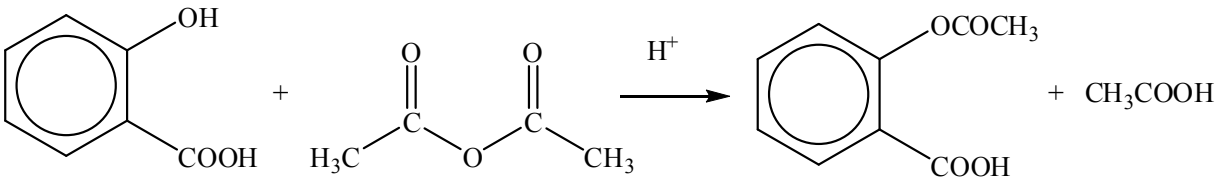
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer one question from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

0110

SECTION A

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

1. Aspirin, one of the most widely used drugs in the world, can be prepared according to the equation given below.



salicylic acid ethanoic anhydride ***aspirin*** ethanoic acid

(a) State the names of the **three** organic functional groups in aspirin. *[3]*

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(b) A student reacted some salicylic acid with excess ethanoic anhydride. Impure solid aspirin was obtained by filtering the reaction mixture. Pure aspirin was obtained by recrystallization. The following table shows the data recorded by the student.

Mass of salicylic acid used	3.15 ± 0.02 g
Mass of pure aspirin obtained	2.50 ± 0.02 g

(i) Determine the amount, in mol, of salicylic acid, $C_6H_4(OH)COOH$, used. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(ii) Calculate the theoretical yield, in g, of aspirin, $C_6H_4(OCOCH_3)COOH$. *[2]*

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(iii) Determine the percentage yield of pure aspirin. *[1]*

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(iv) State the number of significant figures associated with the mass of pure aspirin obtained, and calculate the percentage uncertainty associated with this mass. *[2]*

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(v) Another student repeated the experiment and obtained an experimental yield of 150 %. The teacher checked the calculations and found no errors. Comment on the result. *[1]*

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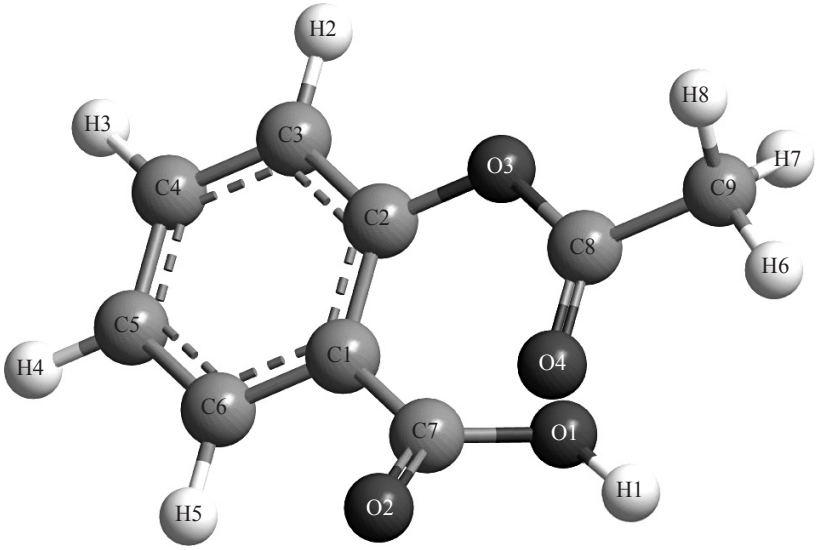
(Question 1 continued)

(vi) The following is a three-dimensional computer-generated representation of aspirin.



A third student measured selected bond lengths in aspirin, using this computer program and reported the following data.

Bond	**Bond length / × 10^{-10} m**
C1–C2	1.4
C2–C3	1.4
C3–C4	1.4
C4–C5	1.4
C5–C6	1.4
C6–C1	1.4
C2–O3	1.4

The following hypothesis was suggested by the student: "*Since all the measured carbon-carbon bond lengths are equal, all the carbon-oxygen bond lengths must also be equal in aspirin. Therefore, the C8–O4 bond length must be 1.4 × 10^{-10} m*". Comment on whether or not this is a valid hypothesis. *[2]*

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(Question 1 continued)

(vii) The other product of the reaction is ethanoic acid, CH_3COOH. Define an acid according to the Brønsted-Lowry theory and state the conjugate base of CH_3COOH. *[2]*

Brønsted-Lowry definition of an acid:

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Conjugate base of CH_3COOH:

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2. Some of the most important processes in chemistry involve acid-base reactions.

(a) Describe the acid-base character of the oxides of each of the period 3 elements, Na to Cl. *[3]*

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(b) State **one** example of an acidic gas, produced by an industrial process or the internal combustion engine, which can cause large-scale pollution to lakes and forests. *[1]*

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(c) Suggest **one** method, other than measuring pH, which could be used to distinguish between solutions of a strong acid and a weak acid of the same molar concentration. State the expected results. *[2]*

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3. Smog is common in cities throughout the world. One component of smog is PAN (peroxyacylnitrate) which consists of 20.2 % C, 11.4 % N, 65.9 % O and 2.50 % H by mass. Determine the empirical formula of PAN, showing your working. *[3]*

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

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(b) State **two** conditions necessary for a reaction to take place between two reactant particles. *[2]*

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(c) Sketch an enthalpy level diagram to describe the effect of a catalyst on an *exothermic* reaction. *[3]*

SECTION B

*Answer **one** question. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

5. (a) Consider the following equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -198 \text{ kJ mol}^{-1}$$

