Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 18 May 2022 (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]**.

2222–6111

13 pages

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

1. When heated in air, magnesium ribbon reacts with oxygen to form magnesium oxide.

(a) (i) Write a balanced equation for the reaction that occurs. [1]

. . . . . .

. . . . . .

(ii) State the block of the periodic table in which magnesium is located. [1]

. . . . . .

(iii) Identify a metal, in the same period as magnesium, that does **not** form a basic oxide. [1]

. . . . . .

(b) The reaction in (a)(i) was carried out in a crucible with a lid and the following data was recorded:

Mass of crucible and lid = 47.372 ±0.001 g

Mass of crucible, lid and magnesium ribbon before heating = 53.726 ±0.001 g

Mass of crucible, lid and product after heating = 56.941 ±0.001 g

(i) Calculate the amount of magnesium, in mol, that was used. [1]

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(ii) Determine the percentage uncertainty of the mass of product after heating. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) Assume the reaction in (a)(i) is the only one occurring and it goes to completion, but some product has been lost from the crucible. Deduce the percentage yield of magnesium oxide in the crucible. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) When magnesium is burnt in air, some of it reacts with nitrogen to form magnesium nitride according to the equation:

$$3\,Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$

(i) Evaluate whether this, rather than the loss of product, could explain the yield found in (b)(iii). [1]

. . . . . .

. . . . . .

. . . . . .

(ii) Suggest an explanation, other than product being lost from the crucible or reacting with nitrogen, that could explain the yield found in (b)(iii). [1]

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(d) The presence of magnesium nitride can be demonstrated by adding water to the product. It is hydrolysed to form magnesium hydroxide and ammonia.

(i) Calculate coefficients that balance the equation for the following reaction. [1]

$$\_\_\ Mg_3N_2(s) + \_\_\ H_2O(l) \rightarrow \_\_\ Mg(OH)_2(s) + \_\_\ NH_3(aq)$$

(ii) Determine the oxidation state of nitrogen in Mg_3N_2 and in NH_3. [1]

Mg_3N_2: . . . . . .

NH_3: . . . . . .

(iii) Deduce, giving reasons, whether the reaction of magnesium nitride with water is an acid–base reaction, a redox reaction, neither or both. [2]

Acid–base: ☐ Yes ☐ No

Reason: . . . . . .

. . . . . .

. . . . . .

Redox: ☐ Yes ☐ No

Reason: . . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(e) Most nitride ions are $^{14}N^{3-}$.

(i) State the number of subatomic particles in this ion. [1]

Protons: . . . . . .

Neutrons: . . . . . .

Electrons: . . . . . .

(ii) Some nitride ions are $^{15}N^{3-}$. State the term that describes the relationship between $^{14}N^{3-}$ and $^{15}N^{3-}$. [1]

. . . . . .

(iii) The nitride ion and the magnesium ion are isoelectronic (they have the same electron configuration). Determine, giving a reason, which has the greater ionic radius. [1]

. . . . . .

. . . . . .

(f) Suggest **two** reasons why atoms are no longer regarded as the indivisible units of matter. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

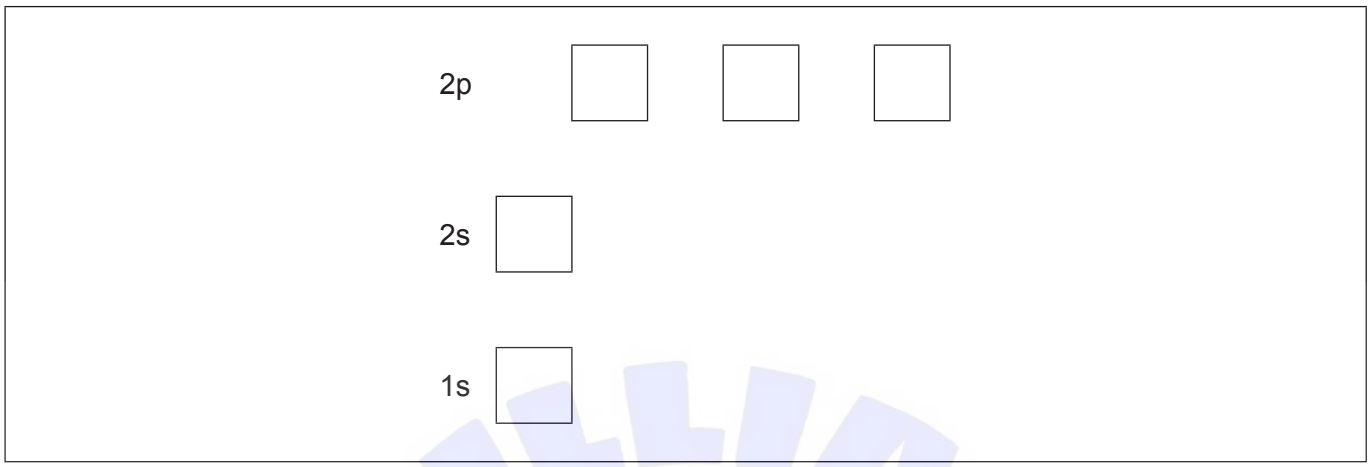
(Question 1 continued)

(g) State the types of bonding in magnesium, oxygen and magnesium oxide, and how the valence electrons produce these types of bonding. [4]

Substance	Bond type	How the valence electrons produce these bonds
Magnesium	. . . .	. . . .
Oxygen	. . . .	. . . .
Magnesium oxide	. . . .	. . . .

