Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 9 November 2022 (morning)

1 hour 15 minutes

Candidate session number

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]**.

8822–6105

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

1. Ammonium nitrate, NH_4NO_3, is used as a high nitrogen fertilizer.

(a) Calculate the percentage by mass of nitrogen in ammonium nitrate. Use section 6 of the data booklet. [1]

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(b) State, with a reason, whether the ammonium ion is a Brønsted-Lowry acid or base. [1]

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(c) Deduce the Lewis (electron dot) structure for the nitrate anion. [1]

(d) Calculate the pH of an ammonium nitrate solution with $[H_3O^+] = 1.07 \times 10^{-5}$ mol dm^{-3}. Use section 1 of the data booklet. [1]

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(Question 1 continued)

(e) Cold packs contain ammonium nitrate and water separated by a membrane.

(i) The mass of the contents of the cold pack is 25.32 g and its initial temperature is 25.2 °C. Once the contents are mixed, the temperature drops to 0.8 °C.

Calculate the energy, in J, absorbed by the dissolution of ammonium nitrate in water within the cold pack. Assume the specific heat capacity of the solution is $4.18\,J\,g^{-1}\,K^{-1}$. Use section 1 of the data booklet. [1]

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(ii) The change in enthalpy when ammonium nitrate dissolves in water is $25.69\,kJ\,mol^{-1}$. Determine the mass of ammonium nitrate in the cold pack using your answer obtained in (e)(i) and section 6 of the data booklet.

If you did not obtain an answer in (e)(i), use 3.11×10^3 J, although this is not the correct answer. [2]

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(iii) The absolute uncertainty in mass of the contents of the cold pack is ±0.01 g and in each temperature reading is ±0.2 °C. Using your answer in (e)(ii), calculate the absolute uncertainty in the mass of ammonium nitrate in the cold pack.

If you did not obtain an answer in (e)(ii), use 6.55 g, although this is not the correct answer. [3]

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(Question 1 continued)

(iv) The cold pack contains 9.50 g of ammonium nitrate. Calculate the percentage error in the experimentally determined mass of ammonium nitrate obtained in (e)(ii).

If you did not obtain an answer in (e)(ii), use 6.55 g, although this is not the correct answer. [1]

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(f) Solid ammonium nitrate can decompose to gaseous dinitrogen monoxide and liquid water.

(i) Write the chemical equation for this decomposition. [1]

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(ii) Calculate the volume of dinitrogen monoxide produced at STP when a 5.00 g sample of ammonium nitrate decomposes. Use section 2 of the data booklet. [2]

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(Question 1 continued)

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

$\Delta H_f^{\ominus}$ ammonium nitrate = –366 kJ mol^{-1}

$\Delta H_f^{\ominus}$ dinitrogen monoxide = 82 kJ mol^{-1}

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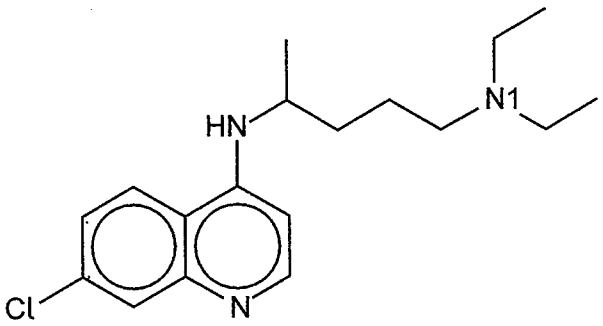
(iv) Deduce the Lewis (electron dot) structure and shape for dinitrogen monoxide showing nitrogen as the central atom. [2]

Lewis structure:

Shape: . . . . . .

