Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Thursday 5 November 2020 (afternoon)

Candidate session number

1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

8820 – 6105

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Chlorine undergoes many reactions.

(a) (i) State the full electron configuration of the chlorine atom. [1]

. . . . . .

. . . . . .

(ii) State, giving a reason, whether the chlorine atom or the chloride ion has a larger radius. [1]

. . . . . .

. . . . . .

. . . . . .

(iii) Outline why the chlorine atom has a smaller atomic radius than the sulfur atom. [2]

. . . . . .

. . . . . .

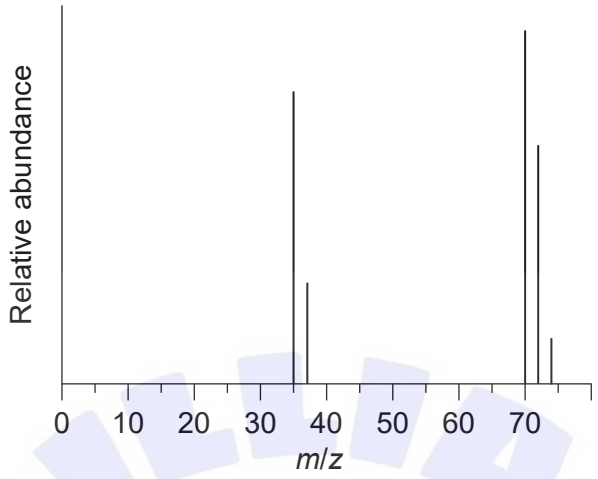
. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(iv) The mass spectrum of chlorine is shown.



Outline the reason for the two peaks at $m/z = 35$ and 37. [1]

. . . . . .

. . . . . .

(v) Explain the presence and relative abundance of the peak at $m/z = 74$. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) 2.67 g of manganese(IV) oxide was added to 200.0 cm^3 of 2.00 mol dm^{-3} HCl.

$$MnO_2(s) + 4HCl(aq) \rightarrow Cl_2(g) + 2H_2O(l) + MnCl_2(aq)$$

(i) Calculate the amount, in mol, of manganese(IV) oxide added. [1]

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(ii) Determine the limiting reactant, showing your calculations. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) Determine the excess amount, in mol, of the other reactant. [1]

. . . . . .

. . . . . .

(iv) Calculate the volume of chlorine, in dm^3, produced if the reaction is conducted at standard temperature and pressure (STP). Use section 2 of the data booklet. [1]

. . . . . .

. . . . . .

. . . . . .

(v) State the oxidation state of manganese in MnO_2 and $MnCl_2$. [2]

MnO_2:

. . . . . .

$MnCl_2$:

. . . . . .

(vi) Deduce, referring to oxidation states, whether MnO_2 is an oxidizing or reducing agent. [1]

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(c) Chlorine gas reacts with water to produce hypochlorous acid and hydrochloric acid.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

(i) Hypochlorous acid is considered a weak acid. Outline what is meant by the term weak acid. [1]

. . . . . .

. . . . . .

(ii) State the formula of the conjugate base of hypochlorous acid. [1]

. . . . . .

(iii) Calculate the concentration of $H^+(aq)$ in a $HClO(aq)$ solution with a pH = 3.61. [1]

. . . . . .

. . . . . .

(d) (i) State the type of reaction occurring when ethane reacts with chlorine to produce chloroethane. [1]

. . . . . .

(ii) Predict, giving a reason, whether ethane or chloroethane is more reactive. [1]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(iii) Write the equation for the reaction of chloroethane with a dilute aqueous solution of sodium hydroxide. [1]

. . . . . .

. . . . . .

(iv) Deduce the nucleophile for the reaction in d(iii). [1]

. . . . . .

(v) Ethoxyethane (diethyl ether) can be used as a solvent for this conversion. Draw the structural formula of ethoxyethane. [1]

(vi) Deduce the number of signals and their chemical shifts in the ^{1}H NMR spectrum of ethoxyethane. Use section 27 of the data booklet. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(e) CCl_2F_2 is a common chlorofluorocarbon, CFC.

(i) Calculate the percentage by mass of chlorine in CCl_2F_2. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Comment on how international cooperation has contributed to the lowering of CFC emissions responsible for ozone depletion. [1]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

2. Compound **A** is in equilibrium with compound **B**.

(a) Predict the electron domain and molecular geometries around the **oxygen** atom of molecule **A** using VSEPR. [2]

Electron domain geometry:

. . . . . .

