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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 **18** 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*.

Relative atomic mass is defined as the ratio of the average mass of one atom of an element to $\frac{1}{12}$ the mass of an atom of ^{12}C isotope, expressed on the ^{12}C scale. [1]

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

A_r of Lu = $\frac{97.4 \times 175 + 2.6 \times 176}{100} = 175.0$ [1]

[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.

number of half-lives = $\frac{1.134 \times 10^{11}}{3.78 \times 10^{10}} = 3$

% of sample remaining = $100 \times \left(\frac{1}{2}\right)^3 = 12.5\,\%$ [2]

[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.

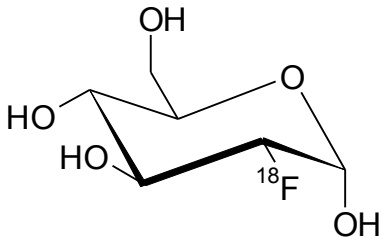
Isotope	Number of protons	Number of neutrons
^{131}I	53	78
^{32}P	15	17

[1]

[1]

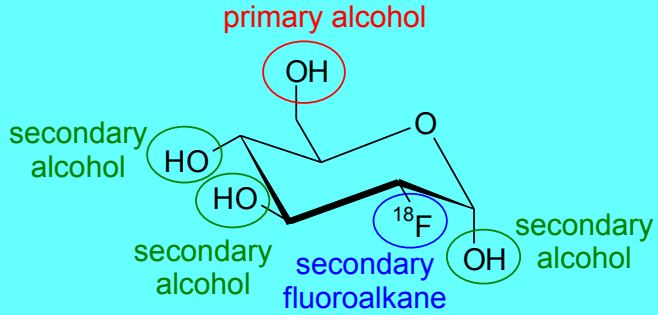
Radioactive isotopes are commonly incorporated into compounds to trace the path of biochemical reactions. These compounds are known as radioactive tracers.

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.



[2]

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

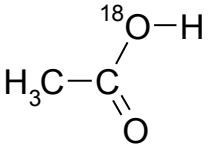
M_r of ^{18}F-FDG = $6\times12.0+5\times16.0+1\times18+11\times1.0=181$

% composition by mass of C in ^{18}F-FDG = $\frac{6\times12.0}{181}\times100\%=39.8\%$ [2]

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

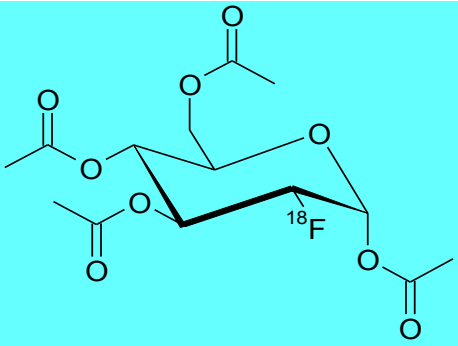
Yes, ^{18}F-FDG is expected to be soluble in water because it has many –OH groups which are capable of forming hydrogen bonds with water. [1]

(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.

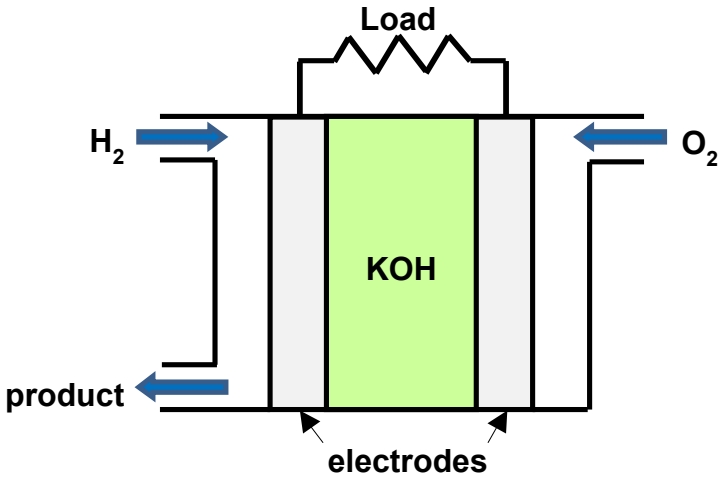
[7]



Reaction Type: Condensation (or addition-elimination) [2]

[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

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

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

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

Oxidation: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ (×2)
Reduction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (×1)
Overall: $2H_2 + O_2 \rightarrow 2H_2O$ [2]

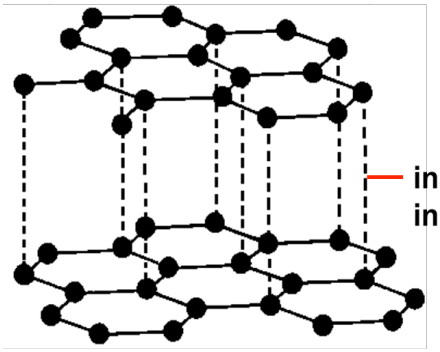
(ii) Use oxidation numbers to show which species in your equation is reduced and which is oxidised.

