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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

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Thursday 16 May 2013 (afternoon)

1 hour 15 minutes

Examination code

2	2	1	3	–	6	1	1	7

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]*.

SECTION A

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

1. Iron tablets are often prescribed to patients. The iron in the tablets is commonly present as iron(II) sulfate, $FeSO_4$.

Two students carried out an experiment to determine the percentage by mass of iron in a brand of tablets marketed in Cyprus.

Experimental Procedure:

- The students took five iron tablets and found that the **total mass** was 1.65 g.
- The five tablets were ground and dissolved in 100 cm^3 dilute sulfuric acid, $H_2SO_4(aq)$. The solution and washings were transferred to a 250 cm^3 volumetric flask and made up to the mark with deionized (distilled) water.
- 25.0 cm^3 of this $Fe^{2+}(aq)$ solution was transferred using a pipette into a conical flask. Some dilute sulfuric acid was added.
- A titration was then carried out using a 5.00×10^{-3} mol dm^{-3} standard solution of potassium permanganate, $KMnO_4(aq)$. The end-point of the titration was indicated by a slight pink colour.

The following results were recorded.

	Rough titre	**First accurate titre**	**Second accurate titre**
Initial burette reading / $cm^3 \pm 0.05$	1.05	1.20	0.00
Final burette reading / $cm^3 \pm 0.05$	20.05	18.00	16.80

(This question continues on the following page)

(Question 1 continued)

(a) When the $Fe^{2+}(aq)$ solution was made up in the 250 cm^3 volumetric flask, deionized (distilled) water was added until the bottom of its meniscus corresponded to the graduation mark on the flask. It was noticed that one of the two students measured the volume of the solution from the top of the meniscus instead of from the bottom. State the name of this type of error. *[1]*

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(b) State what is meant by the term *precision*. *[1]*

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(c) When the students recorded the burette readings, following the titration with $KMnO_4(aq)$, the top of the meniscus was used and not the bottom. Suggest why the students read the top of the meniscus and not the bottom. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(d) This experiment involves the following redox reaction.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

(i) Define the term *reduction* in terms of electrons. *[1]*

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(ii) Deduce the oxidation number of manganese in the $MnO_4^-(aq)$ ion. *[1]*

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(e) (i) Determine the amount, in mol, of $MnO_4^-(aq)$, used in each accurate titre. *[2]*

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(ii) Calculate the amount, in mol, of $Fe^{2+}(aq)$ ions in 250 cm^3 of the solution. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(iii) Determine the total mass of iron, in g, in the 250 cm^3 solution. *[1]*

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(iv) Determine the percentage by mass of iron in the tablets. *[1]*

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(f) (i) One titration was abandoned because a brown precipitate, manganese(IV) oxide, formed. State the chemical formula of this compound. *[1]*

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(ii) Suggest a reason why manganese(IV) oxide formed instead of Mn^{2+}(aq). *[1]*

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2. (a) The standard enthalpy change of three combustion reactions are given below.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H = -286\,kJ\,mol^{-1}$$
$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \qquad \Delta H = -2219\,kJ\,mol^{-1}$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -394\,kJ\,mol^{-1}$$

Determine the change in enthalpy, ΔH, in $kJ\,mol^{-1}$, for the formation of propane in the following reaction.

$$3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$$ *[4]*

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(b) A catalyst provides an alternative pathway for a reaction, lowering the activation energy, E_a. Define the term *activation energy*, E_a. *[1]*

