Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Thursday 11 May 2017 (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 dooklet** is required for this paper.
*   The maximum mark for this examination paper is **[50 marks]**.

14 pages

16EP01

International Baccalaureate
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Answer **all** questions. Write your answers in the boxes provided.

1. The rate of the acid-catalysed iodination of propanone can be followed by measuring how the concentration of iodine changes with time.

$$I_2(aq) + CH_3COCH_3(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$
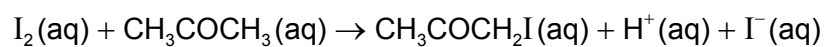
(a) (i) Suggest how the change of iodine concentration could be followed. [1]

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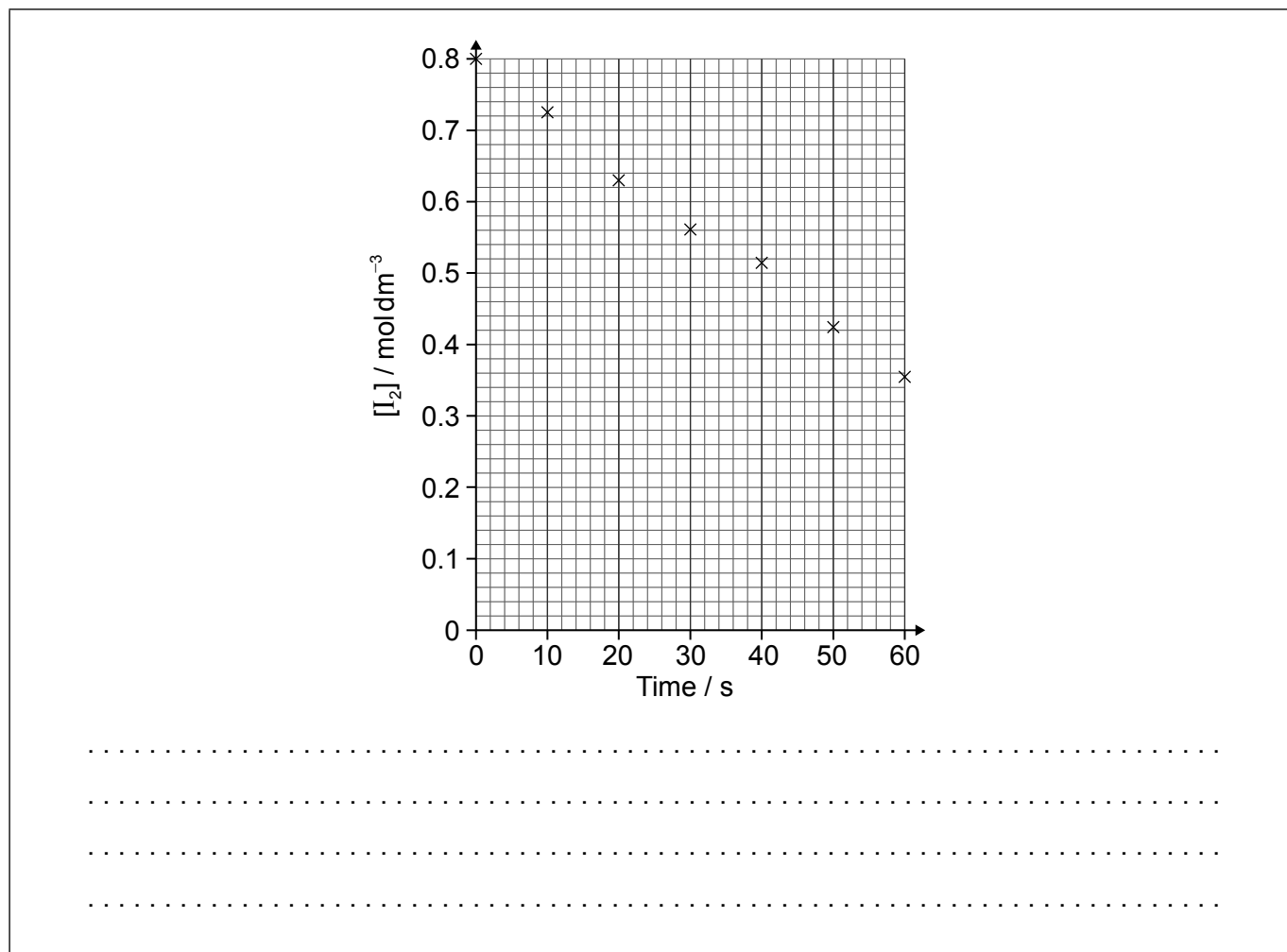
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(Question 1 continued)

(ii)   A student produced these results with $[H^+] = 0.15\,mol\,dm^{-3}$. Propanone and acid were in excess and iodine was the limiting reagent.