H_2 is oxidised as the oxidation number of H increases from 0 in H_2 to +1 in H_2O.
O_2 is reduced as the oxidation number of O decreases from 0 in O_2 to −2 in H_2O. [2]

[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.



Graphite

[3]

Description:

- Graphite has a giant molecular layered structure
- Within each layer, each C atom uses three out of its four valence electrons to form covalent bonds with three other C atoms in a trigonal planar arrangement to form hexagonal rings
- The 4th valence electron is delocalized over the whole layer
- The layers are held together by weak instantaneous dipole – induced dipoles attractions

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

Property Conducts electricity in the solid state.

explanation The delocalised electrons along the graphite layers can act as mobile charge carriers to conduct electricity.

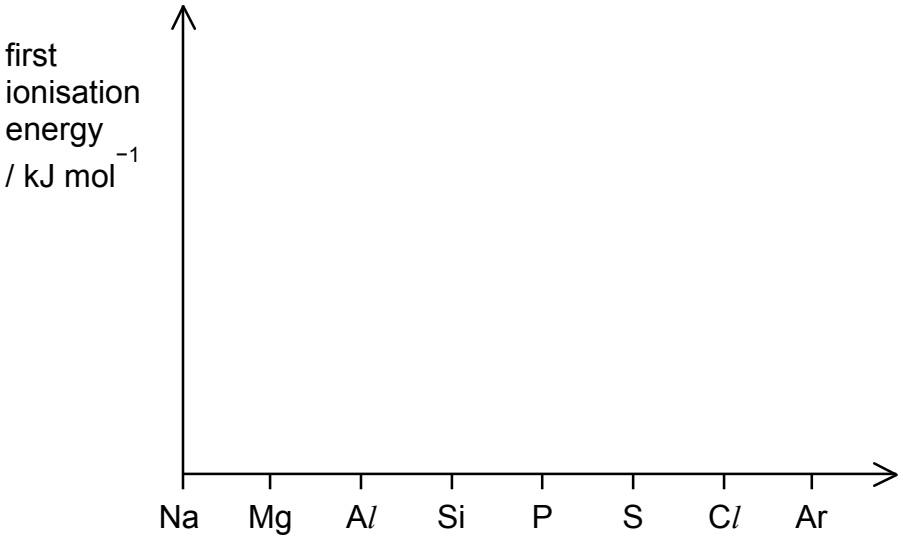
[1]

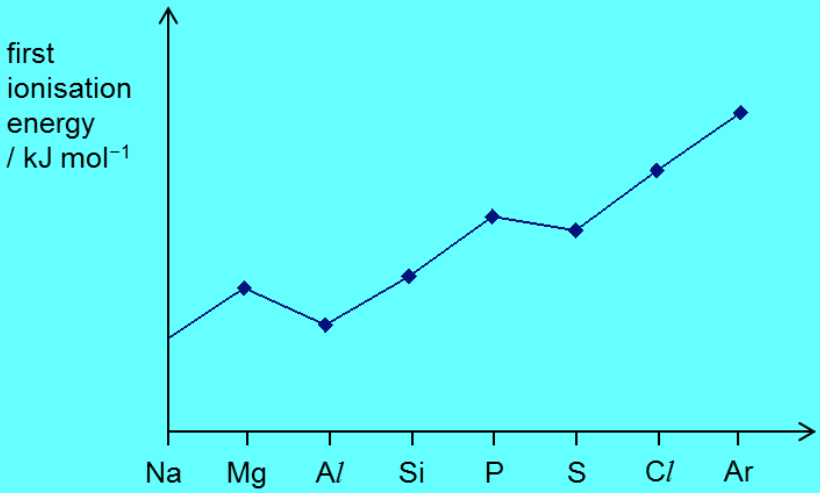
[4]

[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.