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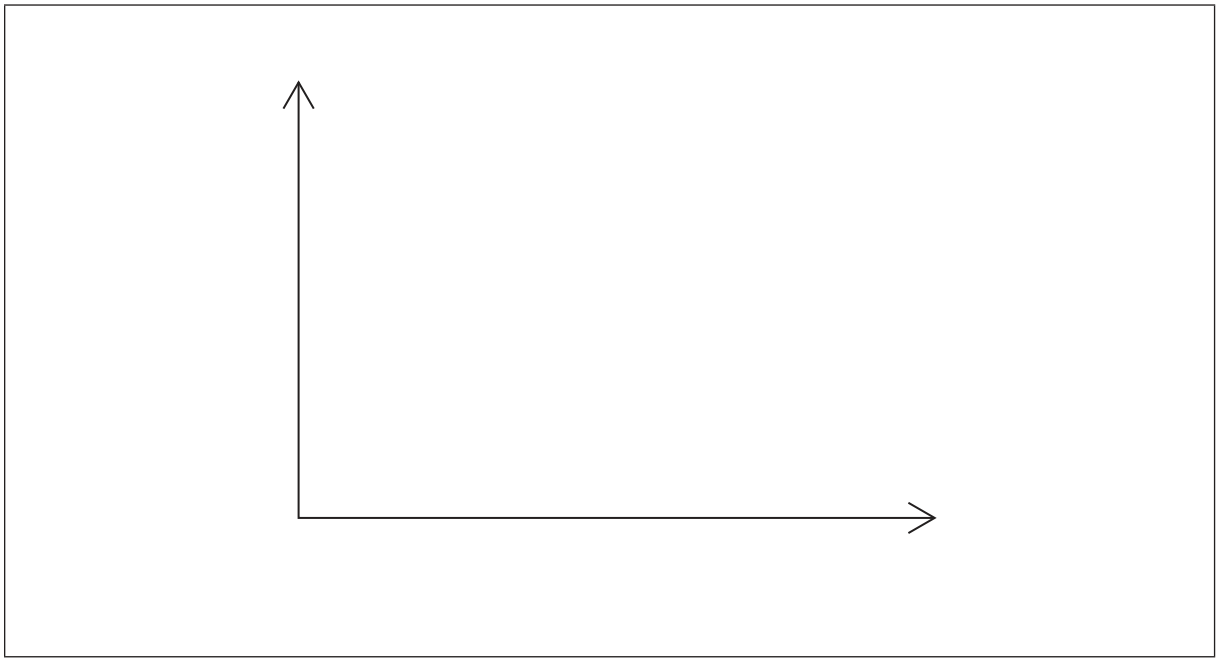
(This question continues on the following page)

(Question 2 continued)

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



3. Acids play a key role in processes in everyday life.

(a) The wine industry is important to the economy of many countries. Wine contains ethanol. In a laboratory in Chile, chemists tested the pH of a bottle of wine when opened and found it to have a pH of 3.8. After a few days, the pH had decreased to 2.8.

(i) Deduce the change in hydrogen ion concentration, $[H^+]$. *[1]*

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(ii) State the name of the compound formed that is responsible for this decreased pH value. *[1]*

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(b) Sulfuric acid present in acid rain can damage buildings made of limestone. Predict the balanced chemical equation for the reaction between limestone and sulfuric acid including state symbols. *[2]*

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4. Intermolecular forces are attractive forces between molecules.

(a) Identify the intermolecular forces present in hydrogen iodide in the liquid state, HI (l). *[1]*

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(b) Consider the compounds $(CH_3)_2NH$ and CH_4.

(i) Deduce the full structural formula for both compounds, showing **all** the bonds present. *[2]*

$(CH_3)_2NH$ CH_4

(ii) State and explain which compound can form hydrogen bonds **with water**. *[2]*

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(This question continues on the following page)

(Question 4 continued)

(iii) Draw a diagram showing the resulting hydrogen bonds between water and the compound chosen in (ii). *[1]*

SECTION B

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

5. Ionic bonding and covalent bonding are two types of bonding.

(a) (i) Ionic bonding occurs in sodium chloride. Describe what is meant by the term *ionic bonding*. *[1]*

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(ii) Sodium chloride has a lattice structure. Describe the lattice structure of sodium chloride including a suitable representative three-dimensional diagram. On the diagram, label each ion and distinguish between the different types of ions present using different sized spheres. *[4]*

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(iii) Ammonium phosphate is also an ionic compound, used in the manufacture of fertilizers. State the chemical formula of ammonium phosphate. *[1]*

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(This question continues on the following page)

(Question 5 continued)

(b) Consider the molecules sulfur difluoride, SF_2, boron trifluoride, BF_3, and phosphorus trichloride, PCl_3.

(i) Deduce the Lewis (electron dot) structure and predict the shape of each molecule, using the valence shell electron pair repulsion theory (VSEPR). *[6]*

	SF_2	BF_3	PCl_3
Lewis (electron dot) structure			
Shape	. . . . .	. . . . .	. . . . .

