Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 22 May 2019 (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]**.

2219–6117

13 pages

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

1. Ethyne, C_2H_2, reacts with oxygen in welding torches.

(a) Write an equation for the complete combustion of ethyne. [1]

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(b) (i) Deduce the Lewis (electron dot) structure of ethyne. [1]

(ii) Compare, giving a reason, the length of the bond between the carbon atoms in ethyne with that in ethane, C_2H_6. [1]

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(iii) Identify the type of interaction that must be overcome when liquid ethyne vaporizes. [1]

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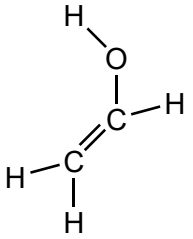
(Question 1 continued)

(c) Ethyne reacts with steam.

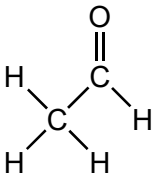
$$C_2H_2(g) + H_2O(g) \rightarrow C_2H_4O(g)$$

Two possible products are:



A

and



B

(i) Product **A** contains a carbon–carbon double bond. State the type of reactions that compounds containing this bond are likely to undergo. [1]

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(ii) State the name of product **B**, applying IUPAC rules. [1]

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(iii) Determine the enthalpy change for the reaction, in kJ, to produce **A** using section 11 of the data booklet. [3]

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(Question 1 continued)

(iv) The enthalpy change for the reaction to produce **B** is −213 kJ.

Predict, giving a reason, which product is the most stable. [1]

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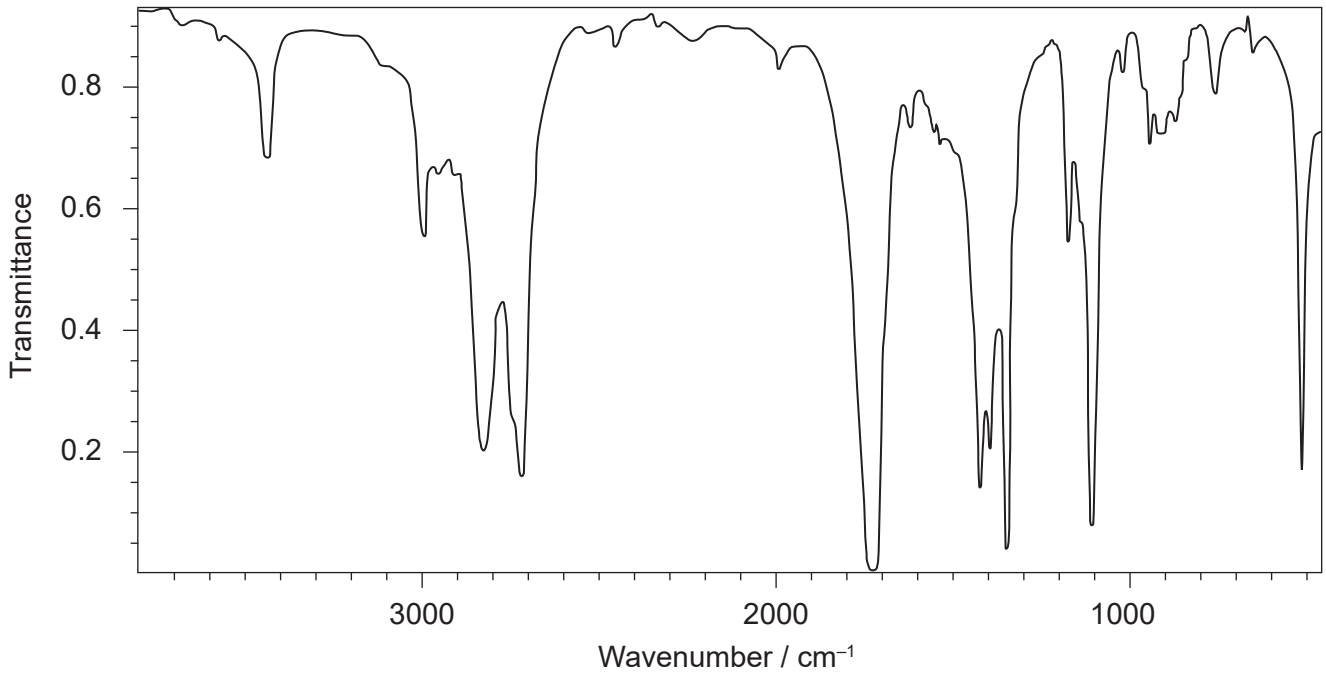
(v) The IR spectrum and low resolution ^{1}H NMR spectrum of the actual product formed are shown.