[1]

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

Across the period, nuclear charge increases while screening effect remains relatively constant. Thus effective nuclear charge increases and the valence electrons are more strongly attracted by the nucleus. Hence more energy is required to remove an electron and ionisation energy increases.

[1]

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

The 3*p* electron to be removed from S is paired and experiences inter-electronic repulsion whereas the 3*p* electron to be removed from P is unpaired. Thus less energy is required to remove the 3*p* electron from S and S has a lower ionisation energy than P.

[1]

[3]

(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:

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

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

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

$$[SO_2Cl_2] = \frac{14.6}{32.1 + 2\times16.0 + 2\times35.5} = \frac{14.6}{135.1} = 0.108 \text{ mol dm}^{-3}$$

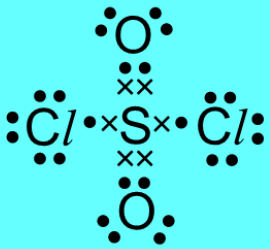
$$[SO_2] = \frac{3.33}{32.1 + 2\times16.0} = \frac{3.33}{64.1} = 0.0520 \text{ mol dm}^{-3}$$

$$[Cl_2] = \frac{11.5}{2\times35.5} = \frac{11.5}{71} = 0.162 \text{ mol dm}^{-3}$$

$$K_c = \frac{[SO_2][Cl_2]}{[SO_2Cl_2]} = \frac{(0.0520)(0.162)}{(0.108)} = 0.0780 \text{ mol dm}^{-3}$$

[3]

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



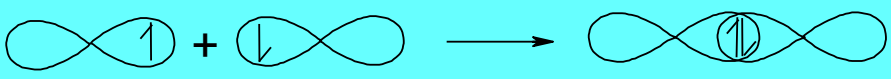
[1]

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

$1s^2$ $2s^22p^63s^23p^5$ [1]

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

In the Cl_2 molecule, the two Cl atoms are covalently bonded via a sigma bond which is formed from the head-on overlap of 3p orbitals.



3p orbital of Cl atom + 3p orbital of Cl atom → head-on overlap to form sigma bond

[2]

[7]

[Total: 10]

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.

$$\eta(NaN_3) = \frac{110}{23.0 + 3 \times 14.0} = \frac{110}{65.0} = 1.69 \text{ mol}$$

$$Na \equiv NaN_3$$

$$\eta(Na) = \eta(NaN_3) = 1.69 \text{ mol}$$

$$3N_2 \equiv 2NaN_3$$

$$\eta(N_2) = \frac{3}{2} \times \eta(NaN_3) = \frac{3}{2} \times 1.69 = 2.54 \text{ mol}$$

[2]

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

$$10Na \equiv N_2$$

$$\eta(N_2) = \frac{1}{10} \times \eta(Na) = \frac{1}{10} \times 1.69 = 0.169 \text{ mol}$$

[1]

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

Total volume of N_2 = $(2.54 + 0.169) \times 24 = 65.0 \text{ dm}^3$ [1]

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

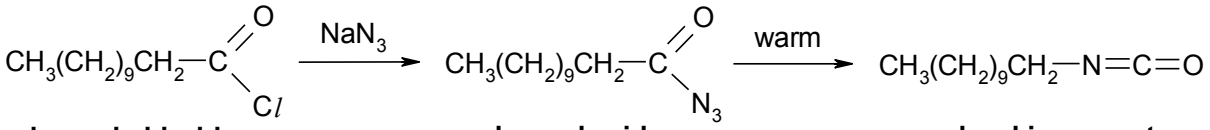
Sodium azide was completely decomposed/ No loss of nitrogen gas from the airbag [1]

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

$K_2O + Na_2O + 2SiO_2 \rightarrow K_2SiO_3 + Na_2SiO_3$ [1]

[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.

N_2 or nitrogen [1]

(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.

$CH_3(CH_2)_9CH_2CH_2OH$ [1]

[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.

Azide ion is a base because it accepts a proton from H_2O. [1]

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

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

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

Linear [1]

[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.

Mg burns with blinding white light.

$2Mg + O_2 \rightarrow 2MgO$

(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.

