H

TAMPINES JUNIOR COLLEGE

JC2 Preliminary Examination

CANDIDATE NAME	

CIVICS GROUP	1	2				TUTOR NAME	

CHEMISTRY 8872/02

Paper 2

Thursday, 05 September 2013

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and civics group on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
B5	
B6	
B7	
Total	

This document consists of **14** printed pages.

Section A

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

For Examiner's Use

1 Radiotherapy is the medical use of radiation generated from radioactive isotopes to destroy or weaken malfunctioning cells. Examples of radioactive isotopes used for the therapy are those of iodine, phosphorus and lutetium.

(a) Lutetium has two naturally occurring isotopes, ^{175}Lu and ^{176}Lu. Their natural abundances are 97.4% and 2.6% respectively.

(i) Define the term *relative atomic mass*.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(ii) Calculate, to one decimal place, the relative atomic mass of lutetium.

[2]

(b) ^{176}Lu has a half-life of 3.78×10^{10} years. The half-life of a radioactive isotope is the time taken for half of the atoms in a given mass to decay.

Calculate the percentage of a sample of ^{176}Lu isotopes remaining after 1.134×10^{11} years.

[2]

Iodine-131 is used to treat the thyroid for cancers and phosphorus-32 is used to control the excess of red blood cells produced in the bone marrow.

(c) Complete the table below for the ^{131}I and ^{32}P isotopes.

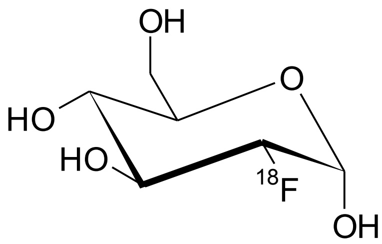
Isotope	Number of protons	Number of neutrons
^{131}I		
^{32}P		

[1]

For Examiner's Use

Radioactive isotopes are commonly incorporated into compounds to trace the path of biochemical reactions. These compounds are known as radioactive tracers.

The structure of fluorodeoxyglucose (^{18}F-FDG), a radioactive tracer widely used in medical imaging, is shown below.



^{18}F-FDG

(d) **(i)** Apart from ether (–O–), circle and name the functional groups that are present in the ^{18}F-FDG shown above.

(ii) Calculate the percentage composition by mass of carbon in ^{18}F-FDG.

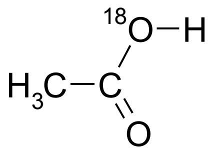
(iii) Would you expect ^{18}F-FDG to be soluble in water? Explain your answer.

……………………………………………………………………………………………

……………………………………………………………………………………………

For Examiner's Use

(iv) ^{18}F-FDG is heated under reflux with an excess of the following isotopically labelled carboxylic acid in the presence of concentrated sulfuric acid.

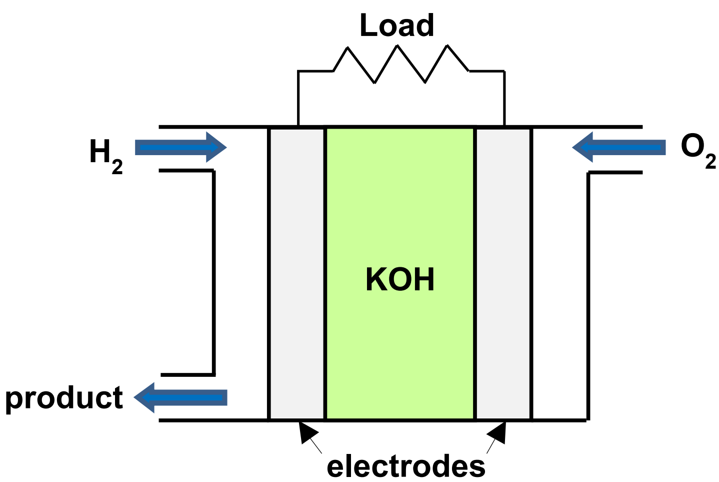


Give the structural formula of the organic product formed and state the type of reaction that has occurred. You may assume that the ether group is inert.

[7]

[Total: 12]

2 In an alkaline fuel cell, the chemical energy from the hydrogen fuel supplied to one electrode is converted into electricity through a chemical reaction with the oxygen supplied to the other electrode. These two electrodes are connected using potassium hydroxide as an electrolyte. A simplified diagram of the fuel cell is shown below.



The two half-equations for this cell are

$$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$$

$$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$$

For Examiner's Use

(a) **(i)** Combine these two half-equations to show the overall reaction occurring in the cell.

(ii) Use oxidation numbers to show which species in your equation is reduced and which is oxidised.