2. Ammonia, NH_3, is industrially important for the manufacture of fertilizers, explosives and plastics.

(a) Draw arrows in the boxes to represent the electron configuration of a nitrogen atom. [1]



(b) Draw the Lewis (electron dot) structure of the ammonia molecule. [1]

(This question continues on the following page)

(Question 2 continued)

(c) Ammonia is produced by the Haber–Bosch process which involves the equilibrium:

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$

(i) Deduce the expression for the equilibrium constant, K_c, for this equation. [1]

. . . . . .

. . . . . .

. . . . . .

(ii) Explain why an increase in pressure shifts the position of equilibrium towards the products and how this affects the value of the equilibrium constant, K_c. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) State how the use of a catalyst affects the position of the equilibrium. [1]

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(d) The effect of temperature on the position of equilibrium depends on the enthalpy change of the reaction.

(i) Determine the enthalpy change, ΔH, for the Haber–Bosch process, in kJ. Use Section 11 of the data booklet. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Calculate the enthalpy change, $\Delta H^{\ominus}$, for the Haber–Bosch process, in kJ, using the following data.

$\Delta H_f^{\ominus}(NH_3) = -46.2\,kJ\ mol^{-1}$. [1]

. . . . . .

. . . . . .

(iii) Suggest why the values obtained in (d)(i) and (d)(ii) differ. [1]

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(e) Ammonia is soluble in water and forms an alkaline solution:

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + HO^-(aq)$$

(i) State the relationship between NH_4^+ and NH_3 in terms of the Brønsted–Lowry theory. [1]

. . . . . .

. . . . . .

(ii) Determine the concentration, in mol dm^{-3}, of the solution formed when 900.0 dm^3 of $NH_3(g)$ at 300.0 K and 100.0 kPa, is dissolved in water to form 2.00 dm^3 of solution. Use sections 1 and 2 of the data booklet. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) Calculate the concentration of hydroxide ions in an ammonia solution with pH = 9.3. Use sections 1 and 2 of the data booklet. [1]

. . . . . .

. . . . . .

. . . . . .

3. Magnesium is a reactive metal often found in alloys.

(a) Magnesium can be produced by the electrolysis of molten magnesium chloride. Write the half-equation for the formation of magnesium. [1]

. . . . . .

. . . . . .

(b) Suggest an experiment that shows that magnesium is more reactive than zinc, giving the observation that would confirm this. [2]

. . . . . .

. . . . . .

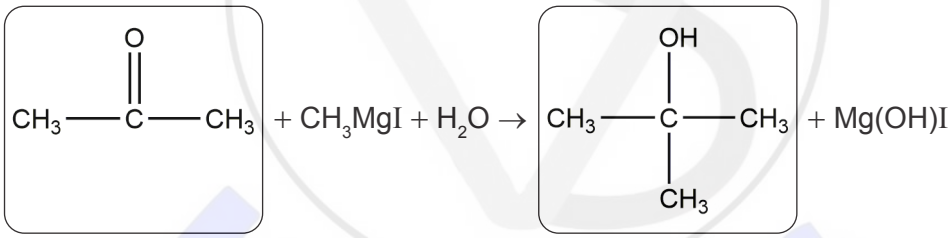
. . . . . .

. . . . . .

. . . . . .

(c) Organomagnesium compounds can react with carbonyl compounds. One overall equation is:

Compound A **Compound B**



(i) State the name of Compound A, applying International Union of Pure and Applied Chemistry (IUPAC) rules. [1]

. . . . . .

(ii) Identify the strongest force between the molecules of Compound B. [1]

. . . . . .

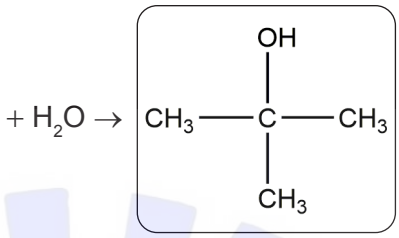
(This question continues on the following page)

(Question 3 continued)

(d) Compound B can also be prepared by reacting an alkene with water.

(i) Draw the structural formula of the alkene required. [1]

Compound B



(ii) Deduce the structural formula of the repeating unit of the polymer formed from this alkene. [1]

(e) Deduce what would be observed when Compound B is warmed with acidified aqueous potassium dichromate(VI). [1]

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 3 continued)

(f) Iodomethane is used to prepare CH_3MgI. It can also be converted into methanol:

$$CH_3I + HO^- \rightarrow CH_3OH + I^-$$

(i) Identify the type of reaction. [1]

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

(ii) Outline the requirements for a collision between reactants to yield products. [2]

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

(iii) The polarity of the carbon–halogen bond, C–X, facilitates attack by HO^-.
Outline, giving a reason, how the bond polarity changes going down group 17. [1]

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

References:

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.