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

$$\eta(Na_2O) = \frac{0.35}{2\times 23.0 + 16.0} = \frac{0.35}{62.0} = 5.65\times 10^{-3} \text{ mol}$$

$2NaOH \equiv Na_2O$

$$n(NaOH) = 2\times n(Na_2O) = 2\times 5.65\times 10^{-3} = 0.0113 \text{ mol}$$

$$[OH^-] = [NaOH] = 0.0113 \text{ mol dm}^{-3}$$

$$pOH = -\lg[OH^-] = -\lg(0.0113) = 1.95$$

$$pH = 14 - pOH = 14 - 1.95 = 12.05$$

[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.

Le Chatelier's Principle states that when a system at equilibrium is subjected to a change (disturbance), the system responds in such a way as to counteract the imposed change and re-establish the equilibrium state.

(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.

The production of sulfur trioxide would be favoured by a low temperature. By Le Chatelier's principle, a low temperature will favour the forward reaction which is exothermic to increase the temperature. Thus the position of equilibrium shifts to the right and more sulfur trioxide will be produced.

A moderate operating temperature of 450 °C was used instead of a lower temperature so that the rate of reaction will not be too slow.

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

Vanadium(V) oxide acts as a catalyst for the reaction.

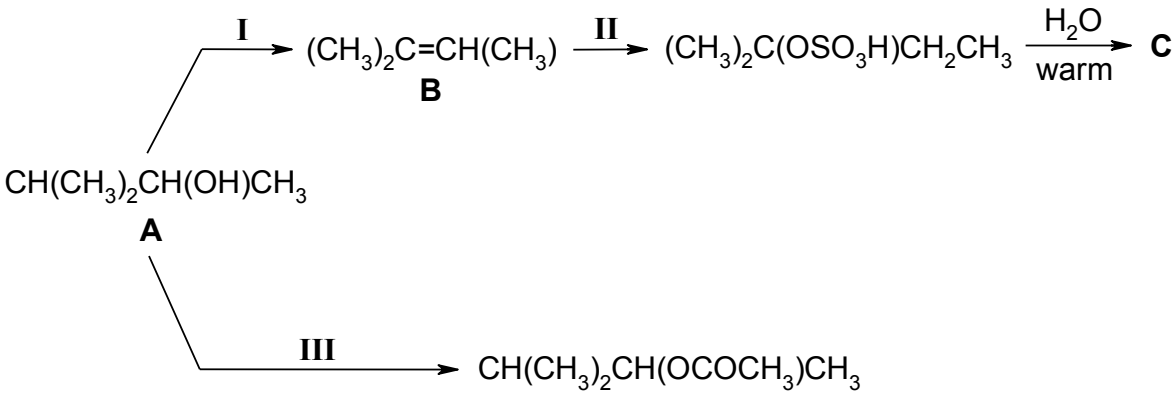
(iv) State the shape around the central atom of sulfur dioxide and suggest a value for its bond angle.

Shape: bent

Bond angle: any value between 110° and 119° inclusive

[7]

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

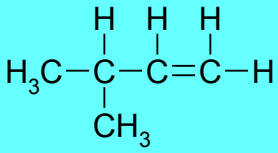


(i) State the conditions required for reactions **I** and **II**.

reaction **I**: excess concentrated sulfuric acid, 170 °C

reaction **II**: cold

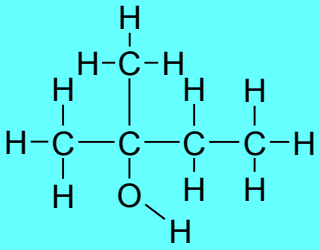
(ii) Suggest the structural formula of an organic impurity that might be found in the product of reaction **I**.



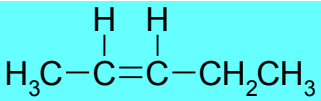
(iii) Name the organic reagent used in reaction **III**.

ethanoic acid

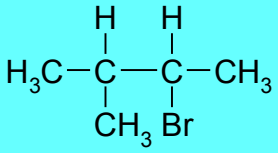
(iv) Give the displayed formula of the organic compound **C**.



(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.

Physical Property of chlorides:

- NaC*l* has high melting and boiling points while P$C l_3$ / P$C l_5$ has low melting and boiling points OR
- Both NaC*l* and P$C l_3$ / P$C l_5$ do not conduct electricity in the solid state.