Determine the relative rate of reaction when $[H^+] = 0.15\,mol\,dm^{-3}$.   [2]

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(Question 1 continued)

(b)   The student then carried out the experiment at other acid concentrations with all other conditions remaining unchanged.

$[H^+]$ / mol dm^{-3}	Relative rate of reaction
0.05	0.0025
0.10	0.0051
0.20	0.0100

State and explain the relationship between the rate of reaction and the concentration of acid. [2]

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2.   Titanium is a transition metal.

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

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(Question 2 continued)

(b) Titanium exists as several isotopes. The mass spectrum of a sample of titanium gave the following data:

Mass number	% abundance
46	7.98
47	7.32
48	73.99
49	5.46
50	5.25

Calculate the relative atomic mass of titanium to two decimal places.   [2]

(c) State the number of protons, neutrons and electrons in the $^{48}_{22}$Ti atom.   [1]

Protons:

Neutrons:

Electrons:

(This question continues on the following page)

(Question 2 continued)

(d)   (i)   State the full electron configuration of the $^{48}_{22}Ti^{2+}$ ion.   [1]

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(ii)   Explain why an aluminium-titanium alloy is harder than pure aluminium.   [2]

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(e)   (i)   State the type of bonding in potassium chloride which melts at 1043 K.   [1]

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(ii)   A chloride of titanium, $TiCl_4$, melts at 248 K. Suggest why the melting point is so much lower than that of KCl.   [1]

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(f) $TiCl_4$ reacts with water and the resulting titanium(IV) oxide can be used as a smoke screen.

(i)   Formulate an equation for this reaction.   [2]

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(This question continues on the following page)

(Question 2 continued)

    (ii)   Suggest **one** disadvantage of using this smoke in an enclosed space. [1]

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3. Vanadium, another transition metal, has a number of different oxidation states.

    (a)   Determine the oxidation state of vanadium in each of the following species. [2]

V_2O_5:

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VO^{2+}:

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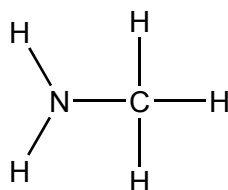
    (b)   Formulate an equation for the reaction between VO^{2+} (aq) and V^{2+} (aq) in acidic solution to form V^{3+} (aq). [1]

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4. Two hydrides of nitrogen are ammonia and hydrazine, N_2H_4. One derivative of ammonia is methanamine whose molecular structure is shown below.

(a) Estimate the H–N–H bond angle in methanamine using VSEPR theory. [1]

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(b) Ammonia reacts reversibly with water.

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
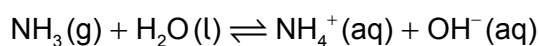
Explain the effect of adding $H^+(aq)$ ions on the position of the equilibrium. [2]

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(c) Hydrazine reacts with water in a similar way to ammonia. Deduce an equation for the reaction of hydrazine with water. [1]

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(This question continues on the following page)

(Question 4 continued)

(d)   Outline, using an ionic equation, what is observed when magnesium powder is added to a solution of ammonium chloride. [2]

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(e)   Hydrazine has been used as a rocket fuel. The propulsion reaction occurs in several stages but the overall reaction is:

$$N_2H_4(l) \rightarrow N_2(g) + 2H_2(g)$$
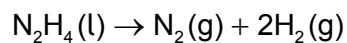
Suggest why this fuel is suitable for use at high altitudes. [1]

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(Question 4 continued)

(f)   Determine the enthalpy change of reaction, ΔH, in kJ, when 1.00 mol of gaseous hydrazine decomposes to its elements. Use bond enthalpy values in section 11 of the data booklet.   [3]

$$N_2H_4(g) \rightarrow N_2(g) + 2H_2(g)$$

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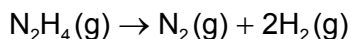. . . . .

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(g)   The standard enthalpy of formation of $N_2H_4(l)$ is $+50.6\,kJ\,mol^{-1}$. Calculate the enthalpy of vaporization, ΔH_{vap}, of hydrazine in $kJ\,mol^{-1}$.

$$N_2H_4(l) \rightarrow N_2H_4(g)$$
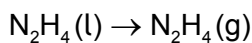
(If you did not get an answer to (f), use $-85\,kJ$ but this is not the correct answer.)   [2]

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(Question 4 continued)

(h)   Hydrazine is used to remove oxygen from water used to generate steam or hot water.