IR spectrum



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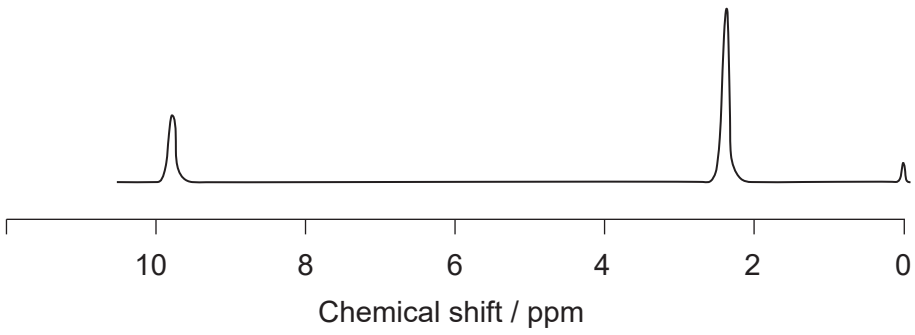
https://webbook.nist.gov/chemistry/ DOI: https://doi.org/10.18434/T4D303
http://webbook.nist.gov/cgi/inchi?Spec=C75070&Index=2&Type=IR
Acetaldehyde: Data compiled by: Coblentz Society, Inc.]

^{1}H NMR spectrum



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(Question 1 continued)

Deduce whether the product is **A** or **B**, using evidence from these spectra together with sections 26 and 27 of the data booklet. [2]

Identity of product:

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One piece of evidence from IR:

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One piece of evidence from ^{1}H NMR:

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(This question continues on page 7)

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(Question 1 continued)

(d) Product **B**, CH_3CHO, can also be synthesized from ethanol.

(i) Suggest the reagents and conditions required to ensure a good yield of product **B**. [2]

Reagents:

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Conditions:

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(ii) Deduce the average oxidation state of carbon in product **B**. [1]

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(iii) Explain why product **B** is water soluble. [3]

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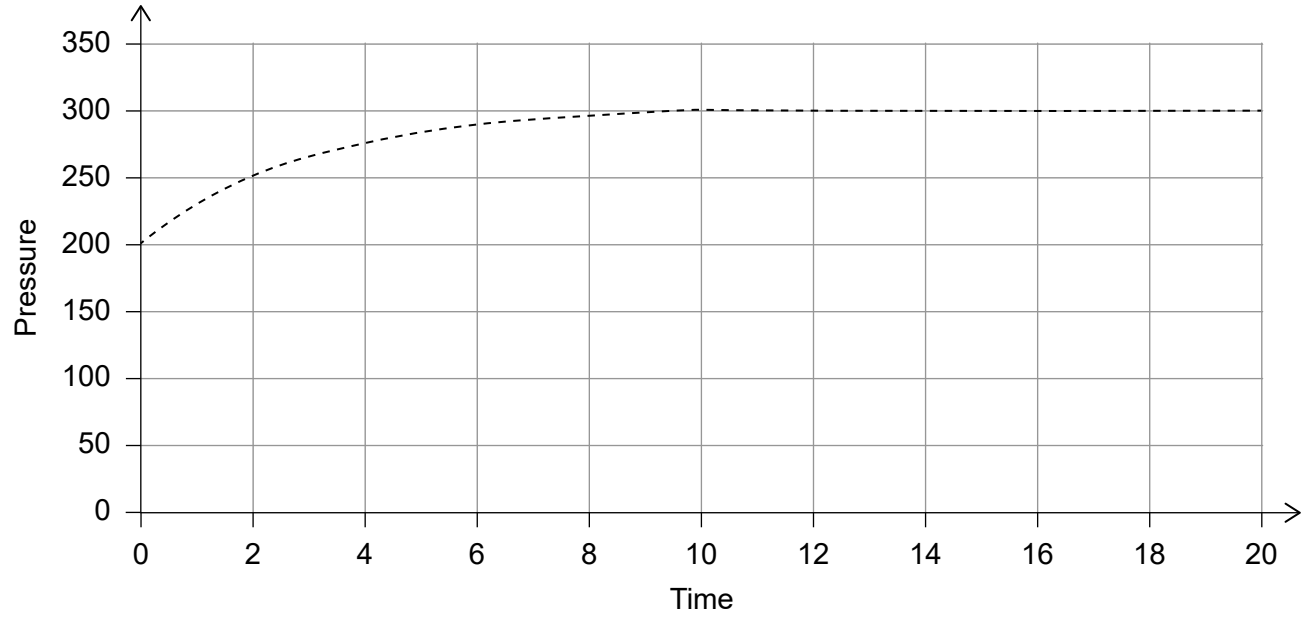
2. The thermal decomposition of dinitrogen monoxide occurs according to the equation:

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

The reaction can be followed by measuring the change in total pressure, at constant temperature, with time.

The x-axis and y-axis are shown with arbitrary units.



(a) Explain why, as the reaction proceeds, the pressure increases by the amount shown. [2]

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(b) Outline, in terms of collision theory, how a decrease in pressure would affect the rate of reaction. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) The experiment is repeated using the same amount of dinitrogen monoxide in the same apparatus, but at a lower temperature.

