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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

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Monday 18 November 2013 (afternoon)

1 hour 15 minutes

Examination code

8	8	1	3	–	6	1	0	5

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the 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]*.

18 pages

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SECTION A

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

1. Reaction kinetics can be investigated using the iodine clock reaction. The equations for two reactions that occur are given below.

Reaction A: $H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$

Reaction B: $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

Reaction B is much faster than reaction A, so the iodine, I_2, formed in reaction A immediately reacts with thiosulfate ions, $S_2O_3^{2-}$, in reaction B, before it can react with starch to form the familiar blue-black, starch-iodine complex.

In one experiment the reaction mixture contained:

$5.0 \pm 0.1\,cm^3$ of $2.00\,mol\,dm^{-3}$ hydrogen peroxide (H_2O_2)
$5.0 \pm 0.1\,cm^3$ of 1% aqueous starch
$20.0 \pm 0.1\,cm^3$ of $1.00\,mol\,dm^{-3}$ sulfuric acid (H_2SO_4)
$20.0 \pm 0.1\,cm^3$ of $0.0100\,mol\,dm^{-3}$ sodium thiosulfate ($Na_2S_2O_3$)
$50.0 \pm 0.1\,cm^3$ of water with 0.0200 ± 0.0001 g of potassium iodide (KI) dissolved in it.

After 45 seconds this mixture suddenly changed from colourless to blue-black.

(a) Calculate the amount, in mol, of KI in the reaction mixture. *[1]*

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(b) Calculate the amount, in mol, of H_2O_2 in the reaction mixture. *[1]*

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(Question 1 continued)

(c) The concentration of iodide ions, I^-, is assumed to be constant. Outline why this is a valid assumption. *[1]*

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(d) For this mixture the concentration of hydrogen peroxide, H_2O_2, can also be assumed to be constant. Explain why this is a valid assumption. *[2]*

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(e) Explain why the solution suddenly changes colour. *[2]*

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(f) Apart from the precision uncertainties given, state **one** source of error that could affect this investigation and identify whether this is a random error or a systematic error. *[2]*

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(Question 1 continued)

(g) Calculate the total uncertainty, in cm^3, of the volume of the reaction mixture. *[1]*

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(h) The colour change occurs when 1.00×10^{-4} mol of iodine has been formed. Use the total volume of the solution and the time taken, to calculate the rate of the reaction, including appropriate units. *[4]*

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(i) In a second experiment, the concentration of the hydrogen peroxide was decreased to $1.00\,mol\,dm^{-3}$ while all other concentrations and volumes remained unchanged. The colour change now occurred after 100 seconds. Explain why the reaction in this experiment is slower than in the original experiment. *[2]*

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(Question 1 continued)

(j) In a third experiment, 0.100 g of a black powder was also added while all other concentrations and volumes remained unchanged. The time taken for the solution to change colour was now 20 seconds. Outline why you think the colour change occurred more rapidly and how you could confirm your hypothesis. *[2]*

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(k) Explain why increasing the temperature also decreases the time required for the colour to change. *[2]*

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2. Ethane reacts with chlorine in the presence of sunlight.

(a) Complete the overall equation for this reaction by stating the products. *[1]*

$C_2H_6 + Cl_2 \rightarrow$

(b) State the type of mechanism by which this reaction occurs. *[1]*

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(c) Traces of butane, C_4H_{10}, are also found amongst the products of this reaction. Explain how this product arises. *[2]*

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3. Calcium nitrate contains both covalent and ionic bonds.

(a) (i) State the formula of **both** ions present and the nature of the force between these ions. *[2]*

Ions:

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Nature of force:

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(ii) State which atoms are covalently bonded. *[1]*

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(b) Nitrogen also forms oxides, which are atmospheric pollutants.

(i) Outline the source of these oxides. *[1]*

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(ii) State **one** product formed from their reaction with water. *[1]*

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(iii) State **one** environmental problem caused by these atmospheric pollutants. *[1]*

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SECTION B

*Answer **one** question. Write your answers in the boxes provided.*

4. In December 2010, researchers in Sweden announced the synthesis of N,N–dinitronitramide, $N(NO_2)_3$. They speculated that this compound, more commonly called trinitramide, may have significant potential as an environmentally friendly rocket fuel oxidant.

(a) Methanol reacts with trinitramide to form nitrogen, carbon dioxide and water. Deduce the coefficients required to balance the equation for this reaction. *[1]*

$$\_\_\_\ N(NO_2)_3(g) + \_\_\_\ CH_3OH(l) \rightarrow \_\_\_\ N_2(g) + \_\_\_\ CO_2(g) + \_\_\_\ H_2O(l)$$

(b) Suggest **one** reason why trinitramide might be more environmentally friendly than other rocket fuel oxidants such as ammonium perchlorate (NH_4ClO_4). *[1]*

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(c) Calculate the enthalpy change, in $kJ\,mol^{-1}$, when one mole of trinitramide decomposes to its elements, using bond enthalpy data from Table 10 of the Data Booklet. Assume that all the N–O bonds in this molecule have a bond enthalpy of $305\,kJ\,mol^{-1}$. *[3]*

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(Question 4 continued)

(d) Outline how the length of the N–N bond in trinitramide compares with the N–N bond in nitrogen gas, N_2. *[2]*