2. Chloroquine is a medication used to prevent and treat malaria.



(a) Draw a circle around the secondary amino group in chloroquine. [1]

(b) Determine the index of hydrogen deficiency, IHD, of chloroquine. [1]

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(c) Compare, giving a reason, the length of the carbon-nitrogen bond in the ring to the length of the carbon-N1 bond. [1]

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(d) State, giving a reason, whether carbon or nitrogen is the most electronegative element. [1]

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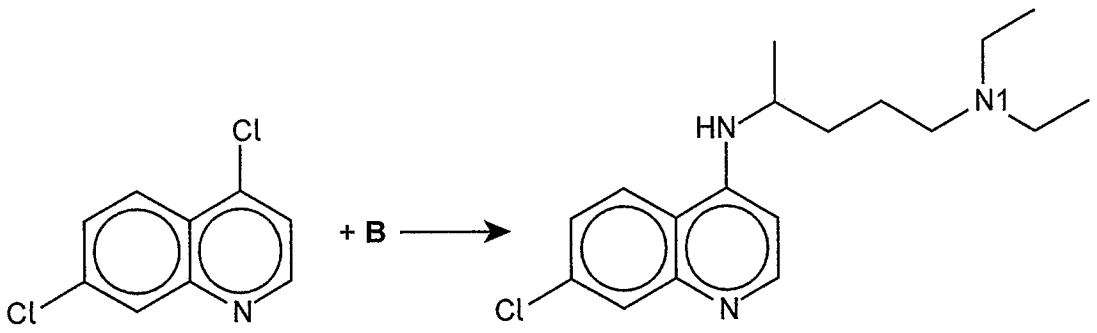
(Question 2 continued)

(e) Chloroquine can be synthesized by reacting 4,7-dichloroquinoline with another reactant, **B**.



4,7-dichloroquinoline **chloroquine**

(i) Deduce the structure of **B**. [2]

(ii) This reaction can be done with a copper catalyst. State the ground-state electron configuration for copper. [1]

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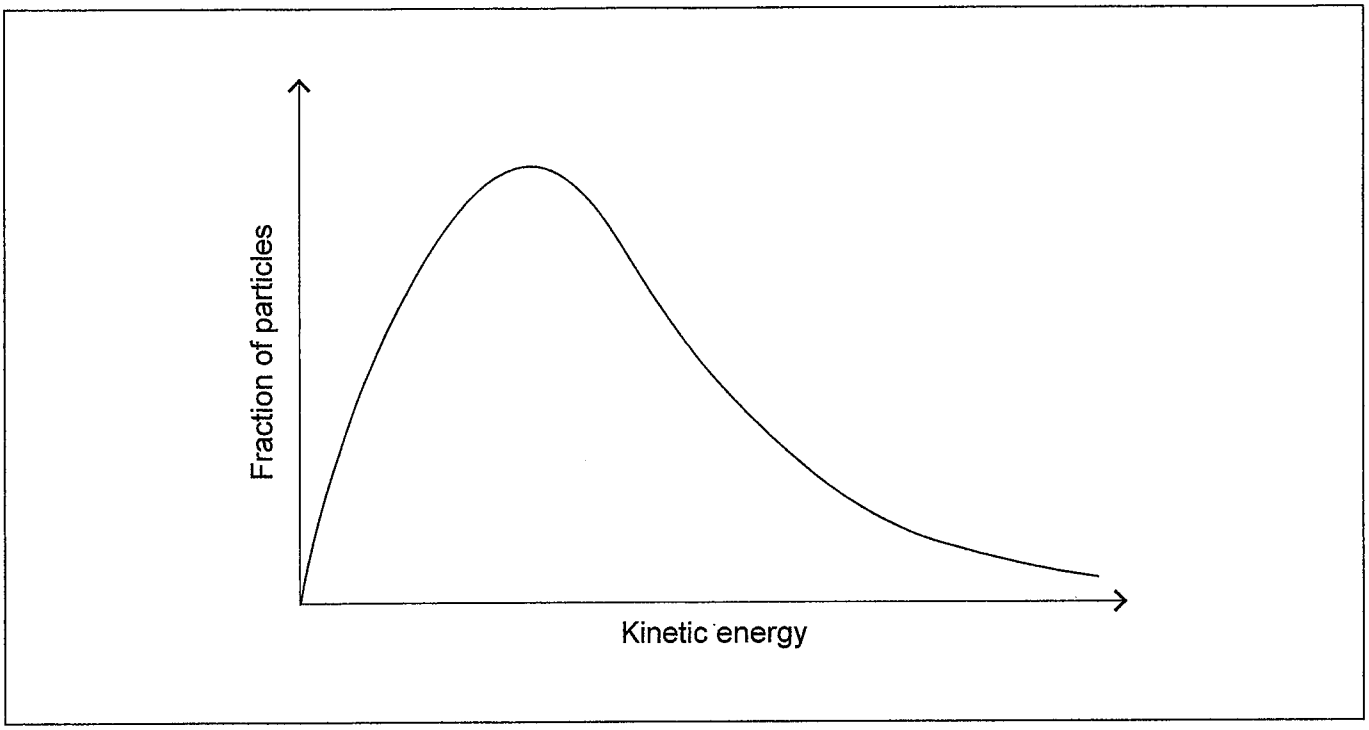
(Question 2 continued)