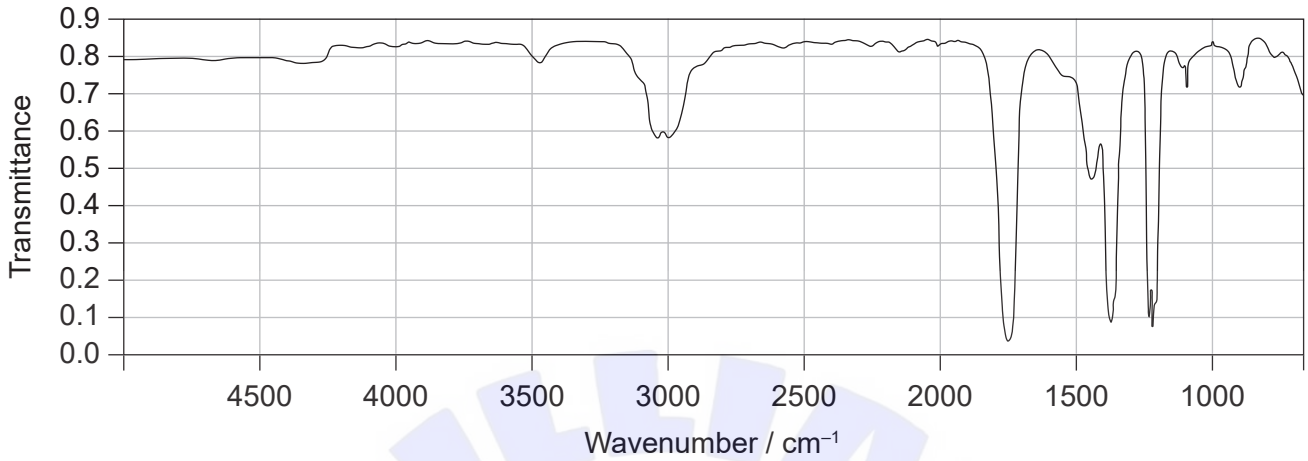
Molecular geometry:

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(b) The IR spectrum of one of the compounds is shown:



Deduce, giving a reason, the compound producing this spectrum. [1]

. . . . . .

. . . . . .

. . . . . .

(c) Compound **A** and **B** are isomers. Draw two other structural isomers with the formula C_3H_6O. [2]

(This question continues on the following page)

(Question 2 continued)

(d) The equilibrium constant, K_c, for the conversion of **A** to **B** is 1.0×10^8 in water at 298 K.

Deduce, giving a reason, which compound, **A** or **B**, is present in greater concentration when equilibrium is reached. [1]

. . . . . .

. . . . . .

. . . . . .

3. An equation for the combustion of propane is given below.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

(a) Determine the standard enthalpy change, $\Delta H^{\ominus}$, for this reaction, using section 11 of the data booklet. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Calculate the standard enthalpy change, $\Delta H^{\ominus}$, for this reaction using section 12 of the data booklet. [2]

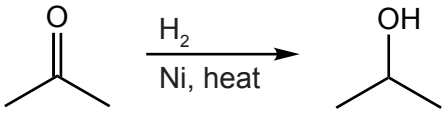
. . . . . .

. . . . . .

. . . . . .

. . . . . .

4. Nickel catalyses the conversion of propanone to propan-2-ol.



(a) Outline how a catalyst increases the rate of reaction. [1]

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

(b) Explain why an increase in temperature increases the rate of reaction. [2]

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

(c) Discuss, referring to intermolecular forces present, the relative volatility of propanone and propan-2-ol. [3]

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

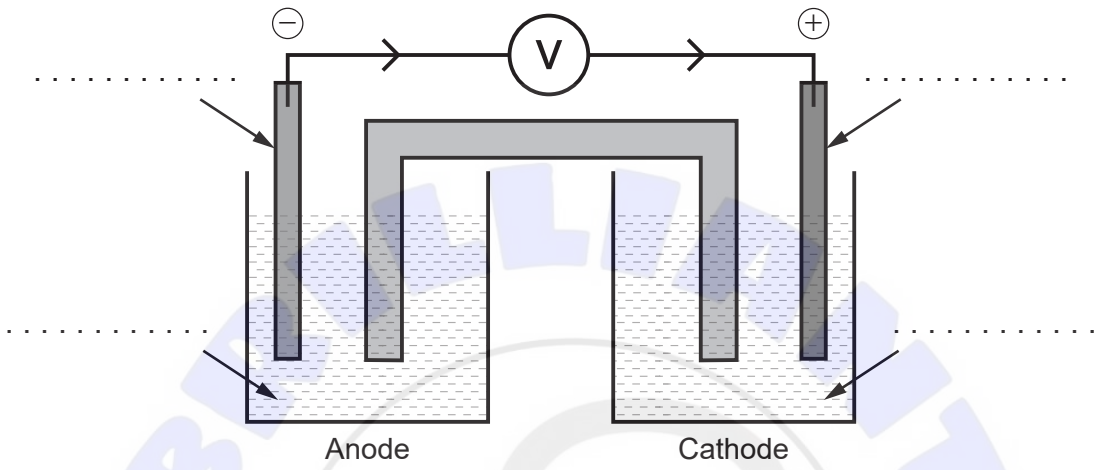
(This question continues on the following page)

(Question 4 continued)

(d) (i) The diagram shows an unlabelled voltaic cell for the reaction

$$Pb^{2+}(aq) + Ni(s) \rightarrow Ni^{2+}(aq) + Pb(s)$$

Label the diagram with the species in the equation. [1]



(ii) Suggest a metal that could replace nickel in a new half-cell and reverse the electron flow. Use section 25 of the data booklet. [1]

. . . . . .

(iii) Describe the bonding in metals. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iv) Nickel alloys are used in aircraft gas turbines. Suggest a physical property altered by the addition of another metal to nickel. [1]

. . . . . .

. . . . . .

References:

1.(a)(iv) NIST Mass Spectrometry Data Center Collection © 2014 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.

2.(b) COBLENTZ SOCIETY. Collection © 2018 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.