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(e) Deduce the N–N–N bond angle in trinitramide and explain your reasoning. *[3]*

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(f) Predict, with an explanation, the polarity of the trinitramide molecule. *[2]*

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(Question 4 continued)

(g) (i) Methanol can also be burnt as a fuel. Describe an experiment that would allow the molar enthalpy change of combustion to be calculated from the results. *[3]*

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(ii) Explain how the results of this experiment could be used to calculate the molar enthalpy change of combustion of methanol. *[3]*

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(iii) Predict, with an explanation, how the result obtained would compare with the value in Table 12 of the Data Booklet. *[2]*

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5. (a) In acidic solution, ions containing titanium can react according to the half-equation below.

$$TiO^{2+}(aq) + 2H^{+}(aq) + e^{-} \rightleftharpoons Ti^{3+}(aq) + H_2O(l)$$

(i) State the initial and final oxidation numbers of titanium and hence deduce whether it is oxidized or reduced in this change. *[2]*

Initial oxidation number	Final oxidation number	Oxidized / reduced

(ii) Considering the above equilibrium, predict, giving a reason, how adding more acid would affect the strength of the TiO^{2+} ion as an oxidizing agent. *[2]*

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(b) A reactivity series comparing titanium, cadmium and europium is given below.

Least reactive $Cd < Ti < Eu$ Most reactive

The half-equations corresponding to these metals are:

$$Eu^{2+}(aq) + 2e^{-} \rightleftharpoons Eu(s)$$
$$Ti^{3+}(aq) + 3e^{-} \rightleftharpoons Ti(s)$$
$$Cd^{2+}(aq) + 2e^{-} \rightleftharpoons Cd(s)$$

(i) Deduce which of the species would react with titanium metal. *[1]*

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(This question continues on the following page)

(Question 5 continued)

(ii) Deduce the balanced equation for this reaction. *[1]*

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(iii) Deduce which of the six species is the strongest oxidizing agent. *[1]*

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(iv) A voltaic cell can be constructed using cadmium and europium half-cells. State how the two solutions involved should be connected and outline how this connection works. *[2]*

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(c) Some students were provided with a $0.100\,mol\,dm^{-3}$ solution of a monobasic acid, HQ, and given the problem of determining whether HQ was a weak acid or a strong acid.

(i) Define a *Brønsted–Lowry acid*. *[1]*

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(Question 5 continued)

(ii) Distinguish between the terms *strong acid* and *weak acid*. *[1]*

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(iii) Neelu and Charles decided to solve the problem by determining the volume of $0.100\,mol\,dm^{-3}$ sodium hydroxide solution needed to neutralize $25.0\,cm^3$ of the acid. Outline whether this was a good choice. *[2]*

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(iv) Neelu and Charles decided to compare the volume of sodium hydroxide solution needed with those required by known $0.100\,mol\,dm^{-3}$ strong and weak acids. Unfortunately they chose sulfuric acid as the strong acid. Outline why this was an unsuitable choice. *[1]*

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(Question 5 continued)

(v) State a suitable choice for both the strong acid and the weak acid. *[2]*

Strong acid:

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Weak acid:

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(vi) Francisco and Shamiso decided to measure the pH of the initial solution, HQ, and they found that its pH was 3.7. Deduce, giving a reason, the strength (weak or strong) of the acid HQ. *[2]*

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(vii) Suggest a method, other than those mentioned above, that could be used to solve the problem and outline how the results would distinguish between a strong acid and a weak acid. *[2]*

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6. 2-methylbutan-2-ol, $(CH_3)_2C(OH)CH_2CH_3$, is a liquid with a smell of camphor that was formerly used as a sedative. One way of producing it starts with 2-methylbut-2-ene.

(a) Draw the structure of 2-methylbut-2-ene. *[1]*

(b) State the other substances required to convert 2-methylbut-2-ene to 2-methylbutan-2-ol. *[2]*

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(c) Explain whether you would expect 2-methylbutan-2-ol to react with acidified potassium dichromate(VI). *[2]*

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(d) Explain why 2-methylbut-2-ene is less soluble in water than 2-methylbutan-2-ol. *[2]*

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(Question 6 continued)

(e) 2-methylbutan-2-ol can also be produced by the hydrolysis of 2-chloro-2-methylbutane, $(CH_3)_2CClC_2H_5$, with aqueous sodium hydroxide.

(i) State the name of the mechanism of this reaction. *[1]*

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(ii) Explain the mechanism of this reaction using curly arrows to represent the movement of electron pairs. *[4]*

(This question continues on the following page)

(Question 6 continued)

(iii) Draw the structure of an isomer of 2-chloro-2-methylbutane that would undergo hydrolysis by a different mechanism. *[1]*

(f) 2-chloro-2-methylbutane contains some molecules with a molar mass of approximately 106 g mol^{-1} and some with a molar mass of approximately 108 g mol^{-1}.

(i) Outline why there are molecules with different molar masses. *[1]*

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(ii) Suggest, with a reason, whether the molecules with different molar masses will undergo hydrolysis at different rates. *[1]*

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(Question 6 continued)

(g) One way of determining the relative amounts of the molecules with slightly different masses would be to use a mass spectrometer. Explain the operation of the mass spectrometer, including details of each stage. *[5]*

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