Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 16 May 2018 (afternoon)

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]**.

2218–6111

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

1. Urea, $(H_2N)_2CO$, is excreted by mammals and can be used as a fertilizer.

(a) (i) Calculate the percentage by mass of nitrogen in urea to two decimal places using section 6 of the data booklet. [2]

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(ii) Suggest how the percentage of nitrogen affects the cost of transport of fertilizers giving a reason. [1]

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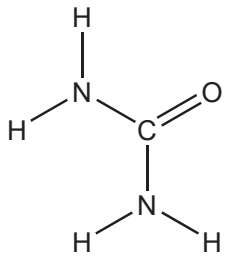
(Question 1 continued)

(b) The structural formula of urea is shown.



Predict the electron domain and molecular geometries at the nitrogen and carbon atoms, applying the VSEPR theory.

	Electron domain geometry	Molecular geometry
Nitrogen	. . . . .	. . . . .
Carbon	. . . . .	trigonal planar

[3]

(c) Urea can be made by reacting potassium cyanate, KNCO, with ammonium chloride, NH_4Cl.

$$KNCO\,(aq) + NH_4Cl\,(aq) \rightarrow (H_2N)_2CO\,(aq) + KCl\,(aq)$$

Determine the maximum mass of urea that could be formed from 50.0 cm^3 of 0.100 mol dm^{-3} potassium cyanate solution. [2]

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(Question 1 continued)

(d) Urea can also be made by the direct combination of ammonia and carbon dioxide gases.

$$2NH_3\,(g) + CO_2\,(g) \rightleftharpoons (H_2N)_2CO\,(g) + H_2O\,(g) \qquad \Delta H < 0$$

Predict, with a reason, the effect on the equilibrium constant, K_c, when the temperature is increased. [1]

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(e) (i) Suggest one reason why urea is a solid and ammonia a gas at room temperature. [1]

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(ii) Sketch **two** different hydrogen bonding interactions between ammonia and water. [2]

(This question continues on the following page)

(Question 1 continued)

(f) The combustion of urea produces water, carbon dioxide and nitrogen.

Formulate a balanced equation for the reaction. [2]

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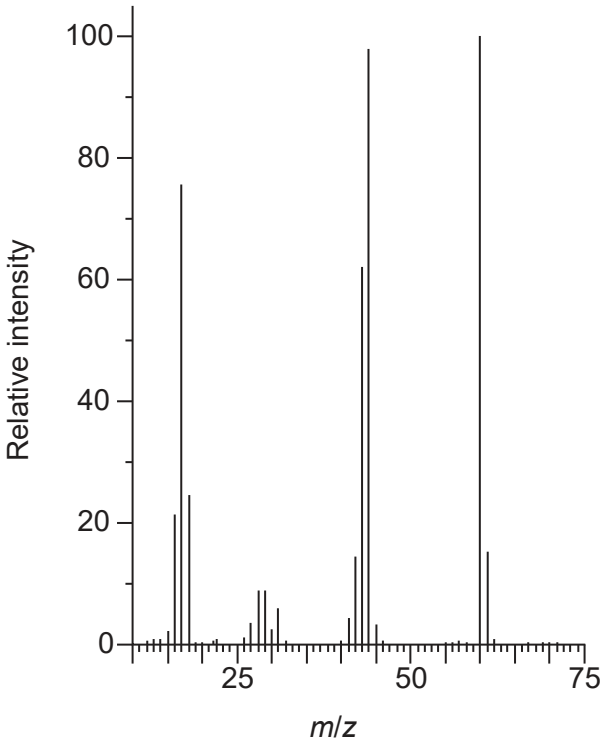
(Question 1 continued)

(g) The mass spectrum of urea is shown below.



[Source: NIST Mass Spec Data Center, S.E. Stein, director, "Mass Spectra" in *NIST Chemistry WebBook*, NIST Standard Reference Database Number 69, Eds. P.J. Linstrom and W.G. Mallard, National Institute of Standards and Technology, Gaithersburg MD, 20899, doi:10.18434/T4D303, (retrieved May 31, 2018).]