Reactions of chlorides with water:

- NaC*l*(s) dissolves in water to form a neutral solution.
  NaC*l*(s) + aq → NaC*l*(aq)

- P$C l_3$ / P$C l_5$ reacts with water to form white fumes (of HC*l*) and a strongly acidic solution.
  $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ or $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

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

Physical Property of chlorides:

- NaC*l* has high melting and boiling points while P$C l_3$ / P$C l_5$ has low melting and boiling points.
  This is because NaC*l* has a giant ionic structure with strong ionic bonds between oppositely charged Na^+ and Cl^- ions whereas P$C l_3$ / P$C l_5$ has a simple molecular structure with weak van der Waals' forces between its molecules.
  More energy is required to overcome the strong ionic bonds than the weak van der Waals' forces during melting and boiling.

OR

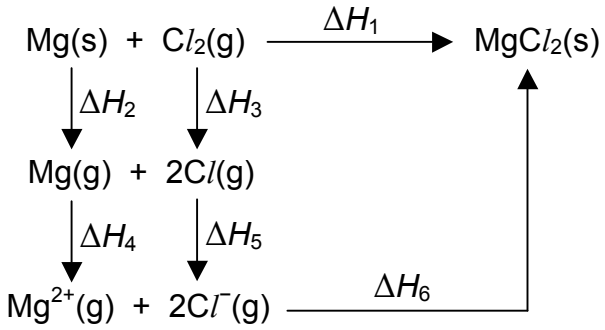
- Both NaC*l* and P$C l_3$ / P$C l_5$ do not conduct electricity in the solid state.
  This is due to the absence of mobile ions and delocalised electrons in NaC*l*(s) and P$C l_3$ / P$C l_5$ to act as mobile charge carriers to conduct electricity.

Reactions of chlorides with water:

- NaC*l*(s) has strong electrostatic forces of attraction between the Na^+ and Cl^- ions. It dissolves in water to give Na^+(aq) and Cl^-(aq) ions.
- P$C l_3$ / P$C l_5$ has weak van der Waals' forces between its molecules. It is hydrolysed by 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*.

It is the heat evolved when one mole of solid magnesium chloride is formed from its constituent gaseous Mg^{2+} and Cl^- ions under standard conditions of 298 K and 1 atm.

(ii) Name the enthalpy change represented as ΔH_1.

Enthalpy change of formation of $MgCl_2(s)$

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

ΔH_3 = bond energy of chlorine = +244 kJ mol^{-1}

ΔH_4 = sum of 1st and 2nd ionisation energies of magnesium
= 736 + 1450 = +2186 kJ mol^{-1}

(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}

By Hess' law,
$\Delta H_1 = \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6$

Lattice energy of magnesium chloride
$= \Delta H_6$
$= \Delta H_1 - (\Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5)$
$= -642 - (148 + 244 + 2186 - 698) = -2522 \approx -2520$ kJ mol^{-1}

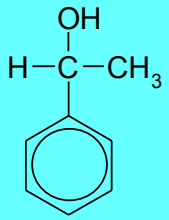
[5]

(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.

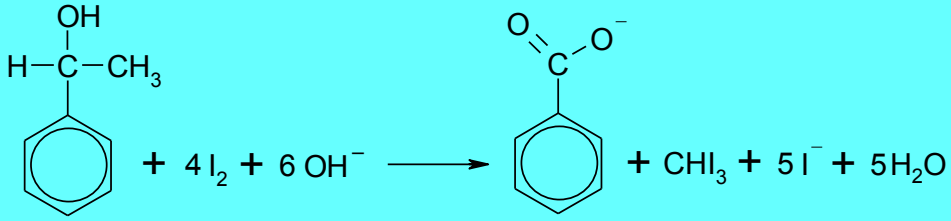
- **J** is an aromatic compound with the molecular formula $C_8H_{10}O$
  ⇒ **J** contains a benzene ring

- **J** undergoes oxidation with alkaline aqueous iodine to give pale yellow ppt
  ⇒ **J** contains the $-CH(OH)CH_3$ group
  ⇒ **J** has the structure shown below
  ⇒ **J** contains a secondary alcohol functional group



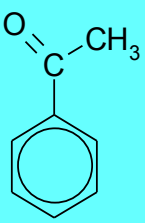
J

Equation:



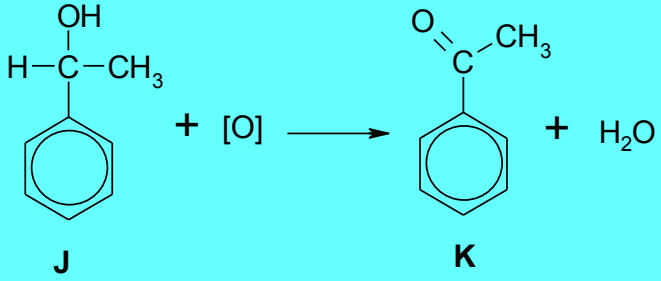
J

- **J** undergoes oxidation with $K_2Cr_2O_7/H^+$ to produce **K** which undergoes oxidation with alkaline aqueous iodine to give pale yellow ppt
  ⇒ **K** has a ketone functional group and contains the $-COCH_3$ group
  ⇒ **K** has the structure shown below.