$$N_2H_4(aq) + O_2(aq) \rightarrow N_2(g) + 2H_2O(l)$$

The concentration of dissolved oxygen in a sample of water is $8.0 \times 10^{-3}\,g\,dm^{-3}$.
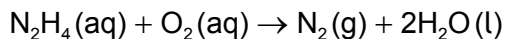
(i)   Calculate, showing your working, the mass of hydrazine needed to remove all the dissolved oxygen from $1000\,dm^3$ of the sample.   [3]

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(ii)   Calculate the volume, in dm^3, of nitrogen formed under SATP conditions. (The volume of 1 mol of gas $= 24.8\,dm^3$ at SATP.)   [1]

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Turn over

5. This question is about carbon and chlorine compounds.

(a) Ethane, C_2H_6, reacts with chlorine in sunlight. State the type of this reaction and the name of the mechanism by which it occurs. [1]

Type of reaction:

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Mechanism:

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(b) Formulate equations for the two propagation steps and one termination step in the formation of chloroethane from ethane. [3]

Two propagation steps:

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One termination step:

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(c) (i) One possible product, **X**, of the reaction of ethane with chlorine has the following composition by mass:

carbon: 24.27 %, hydrogen: 4.08 %, chlorine: 71.65 %

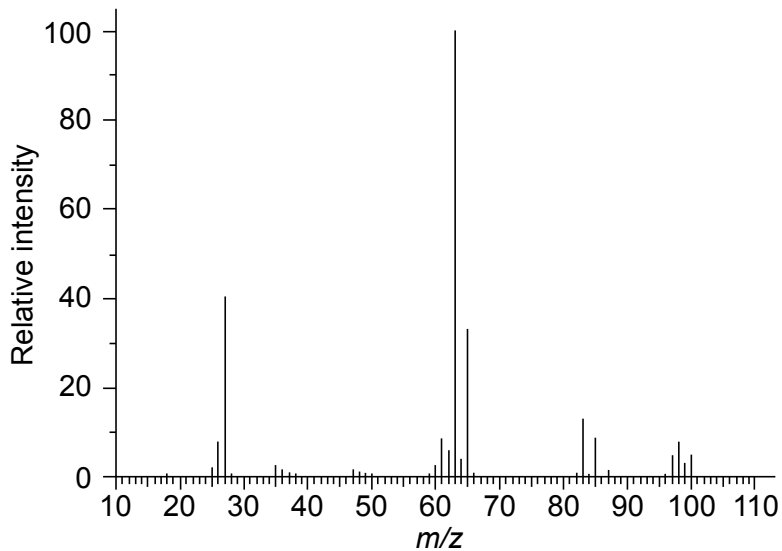Determine the empirical formula of the product. [2]

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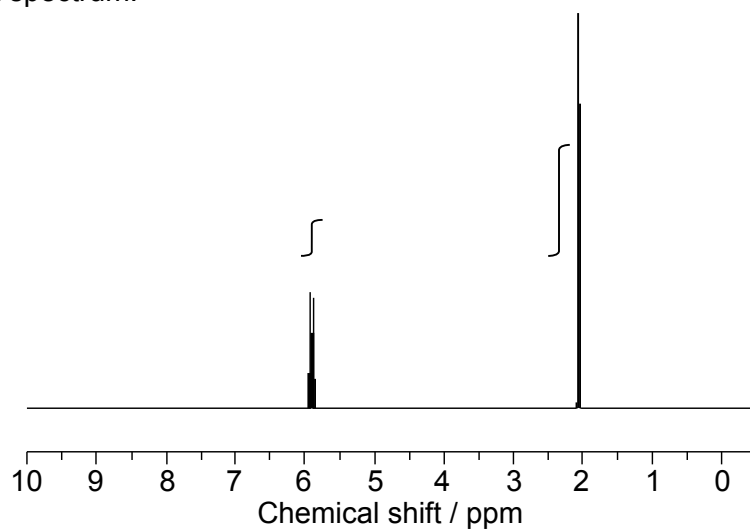**(This question continues on the following page)**

(Question 5 continued)

(ii) The mass and ^1H NMR spectra of product **X** are shown below. Deduce, giving your reasons, its structural formula and hence the name of the compound. [3]

Mass spectrum:

^1H NMR spectrum:

[Source: http://sdbs.db.aist.go.jp]

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Turn over

(Question 5 continued)

(d)   Chloroethene, C_2H_3Cl, can undergo polymerization. Draw a section of the polymer with three repeating units.   [1]

6.   Benzene is an aromatic hydrocarbon.

(a)   Discuss the physical evidence for the structure of benzene.   [2]

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(b)   State the typical reactions that benzene and cyclohexene undergo with bromine.   [1]

Benzene:

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Cyclohexene:

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Answers written on this page
will not be marked.