Identify the species responsible for the peaks at m/z = 60 and 44. [2]

60:

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44:

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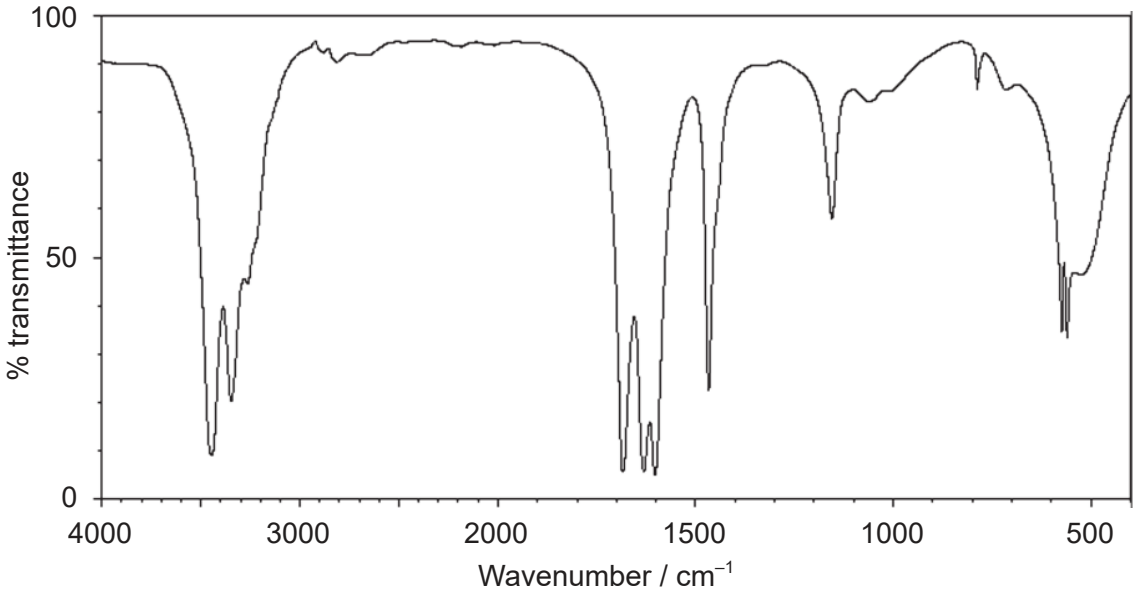
(Question 1 continued)

(h) The IR spectrum of urea is shown below.



[Source: SDBS, National Institute of Advanced Industrial Science and Technology]

Identify the bonds causing the absorptions at 3450 cm^{-1} and 1700 cm^{-1} using section 26 of the data booklet. [2]

3450 cm^{-1}:

. . . . . .

1700 cm^{-1}:

. . . . . .

(i) Predict the number of signals in the ^{1}H NMR spectrum of urea. [1]

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2. Calcium carbide, CaC_2, is an ionic solid.

(a) Describe the nature of ionic bonding. [1]

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(b) State the electron configuration of the Ca^{2+} ion. [1]

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(c) When calcium compounds are introduced into a gas flame a red colour is seen; sodium compounds give a yellow flame. Outline the source of the colours and why they are different. [2]

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(d) (i) Suggest **two** reasons why solid calcium has a greater density than solid potassium. [2]

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(Question 2 continued)

(ii) Outline why solid calcium is a good conductor of electricity. [1]

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(e) Calcium carbide reacts with water to form ethyne and calcium hydroxide.

$$CaC_2(s) + H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(aq)$$

Estimate the pH of the resultant solution. [1]

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3. This question is about ethene, C_2H_4, and ethyne, C_2H_2.

(a) (i) Ethyne, like ethene, undergoes hydrogenation to form ethane. State the conditions required. [2]

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(ii) Outline the formation of polyethene from ethene by drawing three repeating units of the polymer. [1]

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(Question 3 continued)

(b) (i) Under certain conditions, ethyne can be converted to benzene.

Determine the standard enthalpy change, $\Delta H^{\ominus}$, for the reaction stated, using section 11 of the data booklet. [2]

$$3C_2H_2(g) \rightarrow C_6H_6(g)$$

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(ii) Determine the standard enthalpy change, $\Delta H^{\ominus}$, for the following similar reaction, using ΔH_f values in section 12 of the data booklet. [2]

$$3C_2H_2(g) \rightarrow C_6H_6(l)$$

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(iii) Explain, giving two reasons, the difference in the values for (b)(i) and (ii). If you did not obtain answers, use –475 kJ for (i) and –600 kJ for (ii). [2]

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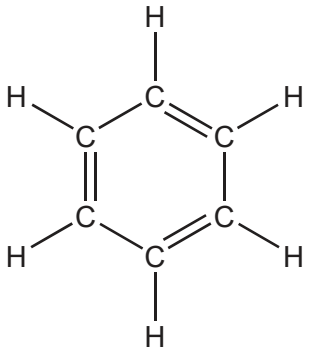
(Question 3 continued)

(c) One possible Lewis structure for benzene is shown.