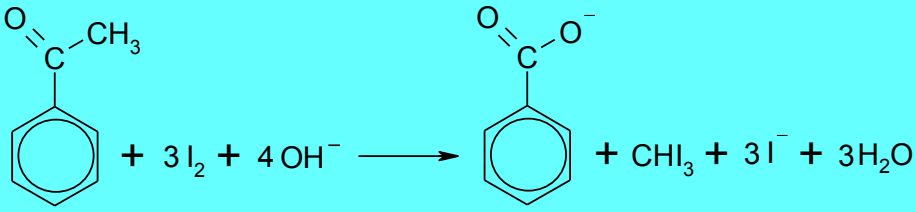


K

Equations:

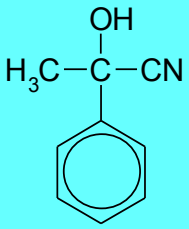


J **K**



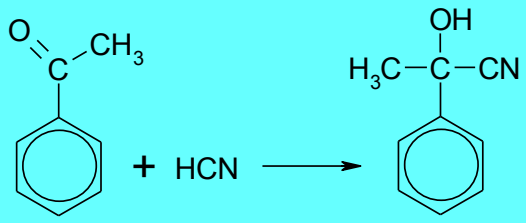
K

- **K** undergoes nucleophilic addition with HCN to produce **L**
  ⇒ **L** is a cyanohydrin which has the structure shown below.



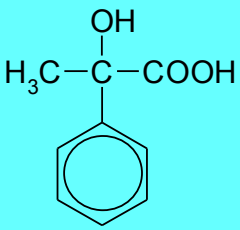
L

Equation:



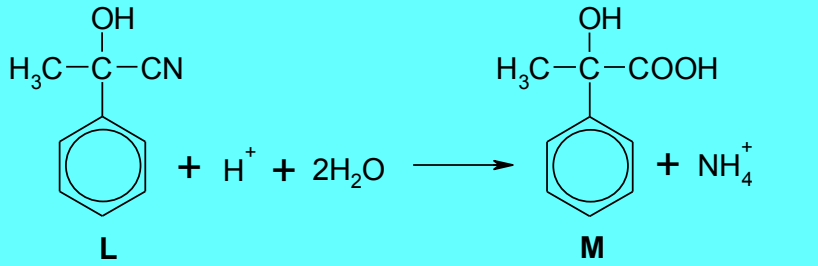
K **L**

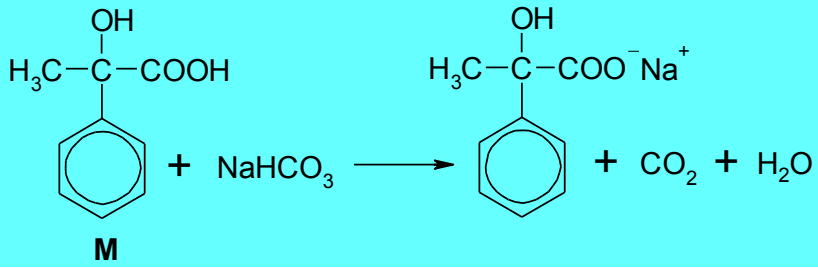
- **L** undergoes acid hydrolysis with $H_2SO_4(aq)$ to produce **M** which undergoes acid-base reaction with $NaHCO_3$ to liberate carbon dioxide gas.
  ⇒ **M** contains a carboxylic acid functional group and has the structure shown below.



M

Equations:





[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.

- Al_2O_3; it has high lattice energy which requires a large amount of energy to overcome OR
- SiO_2; it has a giant molecular structure with numerous strong covalent bonds which require a lot of energy to break

(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.

X is $SiCl_4$.