(ii) State and explain the F–S–F bond angle in SF_2. *[3]*

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(This question continues on the following page)

(Question 5 continued)

(iii) Deduce whether each of the three molecules is polar or non-polar, giving your reason in each case. *[3]*

SF_2:

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BF_3:

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PCl_3:

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(This question continues on the following page)

(Question 5 continued)

(c) Using electronegativity values from Table 7 of the Data Booklet, state and explain which of the following compounds, IBr, $BaCl_2$, CsI and HBr are ionic and which compounds are covalent. *[2]*

IBr:

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$BaCl_2$:

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CsI:

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HBr:

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6. Chlorine occurs in Group 7, the halogens.

(a) Two stable isotopes of chlorine are ^{35}Cl and ^{37}Cl with mass numbers 35 and 37 respectively.

(i) Define the term *isotopes of an element*. *[2]*

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(ii) Calculate the number of protons, neutrons and electrons in the isotopes ^{35}Cl and ^{37}Cl. *[2]*

Isotope	Number of protons	Number of neutrons	Number of electrons
^{35}Cl			
^{37}Cl			

(This question continues on the following page)

(Question 6 continued)

(iii) Using the mass numbers of the two isotopes and the relative atomic mass of chlorine from Table 5 of the Data Booklet, determine the percentage abundance of each isotope. *[2]*

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Percentage abundance ^{35}Cl:

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Percentage abundance ^{37}Cl:

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(iv) Deduce the electron arrangement for the chloride ion, Cl^-. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(b) Chlorine has an electronegativity value of 3.2 on the Pauling scale.

(i) Define the term *electronegativity*. *[1]*

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(ii) Using Table 7 of the Data Booklet, explain the trends in electronegativity values of the Group 7 elements from F to I. *[2]*

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(iii) State the balanced chemical equation for the reaction of potassium bromide, KBr(aq), with chlorine, $Cl_2(aq)$. *[1]*

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(iv) Describe the colour change likely to be observed in this reaction. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(c) Chloroethene, $H_2C=CHCl$, the monomer used in the polymerization reaction in the manufacture of the polymer poly(chloroethene), PVC, can be synthesized in the following two-stage reaction pathway.

Stage 1: $C_2H_4(g) + Cl_2(g) \rightarrow ClCH_2CH_2Cl(g)$

Stage 2: $ClCH_2CH_2Cl(g) \rightarrow H_2C=CHCl(g) + HCl(g)$

(i) State **one** use of the plastic PVC. *[1]*

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(ii) Determine the enthalpy change, ΔH, in $kJ\,mol^{-1}$, for stage 1 using average bond enthalpy data from Table 10 of the Data Booklet. *[3]*

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(Question 6 continued)

(iii) State whether the reaction given in stage 1 is exothermic or endothermic. *[1]*

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(iv) Draw the structure of poly(chloroethene) showing **two** repeating units. *[1]*

(v) Suggest why monomers are often gases or volatile liquids whereas polymers are solids. *[2]*