[4]

Porous graphite impregnated with suitable catalysts could be used as electrodes for an alkaline fuel cell.

(b) **(i)** Describe the structure of, and the bonding in, the element graphite.
Draw a diagram to illustrate your answer.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

For Examiner's Use

(ii) State a physical property of graphite that metals also possess.
Explain, in terms of the bonding present, why it possesses this property.

property ……………………………………………………………………………..

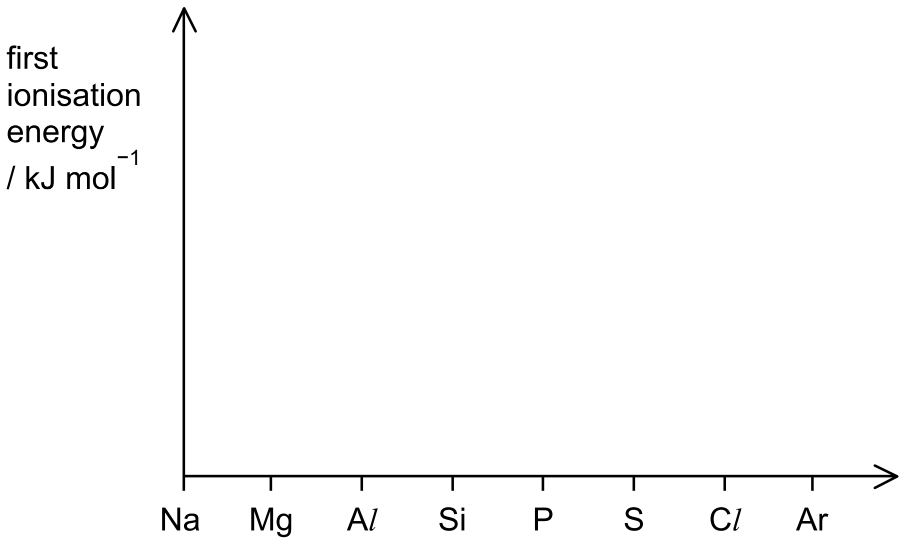
explanation ………………………………………………………………………

……………………………………………………………………………………..[4]

[Total: 8]

3 This question is about period three elements and their compounds.

(a) **(i)** Sketch on the axes provided, the trend in first ionisation energy across period three.



(ii) Explain the **general** trend in first ionisation energy of period three elements.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(iii) Explain the difference between the values of the first ionisation energies of phosphorus and sulfur.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[3]

For Examiner's Use

(b) Sulfuryl chloride, SO_2Cl_2, decomposes as follows when heated to 100 °C.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$$

(i) Calculate the equilibrium constant, K_c, at 100 °C, given the following values:

$[SO_2Cl_2] = 14.6\ g\ dm^{-3}$,

$[SO_2] = 3.33\ g\ dm^{-3}$,

$[Cl_2] = 11.5\ g\ dm^{-3}$.

(ii) Draw a dot-and-cross diagram for sulfuryl chloride.

(iii) Complete the electronic configuration of a chlorine **atom**.

$1s^2$ ………………………………………………..

Hence describe the bonding in the Cl_2 molecule in terms of orbital overlap. Include a diagram in your answer.

[7]

[Total: 10]

For Examiner's Use

4 An airbag is a vehicle safety device which is designed to inflate rapidly during an automobile collision. Its purpose is to cushion occupants during a crash and provide protection to their bodies when they strike interior objects such as the steering wheel or a window.

An airbag typically contains a mixture of sodium azide (NaN_3), potassium nitrate (KNO_3) and silicon dioxide (SiO_2). Within about 40 milliseconds of impact, all these components react in three separate reactions as described in order below.

The first reaction is the decomposition of sodium azide to produce sodium metal and nitrogen gas. The equation is as follows.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

The highly reactive sodium metal formed then reacts with potassium nitrate to produce more nitrogen gas according to the following equation.

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

The third reaction involves the removal of K_2O and Na_2O by silicon dioxide to produce the metal silicates, K_2SiO_3 and Na_2SiO_3.

The airbag is inflated by the nitrogen gas produced in the first and second reactions.

(a) **(i)** Calculate the amount, in moles, of sodium metal and of nitrogen gas formed when 110 g of sodium azide in an airbag is decomposed.

(ii) Hence calculate the number of moles of nitrogen gas produced in the second reaction.

(iii) Using your answers to **(i)** and **(ii)**, calculate the total volume of nitrogen gas contained in the airbag at room temperature and pressure.

(iv) State an assumption you have made in the calculations above.