- The white fumes observed on adding **X** to water were due to the $HCl(g)$ evolved.

$$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$$

- The $HCl(g)$ produced readily ionises in water to give $H^+(aq)$ ions, making the solution strongly acidic. Thus the universal indicator turns red.

$$HCl(g) + aq \rightarrow HCl(aq)$$

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

- Al_2O_3 is the amphoteric oxide.
- Equations:

  $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

  $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$

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

Phosphorus.

Oxidation number of P in P_4O_{10} is +5.

[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} HC*l*(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 HC*l* neutralised by NaOH.

$HCl \equiv NaOH$

$$\eta(\text{HCl}) \text{ neutralised } = \eta(\text{NaOH}) = \frac{21.40}{1000} \times 0.100 = 0.00214 \text{ mol}$$

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

$$\text{Initial } \eta(\text{HCl}) = \frac{25.0}{1000} \times 0.160 = 0.00400 \text{ mol}$$

η(HCl) that reacted with $CaCO_3$ = 0.00400 − 0.00214 = 0.00186 mol

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

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

$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

$CaCO_3 \equiv 2HCl$

$$\eta(CaCO_3) = \frac{1}{2} \times \eta(\text{HCl}) = \frac{1}{2} \times 0.00186 = 9.30 \times 10^{-4} \text{ mol}$$

$$\text{mass of } CaCO_3 = \left(9.30 \times 10^{-4}\right)\left(40.1 + 12.0 + 3 \times 16.0\right) = 0.0931 \text{ g}$$

[4]

(c) Consider the following equilibrium.

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

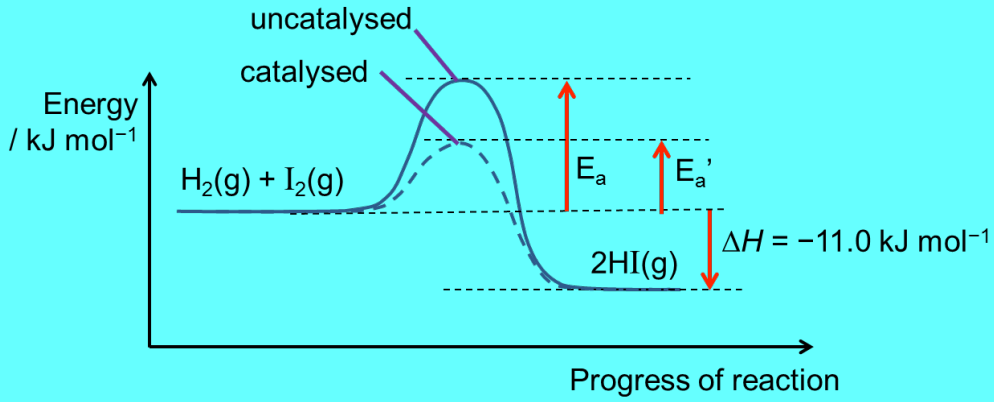
(i) Using suitable values from the *Data Booklet*, calculate the enthalpy change of the reaction.

$$\Delta H = \sum \text{BE(bonds broken)} - \sum \text{BE(bonds formed)}$$
$$= \left(1 \times \text{BE(H – H)} + 1 \times \text{BE(I – I)}\right) - \left(2 \times \text{BE(H – I)}\right)$$
$$= (436 + 151) - (2 \times 299)$$
$$= -11.0 \text{ kJ mol}^{-1}$$

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

The equilibrium composition remains unchanged in the presence of a catalyst. This is because both the rates of the forward and backward reactions will increase to the same extent.

(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.

When a small amount of acid is added, it is removed by HCO_3^-.

$$H^+ + HCO_3^- \rightarrow H_2CO_3$$

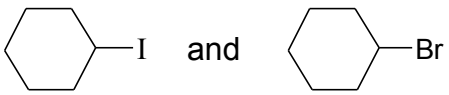
When a small amount of base is added, it is removed by H_2CO_3.

$$OH^- + H_2CO_3 \rightarrow HCO_3^- + H_2O$$

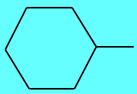
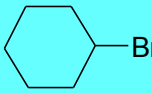
Therefore, pH of blood remains fairly constant.

[2]

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



To separate samples of the two compounds, add NaOH(aq) and heat. Then acidify with excess HNO_3(aq) followed by the addition of $AgNO_3$(aq).

Compound	Observations
	Yellow ppt is formed.
	Cream ppt is formed.

[2]

[Total: 20]