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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

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Friday 9 November 2012 (afternoon)

1 hour 15 minutes

Examination code

8	8	1	2	–	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]*.

0124

SECTION A

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

1. Two groups of students (Group A and Group B) carried out a project* on the chemistry of some group 7 elements (the halogens) and their compounds.

(a) In the first part of the project, the two groups had a sample of iodine monochloride (a corrosive brown liquid) prepared for them by their teacher using the following reaction.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$$

The following data were recorded.

Mass of $I_2(s)$	10.00 g
Mass of $Cl_2(g)$	2.24 g
Mass of $ICl(l)$ obtained	8.60 g

(i) State the number of significant figures for the masses of $I_2(s)$ and $ICl(l)$. *[1]*

$I_2(s)$: . . . . . .

$ICl(l)$: . . . . . .

(ii) The iodine used in the reaction was in excess. Determine the theoretical yield, in g, of $ICl(l)$. *[3]*

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* Adapted from J Derek Woollins, (2009), *Inorganic Experiments* and Open University, (2008), *Exploring the Molecular World*.

(Question 1 continued)

(iii) Calculate the percentage yield of ICl(l). *[1]*

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(iv) Using a digital thermometer, the students discovered that the reaction was exothermic. State the sign of the enthalpy change of the reaction, ΔH. *[1]*

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(b) Although the molar masses of ICl and Br_2 are very similar, the boiling point of ICl is 97.4 °C and that of Br_2 is 58.8 °C. Explain the difference in these boiling points in terms of the intermolecular forces present in each liquid. *[2]*

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(Question 1 continued)

(c) The students reacted ICl(l) with CsBr(s) to form a yellow solid, $CsICl_2(s)$, as one of the products. $CsICl_2(s)$ has been found to produce very pure CsCl(s) which is used in cancer treatment.

To confirm the composition of the yellow solid, Group A determined the amount of iodine in 0.2015 g of $CsICl_2(s)$ by titrating it with 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$. The following data were recorded for the titration.

Mass of $CsICl_2(s)$ taken (in g ± 0.0001)	0.2015
Initial burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	1.05
Final burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	25.25

(i) Calculate the percentage of iodine by mass in $CsICl_2(s)$, correct to **three** significant figures. *[1]*

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(ii) State the volume, in cm^3, of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ used in the titration. *[1]*

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(Question 1 continued)

(iii) Determine the amount, in mol, of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ added in the titration. *[1]*

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(iv) The overall reaction taking place during the titration is:

$$CsICl_2(s) + 2Na_2S_2O_3(aq) \rightarrow NaCl(aq) + Na_2S_4O_6(aq) + CsCl(aq) + NaI(aq)$$

Calculate the amount, in mol, of iodine atoms, I, present in the sample of $CsICl_2(s)$. *[1]*

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(v) Calculate the mass of iodine, in g, present in the sample of $CsICl_2(s)$. *[1]*

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(vi) Determine the percentage by mass of iodine in the sample of $CsICl_2(s)$, correct to **three** significant figures, using your answer from (v). *[1]*

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(Question 1 continued)

(d) Group B heated the yellow solid, $CsICl_2(s)$, which turned white and released a brown gas which condensed into a brown liquid.

Group B identified the white solid as $CsCl(s)$. Suggest the identity of the brown liquid. *[1]*

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2. (a) Define the term *average bond enthalpy*. *[2]*

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(b) The following equation represents a combustion reaction of propane, $C_3H_8(g)$ when the oxygen supply is limited.

$$C_3H_8(g) + 3\tfrac{1}{2}O_2(g) \rightarrow 3CO(g) + 4H_2O(g)$$

(i) Determine ΔH, the enthalpy change of the reaction, in kJ mol^{-1}, using average bond enthalpy data from Table 10 of the Data Booklet. The bond enthalpy for the carbon-oxygen bond in carbon monoxide, CO, is 1072 kJ mol^{-1}. *[3]*

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(ii) The CO molecule has dative covalent bonding. Identify a nitrogen-containing positive ion which also has this type of bonding. *[1]*

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3. Chemical equilibrium and kinetics are important concepts in chemistry.