(iii) Annotate the Maxwell–Boltzmann distribution curve showing the activation energies, E_a, for the catalysed and uncatalysed reactions. [1]



(iv) Explain, referring to the Maxwell–Boltzmann distribution curve, the effect of a catalyst on a chemical reaction. [1]

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3. Consider the following reaction:

$$Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Cu(s)$$

(a) State the ground-state electron configuration for Fe^{2+}. [1]

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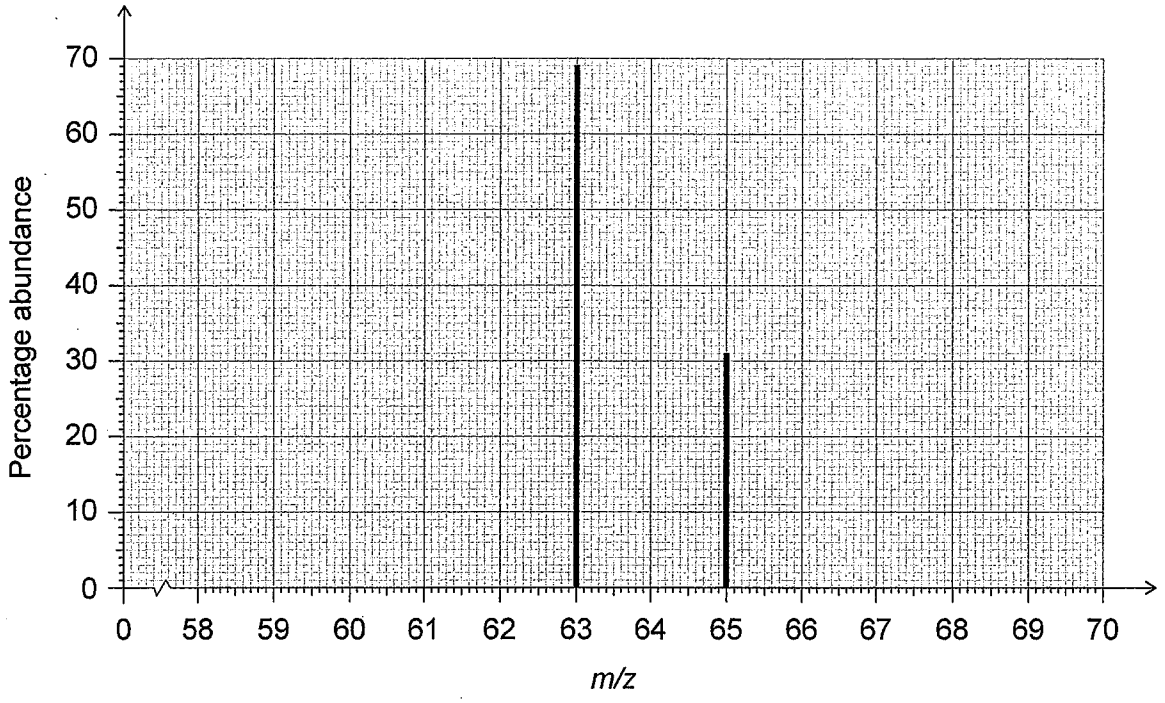
(b) The mass spectrum for copper is shown:



Show how a relative atomic mass of copper of 63.62 can be obtained from this mass spectrum. [1]

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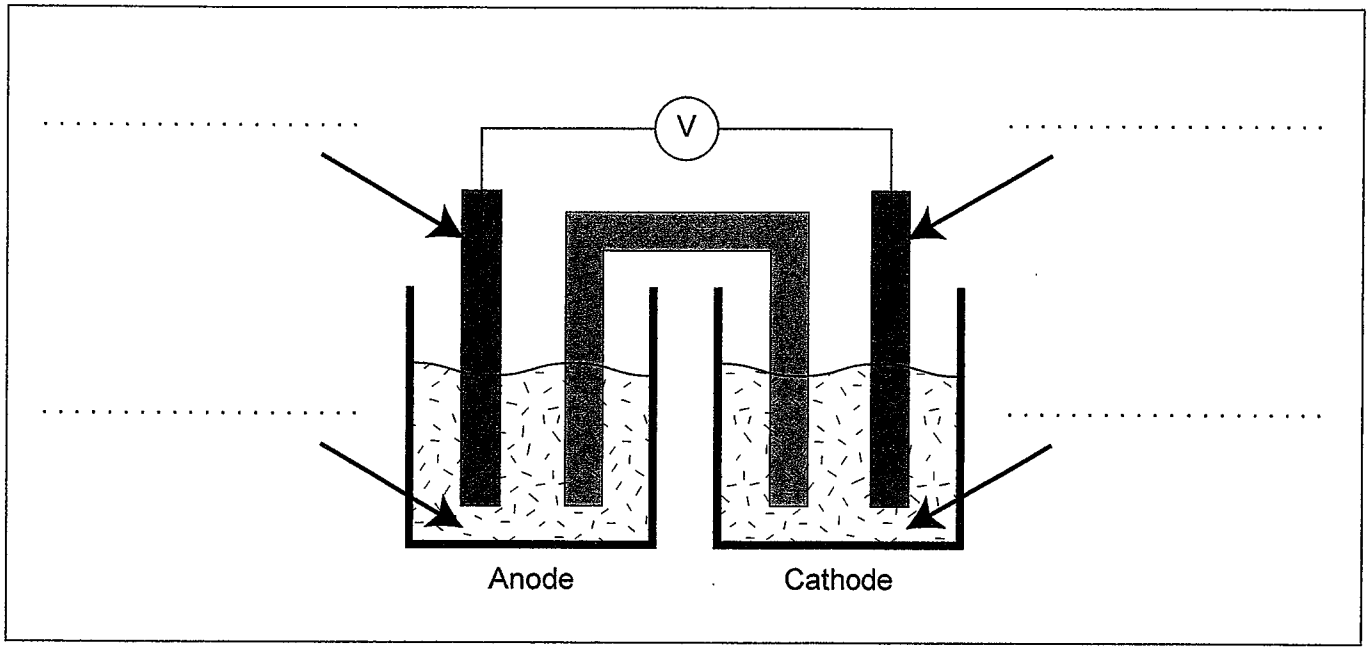
(Question 3 continued)

(c) The diagram shows an unlabelled voltaic cell for the reaction:

$$Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Cu(s)$$



(i) Label the diagram with the species from the equation and the direction of electron flow. [2]

(ii) Write the half-equation for the reaction occurring at the anode (negative electrode). [1]

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(iii) The diagram includes a salt bridge that is filled with a saturated solution of KNO_3. Outline the function of the salt bridge. [1]