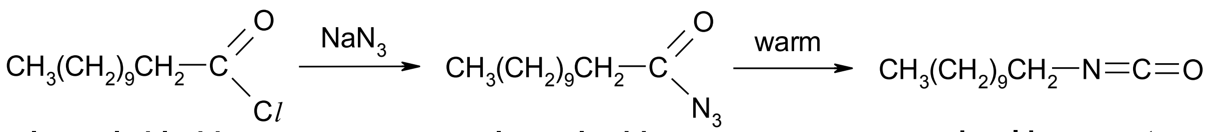
……………………………………………………………………………………………

For Examiner's Use

(v) Construct a balanced equation for the third reaction.

……………………………………………………………………………………[6]

Sodium azide is also used in the following synthesis of undecyl isocyanate from lauroyl chloride.



lauroyl chloride **lauroyl azide** **undecyl isocyanate**

(b) **(i)** Suggest the identity of the gas evolved in the conversion of lauroyl azide to undecyl isocyanate.

……………………………………………………………………………………

(ii) Lauroyl chloride can be obtained from the reaction between lauric acid, $CH_3(CH_2)_9CH_2CO_2H$, and thionyl chloride, $SOCl_2$.

Give the structural formula of the organic product formed when lauric acid is treated with lithium aluminium hydride.

[2]

(c) In aqueous solutions, azide ions partially ionise as shown by the following equilibrium.

$$N_3^- + H_2O \rightleftharpoons HN_3 + OH^-$$

(i) Is azide ion behaving as an acid or a base? Explain your answer using the Brønsted-Lowry theory of acids and bases.

……………………………………………………………………………………

……………………………………………………………………………………

(ii) The structure of the azide ion is given below.

$$^-N=\overset{+}{N}=N^-$$

State the shape of the ion around the central N atom.

……………………………………………………………………………………[2]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** **(i)** Describe what is observed during the combustion in oxygen of magnesium, writing an equation for the reaction.

(ii) Write an equation, with state symbols, for the reaction of sodium oxide with water. Hence calculate the pH of the resulting solution when 0.35 g of sodium oxide is added to 1 dm^3 of water.

[6]

(b) An important step in the contact process is the conversion of sulfur dioxide to sulfur trioxide as shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

Industrially, this reaction is carried out at 450 °C and at a pressure of 1-2 atm in the presence of vanadium(V) oxide, V_2O_5.

(i) State Le Chatelier's Principle.

(ii) Would the production of sulfur trioxide be favoured by a high or low temperature? Explain your reasoning.

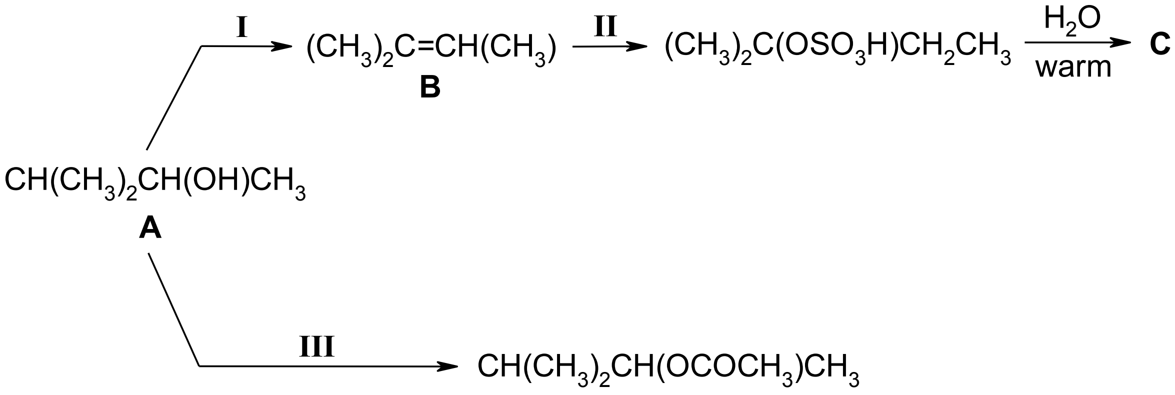
Hence comment on the significance of the operating temperature.

(iii) Suggest the role of vanadium(V) oxide in the above reaction.

(iv) State the shape around the central atom of sulfur dioxide and suggest a value for its bond angle.

[7]

(c) The following organic reactions (**I**, **II** and **III**) involve the use of concentrated sulfuric acid.



(i) State the conditions required for reactions **I** and **II**.

(ii) Suggest the structural formula of an organic impurity that might be found in the product of reaction **I**.

(iii) Name the organic reagent used in reaction **III**.

(iv) Give the displayed formula of the organic compound **C**.

(v) Draw the structural isomer of **B** that exhibits cis-trans isomerism.

(vi) Give the structure of the organic product formed when **A** is heated under reflux with a mixture of concentrated sulfuric acid and NaBr.