(a) A glass container is half-filled with liquid bromine and then sealed. The system eventually reaches a dynamic equilibrium. State **one** characteristic of a system in equilibrium. *[1]*

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(b) The oxidation of sulfur dioxide is an important reaction in the Contact process used to manufacture sulfuric acid.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198.2 \text{ kJ}$$

(i) Deduce the equilibrium constant expression, K_c. *[1]*

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(ii) Predict how each of the following changes affects the position of equilibrium and the value of K_c. *[3]*

	Position of equilibrium	**Value of K_c**
Decrease in temperature		
Increase in pressure		
Addition of a catalyst		

(This question continues on the following page)

(Question 3 continued)

(c) Vanadium(V) oxide, V_2O_5, is a catalyst that can be used in the Contact process. It provides an alternative pathway for the reaction, lowering the activation energy, E_a.

(i) Define the term *activation energy*, E_a. *[1]*

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(ii) Sketch the **two** Maxwell–Boltzmann energy distribution curves for a fixed amount of gas at two different temperatures, T_1 and T_2 ($T_2 > T_1$). Label **both** axes. *[3]*

SECTION B

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

4. Lithium and boron are elements in period 2 of the periodic table. Lithium occurs in group 1 (the alkali metals) and boron occurs in group 3. Isotopes exist for both elements.

(a) (i) Define the terms *atomic number*, *mass number* and *isotopes of an element*. *[3]*

Atomic number:

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. . . . . .

Mass number:

. . . . . .
. . . . . .

Isotopes of an element:

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(ii) Distinguish between the terms *group* and *period*. *[1]*

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(iii) Deduce the electron arrangements of the lithium ion, Li^+, and the boron atom, B. *[2]*

Li^+: . . . . . .

B: . . . . . .

(This question continues on the following page)

(Question 4 continued)

(iv) Naturally occurring boron exists as two isotopes with mass numbers of 10 and 11. Calculate the percentage abundance of the lighter isotope, using this information and the relative atomic mass of boron in Table 5 of the Data Booklet. *[2]*

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(v) Lithium exists as two isotopes with mass numbers of 6 and 7. Deduce the number of protons, electrons and neutrons for each isotope. *[2]*

Mass number (*A*)	**Number of protons**	**Number of electrons**	**Number of neutrons**
6			
7			

(This question continues on the following page)

(Question 4 continued)

(b) Every element has its own unique line emission spectrum.

(i) Distinguish between a *continuous spectrum* and a *line spectrum*. *[2]*

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(ii) Draw a diagram to show the electron transitions between energy levels in a hydrogen atom that are responsible for the two series of lines in the ultraviolet and visible regions of the spectrum. Label your diagram to show **three** transitions for each series. *[4]*

(This question continues on the following page)

(Question 4 continued)

(c) (i) Explain why metals are good conductors of electricity and why they are malleable. *[2]*

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(ii) Iron is described as a transition metal. Identify the **two** most common ions of iron. *[1]*

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(iii) Deduce the chemical formulas of lithium oxide and iron(II) oxide. *[1]*

Lithium oxide:

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Iron(II) oxide:

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5. Arsenic and nitrogen play a significant role in environmental chemistry. Arsenous acid, H_3AsO_3, can be found in oxygen-poor (anaerobic) water, and nitrogen-containing fertilizers can contaminate water.

(a) (i) Define *oxidation* and *reduction* in terms of electron loss or gain. *[1]*

Oxidation:

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Reduction:

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(ii) Deduce the oxidation numbers of arsenic and nitrogen in each of the following species. *[4]*

As_2O_3: . . . . . .

NO_3^-: . . . . . .

H_3AsO_3: . . . . . .

N_2O_3: . . . . . .