State one piece of physical evidence that this structure is **incorrect**. [1]

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(d) State the characteristic reaction mechanism of benzene. [1]

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4. Calcium carbonate reacts with hydrochloric acid.

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

(a) Outline **two** ways in which the progress of the reaction can be monitored. No practical details are required. [2]

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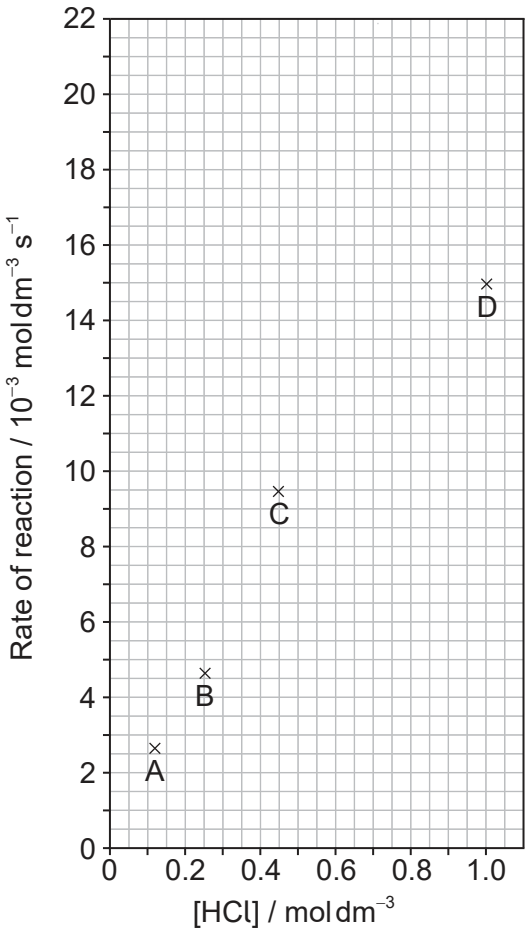
(Question 4 continued)

(b) The results of a series of experiments in which the concentration of HCl was varied are shown below.



(i) Suggest why point D is so far out of line assuming human error is not the cause. [1]

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(ii) Suggest the relationship that points A, B and C show between the concentration of the acid and the rate of reaction. [1]

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5. Limescale, $CaCO_3$ (s), can be removed from water kettles by using vinegar, a dilute solution of ethanoic acid, CH_3COOH (aq).

(a) Predict, giving a reason, a difference between the reactions of the same concentrations of hydrochloric acid and ethanoic acid with samples of calcium carbonate. [2]

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(b) Dissolved carbon dioxide causes unpolluted rain to have a pH of approximately 5, but other dissolved gases can result in a much lower pH. State one environmental effect of acid rain. [1]

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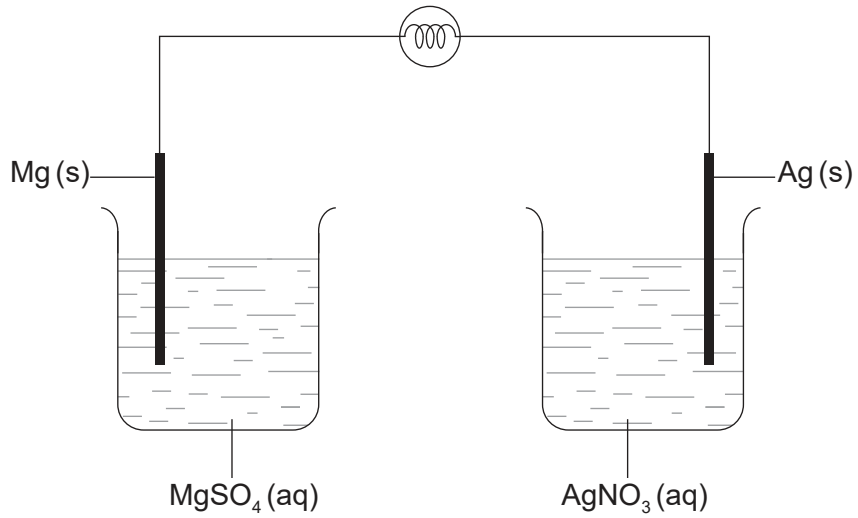
6. The diagram shows an incomplete voltaic cell with a light bulb in the circuit.



(a) Identify the missing component of the cell and its function. [2]

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(b) Deduce the half-equations for the reaction at each electrode when current flows. [2]

Positive electrode (cathode):

. . . . . .

Negative electrode (anode):

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(c) Annotate the diagram with the location and direction of electron movement when current flows. [1]

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