[7]

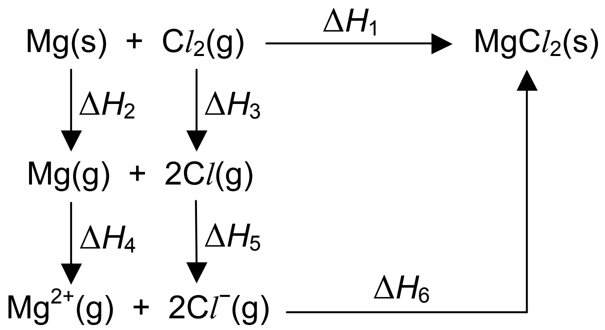
[Total: 20]

6 (a) (i) Describe **one** physical property of the chlorides of sodium and phosphorus and the reactions, if any, of these chlorides with water. Give equations where appropriate.

(ii) Relate the structures of, and bonding in, these chlorides to their physical property and reaction with water.

[5]

(b) The lattice energy of magnesium chloride can be determined using the energy cycle given below.



(i) Explain what is meant by the term *lattice energy of magnesium chloride*.

(ii) Name the enthalpy change represented as ΔH_1.

(iii) Use relevant bond energy and ionisation energy values from the *Data Booklet* to determine the values of ΔH_3 and ΔH_4.

(iv) Hence calculate the lattice energy of magnesium chloride given the following data.

$\Delta H_1 = -642$ kJ mol^{-1}
$\Delta H_2 = +148$ kJ mol^{-1}
$\Delta H_5 = -698$ kJ mol^{-1}

[5]

(c) **J** is an aromatic compound with the molecular formula $C_8H_{10}O$. When **J** is heated with acidified potassium dichromate(VI), the orange solution turned green and **K** is produced. When warmed with alkaline aqueous iodine, both **J** and **K** gave pale yellow precipitate. Treatment of **K** with HCN and a trace amount of NaCN produced **L**. Heating **L** under reflux with H_2SO_4(aq) formed **M** which liberates carbon dioxide gas from $NaHCO_3$.

Draw a structural formula for **each** of the organic compounds **J** – **M** and write equations where appropriate to show the reactions that are occurring. Clearly show the deductions that you make from the information that you have been given: full marks cannot be gained by only giving the structures required.

[10]

[Total: 20]

7 **(a)** Consider the following oxides and chlorides of period three elements.

$$Al_2O_3,\ AlCl_3,\ SiO_2,\ SiCl_4,\ P_4O_{10},\ SO_2$$

(i) Identify, with reason(s), one compound above which is insoluble in water.

(ii) White fumes were produced when compound **X** was added to water and a red solution was formed on adding Universal Indicator to the resulting solution. Identify **X** from the compounds above and account for the observations. Include suitable equation(s) in your answer.

(iii) One of the oxides above is amphoteric in nature. Illustrate the property of this oxide by the use of relevant equations.

(iv) Identify the element having the highest oxidation state in the compounds above and write its oxidation number.

[6]

(b) The following experimental procedure was carried out to determine the mass of calcium carbonate (a weak base) in a sample of chalk powder.

25.0 cm^3 of 0.160 mol dm^{-3} $HCl(aq)$ was added in excess to 0.12 g of chalk powder in a 250 cm^3 conical flask. The resulting solution in the conical flask was then titrated with 0.100 mol dm^{-3} $NaOH(aq)$. 21.40 cm^3 of $NaOH(aq)$ was required to reach the end-point using phenolphthalein as indicator.

(i) Calculate the number of moles of HCl neutralised by NaOH.

(ii) Calculate the initial number of moles of HCl added to the chalk powder and hence determine the number of moles of HCl that reacted with $CaCO_3$ found in the sample.

(iii) Construct a balanced equation, with state symbols, for the reaction between HCl and $CaCO_3$.

Hence find the mass of $CaCO_3$ present in the sample using your answer to **(b)(ii)**.

[4]

(c) Consider the following equilibrium.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(i) Using suitable values from the *Data Booklet*, calculate the enthalpy change of the reaction.

(ii) State and explain the effect of a catalyst on the equilibrium composition.

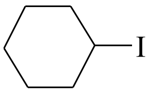
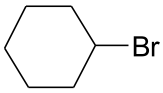
(iii) On the same axes, sketch the energy profile diagram for the reaction when it is uncatalysed and catalysed respectively.

[6]

(d) Describe, with the aid of equations, the role of the H_2CO_3/HCO_3^- buffer system in controlling the pH of blood.

[2]

(e) Describe a simple chemical test to distinguish the pair of compounds below.

 and 

[2]

[Total: 20]