(iii) Distinguish between the terms *oxidizing agent* and *reducing agent*. *[1]*

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(This question continues on the following page)

(Question 5 continued)

(iv) In the removal of arsenic from contaminated groundwater, H_3AsO_3 is often first oxidized to arsenic acid, H_3AsO_4.

The following **unbalanced** redox reaction shows another method of forming H_3AsO_4.

$$As_2O_3(s) + NO_3^-(aq) \rightarrow H_3AsO_4(aq) + N_2O_3(aq)$$

Deduce the balanced redox equation in **acid**, and then identify both the oxidizing and reducing agents. *[3]*

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(b) Nitric acid, HNO_3, is strong and nitrous acid, HNO_2, is weak.

(i) Define an *acid* according to the Brønsted–Lowry and Lewis theories. *[2]*

Brønsted–Lowry theory:

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Lewis theory:

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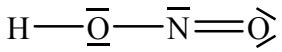
(Question 5 continued)

(ii) The Lewis (electron dot) structure of nitrous acid is given below.



Identify which nitrogen-oxygen bond is the shorter. *[1]*

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(iii) Deduce the approximate value of the hydrogen-oxygen-nitrogen bond angle in nitrous acid and explain your answer. *[2]*

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(iv) Distinguish between a *strong acid* and a *weak acid* in terms of their dissociation in aqueous solution. *[1]*

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(Question 5 continued)

(v) Ammonia, NH_3, is a weak base. Deduce the Lewis (electron dot) structure of NH_3. State the name of the shape of the molecule and explain why NH_3 is a polar molecule. *[3]*

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(vi) When lime was added to a sample of soil, the pH changed from 5 to 7. Calculate the **factor** by which the hydrogen ion concentration changes. *[1]*

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(vii) One common nitrogen-containing fertilizer is ammonium sulfate. State its chemical formula. *[1]*

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6. Alkenes, alcohols and esters are three families of organic compounds with many commercial uses.

(a) (i) State **two** industrial uses of ethene. *[2]*

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(ii) State the meaning of the term *structural isomers*. *[1]*

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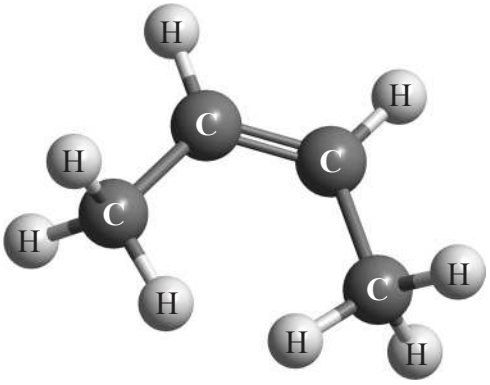
(Question 6 continued)

(iii) **X** is an isomer of C_4H_8 and has the structural formula shown below.



Apply IUPAC rules to name this isomer. Deduce the structural formulas of **two** other isomers of C_4H_8. *[3]*

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(iv) State the balanced chemical equation for the reaction of **X** with HBr to form **Y**. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(v) **Y** reacts with aqueous sodium hydroxide, NaOH(aq), to form an alcohol, **Z**. Identify whether **Z** is a primary, secondary or tertiary alcohol. *[1]*

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(vi) Explain **one** suitable mechanism for the reaction in (v) using curly arrows to represent the movement of electron pairs. *[4]*

(vii) Deduce the structural formula of the organic product formed when **Z** is oxidized by heating under reflux with acidified potassium dichromate(VI) **and** state the name of the functional group of this organic product. *[2]*

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(Question 6 continued)

(b) Esters are often used in perfumes. Analysis of a compound containing the ester functional group only, gives a percentage composition by mass of C: 62.0 % and H: 10.4 %.

(i) Draw the ester functional group. *[1]*

(ii) Determine the empirical formula of the ester, showing your working. *[4]*

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(iii) The molar mass of the ester is 116.18 g mol^{-1}. Determine its molecular formula. *[1]*

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