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(Question 3 continued)

(iv) Predict the movement of **all** ionic species through the salt bridge. [2]

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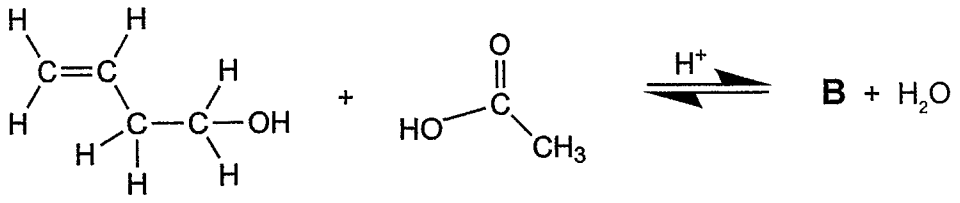
4. An organic compound, **A**, reacts with ethanoic acid to produce **B** using concentrated sulfuric acid as a catalyst.



A ethanoic acid

(a) (i) Deduce the structural and empirical formulas of **B**. [3]

Structural formula:

Empirical formula: .....

(ii) Explain, with reference to Le Châtelier's principle, the effect of using dilute rather than concentrated sulfuric acid as the catalyst on the yield of the reaction. [2]

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(Question 4 continued)

(iii) Explain, with reference to intermolecular forces, why **B** is more volatile than **A**. [2]

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(b) Compound **A** can also react with bromine. Describe the change observed if **A** is reacted with bromine. [1]

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5. Lignite, a type of coal, contains about 0.40 % sulfur by mass.

(a) Calculate the amount, in mol, of sulfur dioxide produced when 500.0 g of lignite undergoes combustion. [2]

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

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(b) Write an equation that shows how sulfur dioxide can produce acid rain. [1]

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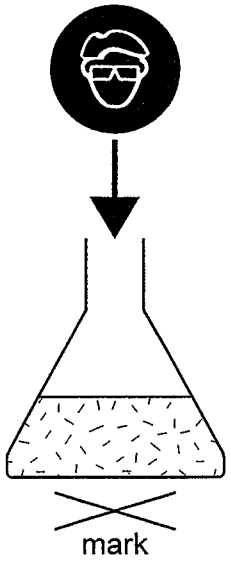
(Question 5 continued)

(c) Sodium thiosulfate reacts with hydrochloric acid as shown:

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(aq) + 2NaCl(aq) + H_2O(l)$$

The precipitate of sulfur makes the mixture cloudy, so a mark underneath the reaction mixture becomes invisible with time.



Suggest **two** variables, other than concentration, that should be controlled when comparing relative rates at different temperatures. [2]

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(d) Discuss **two** different ways to reduce the environmental impact of energy production from coal. [2]

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References:

1.(f)(iii) Cliffsnotes, n.d. *Enthalpy* [online] Available at: <https://www.cliffsnotes.com/study-guides/chemistry/chemistry/thermodynamics/enthalpy> [Accessed 6 October 2021]

NIST, n.d. *Gas phase thermochemistry data* [online] Available at: <https://webbook.nist.gov/cgi/cbook.cgi?ID=C10024972&Mask=1#Thermo-Gas> [Accessed 6 October 2021]

2.(e)(ii) ScienceDirect, 1994. *Vapor-Phase Substitution of Chlorobenzene with Ammonia, Catalyzed by Copper-Exchanged Zeolites* [online] Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0021951784711869> [Accessed 6 October 2021]

3.(b) WebElements, n.d. *Copper: isotope data* [online] Available at: <https://www.webelements.com/copper/isotopes.html> [Accessed 6 October 2021]

4.(a)(iii) The Good Scents company, n.d. *TGSC Information System* [online] Available at: <https://www.thegoodscentscompany.com/data/rw1416161.html> and <https://www.thegoodscentscompany.com/data/rw1188221.html> [Accessed 6 October 2021]

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