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

(ii) State and explain the effect of increasing the temperature on the yield of sulfur trioxide. *[2]*

(iii) State the effect of a catalyst on the value of K_c. *[1]*

(iv) State and explain the effect of a catalyst on the position of equilibrium. *[2]*

(b) (i) Define *oxidation* in terms of oxidation numbers. *[1]*

(ii) Describe using a labelled diagram, the essential components of an electrolytic cell. *[3]*

(iii) Explain why solid sodium chloride does not conduct electricity but **molten** sodium chloride does. *[2]*

(iv) Molten sodium chloride undergoes electrolysis in an electrolytic cell. For each electrode deduce the half-equation and state whether oxidation or reduction takes place. Deduce the equation of the overall cell reaction including state symbols. *[5]*

(v) Electrolysis has made it possible to obtain reactive metals such as aluminium from their ores, which has resulted in significant developments in engineering and technology. State **one** reason why aluminium is preferred to iron in many uses. *[1]*

(vi) Outline **two** differences between an electrolytic cell and a voltaic cell. *[2]*

6. In some countries, ethanol is mixed with gasoline (petrol) to produce a fuel for cars called gasohol.

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

(ii) Use the information from Table 10 of the Data Booklet to determine the standard enthalpy change for the complete combustion of ethanol.

$$CH_3CH_2OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$$ *[3]*

(iii) The standard enthalpy change for the complete combustion of octane, C_8H_{18}, is –5471 kJ mol^{-1}. Calculate the amount of energy produced in kJ when 1 g of ethanol and 1 g of octane is burned completely in air. *[2]*

(iv) Ethanol can be oxidized using acidified potassium dichromate, $K_2Cr_2O_7$, to form two different organic products.

$$CH_3CH_2OH \xrightarrow[H^+]{Cr_2O_7^{2-}} \mathbf{A} \xrightarrow[H^+]{Cr_2O_7^{2-}} \mathbf{B}$$

State the structural formulas of the organic products **A** and **B** and describe the conditions required to obtain a high yield of each of them. *[4]*

(v) Deduce and explain whether ethanol or **A** has the higher boiling point. *[2]*

(vi) Ethene can be converted into ethanol by direct hydration in the presence of a catalyst according to the following equation.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$$

For this reaction identify the catalyst used and state **one** use of the ethanol formed other than as a fuel. *[2]*

(b) (i) State the name of **one** structural isomer of pentane. *[1]*

(ii) Sodium hydroxide reacts with 1-bromopentane via an S_N2 mechanism. Describe the mechanism of this reaction using curly arrows to represent the movement of electron pairs. *[4]*

7. (a) (i) Define the term *isotopes*. *[1]*

(ii) A sample of silicon contains three isotopes.

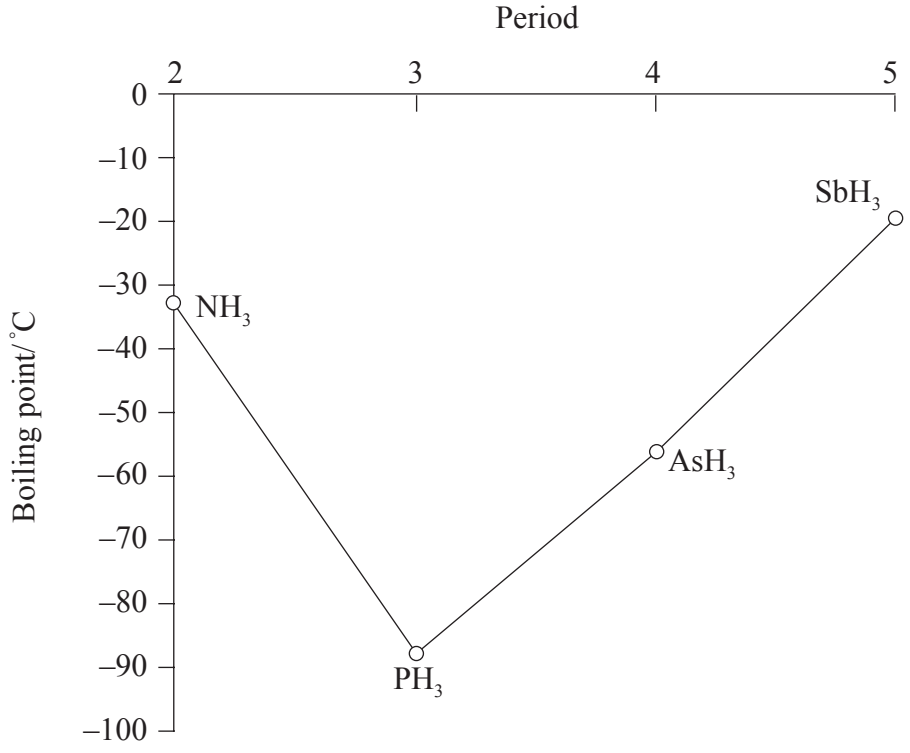
Isotope	Percentage abundance / %
^{28}Si	92.23
^{29}Si	4.68
^{30}Si	3.09

Calculate the relative atomic mass of silicon using this data. *[2]*

(iii) Describe the structure and bonding in silicon dioxide and carbon dioxide. *[4]*

(b) (i) Draw the Lewis structure of NH_3, state its shape and deduce and explain the H–N–H bond angle in NH_3. *[4]*

(ii) The graph below shows the boiling points of the hydrides of group 5. Discuss the variation in the boiling points. *[4]*



(c) Explain, using diagrams, why CO and NO_2 are polar molecules but CO_2 is a non-polar molecule. *[5]*