Sketch, on the axes in question 2, the graph that you would expect. [2]

(d) The experiment gave an error in the rate because the pressure gauge was inaccurate. Outline whether repeating the experiment, using the same apparatus, and averaging the results would reduce the error. [1]

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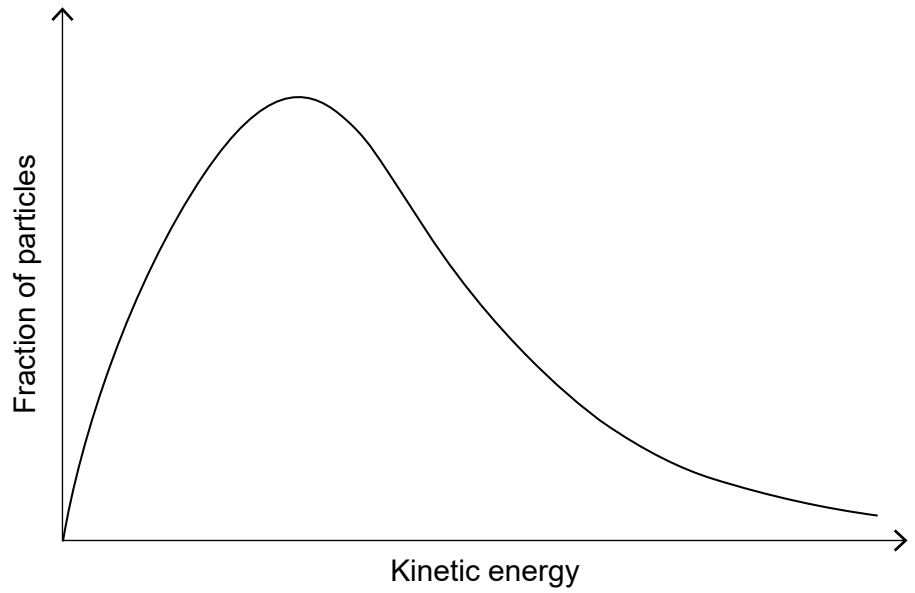
(e) The graph below shows the Maxwell–Boltzmann distribution of molecular energies at a particular temperature.



The rate at which dinitrogen monoxide decomposes is significantly increased by a metal oxide catalyst.

Annotate and use the graph to outline why a catalyst has this effect. [2]

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3. Dinitrogen monoxide, N_2O, causes depletion of ozone in the stratosphere.

(a) Outline why ozone in the stratosphere is important. [1]

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(b) Different sources of N_2O have different ratios of $^{14}N:{}^{15}N$.

(i) State **one** analytical technique that could be used to determine the ratio of $^{14}N:{}^{15}N$. [1]

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(ii) A sample of gas was enriched to contain 2 % by mass of ^{15}N with the remainder being ^{14}N.

Calculate the relative molecular mass of the resulting N_2O. [2]

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(iii) Predict, giving **two** reasons, how the first ionization energy of ^{15}N compares with that of ^{14}N. [2]

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(c) Suggest why it is surprising that dinitrogen monoxide dissolves in water to give a neutral solution. [1]

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4. Rhenium, Re, was the last element with a stable isotope to be isolated.

(a) Before its isolation, scientists predicted the existence of rhenium and some of its properties.

Suggest the basis of these predictions. [2]

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(b) Describe how the relative reactivity of rhenium, compared to silver, zinc, and copper, can be established using pieces of rhenium and solutions of these metal sulfates. [2]

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(c) One chloride of rhenium has the empirical formula $ReCl_3$.

(i) State the name of this compound, applying IUPAC rules. [1]

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(ii) Calculate the percentage, by mass, of rhenium in $ReCl_3$. [2]

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5. Carbonated water is produced when carbon dioxide is dissolved in water under pressure. The following equilibria are established.

Equilibrium (1) $CO_2(g) \overset{H_2O(l)}{\rightleftharpoons} CO_2(aq)$

Equilibrium (2) $CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

(a) Carbon dioxide acts as a weak acid.

(i) Distinguish between a weak and strong acid. [1]

Weak acid:

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Strong acid:

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(ii) The hydrogencarbonate ion, produced in Equilibrium (2), can also act as an acid.

State the formula of its conjugate base. [1]

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(iii) When a bottle of carbonated water is opened, these equilibria are disturbed.

State, giving a reason, how a decrease in pressure affects the position of Equilibrium (1). [1]

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(This question continues on the following page)

(Question 5 continued)

(b) Soda water has sodium hydrogencarbonate, $NaHCO_3$, dissolved in the carbonated water.

(i) Predict, referring to Equilibrium (2), how the added sodium hydrogencarbonate affects the pH. (Assume pressure and temperature remain constant.) [2]

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(ii) $100.0\,cm^3$ of soda water contains 3.0×10^{-2} g $NaHCO_3$.

Calculate the concentration of $NaHCO_3$ in $mol\,dm^{-3}$. [2]

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(iii) Identify the type of bonding in sodium hydrogencarbonate. [2]

Between sodium and hydrogencarbonate:

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Between hydrogen and oxygen in hydrogencarbonate:

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