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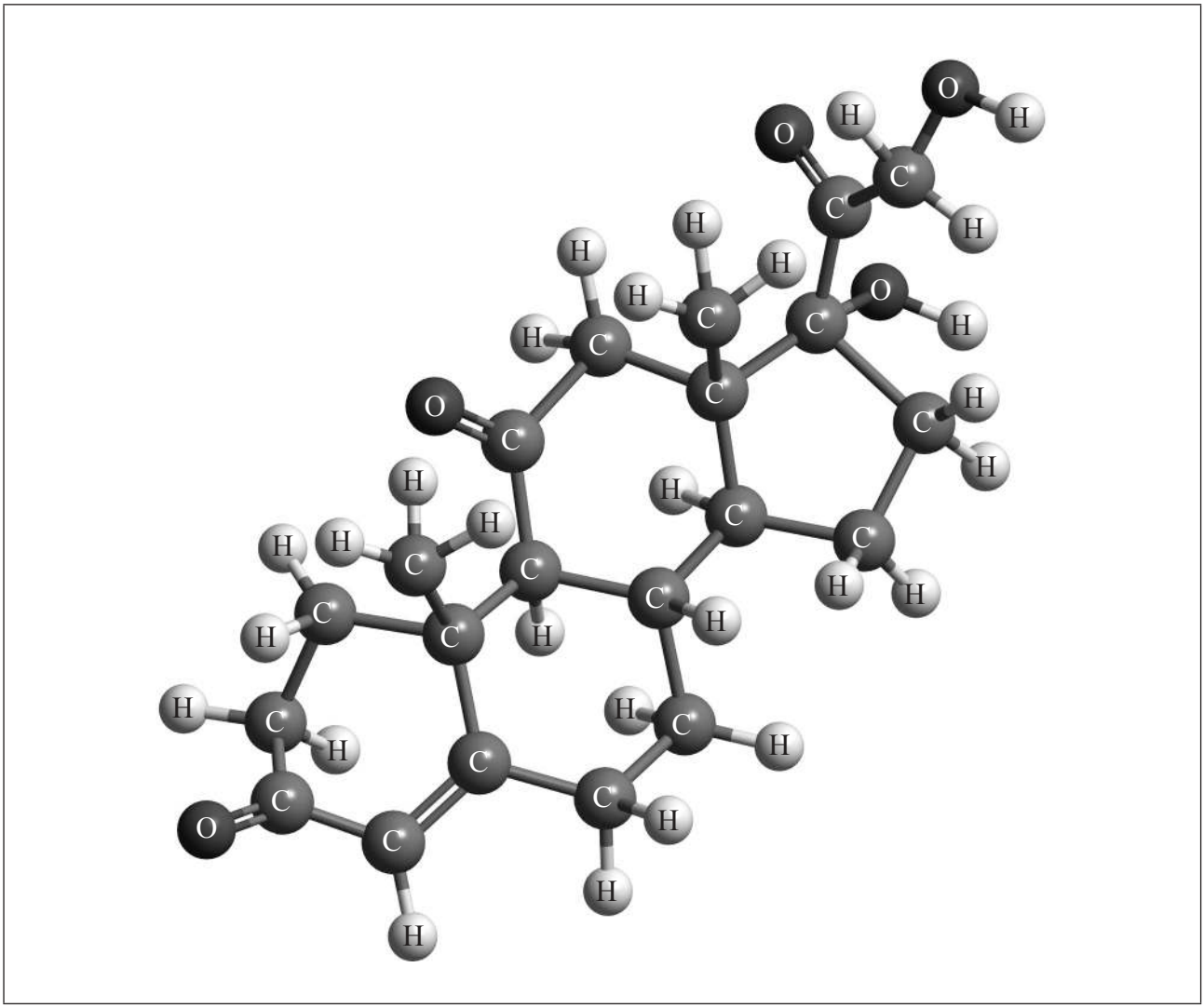
7. (a) Cortisone is a therapeutic drug whose three-dimensional structure is represented below.



(i) Identify the names of **two** functional groups present in cortisone. *[2]*

1. . . . . .

2. . . . . .

(ii) Draw a circle around each of these **two** functional groups in the structure above and label them 1 and 2 as identified in (a) (i). *[1]*

(This question continues on the following page)

(Question 7 continued)

(b) Describe what is meant by the term *structural isomers*. *[1]*

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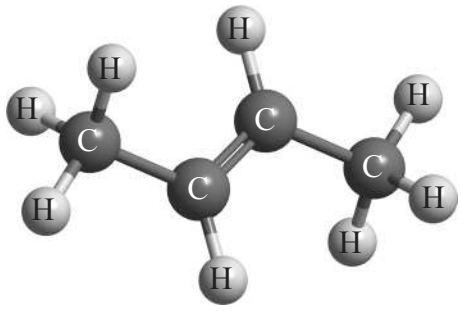
(c) Compound **P** has the following three-dimensional structure.



P

(i) Apply IUPAC rules to state the name of **P**. *[1]*

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(ii) **X** is a straight-chain structural isomer of **P**. Draw the structure of **X**. *[1]*

(This question continues on the following page)

(Question 7 continued)

(iii) State the structural formula of the organic products, **Q** and **R** formed in the following reactions. *[2]*

$$CH_3CH{=}CHCH_3 \xrightarrow[(2)\ H_2O(l)]{(1)\ \text{concentrated } H_2SO_4(aq)} \mathbf{Q}$$

Q:

$$CH_3CH{=}CHCH_3 + H_2(g) \xrightarrow{\text{catalyst}} \mathbf{R}$$

R:

(iv) Identify a suitable catalyst used in the reaction to form **R**. *[1]*

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(This question continues on the following page)

(Question 7 continued)

(v) **P**, $CH_3CH{=}CHCH_3$, reacts with HBr to form $CH_3CHBrCH_2CH_3$. Suggest **one** suitable mechanism for the reaction of $CH_3CHBrCH_2CH_3$ with aqueous sodium hydroxide, using curly arrows to represent the movement of electron pairs. *[4]*

(vi) State the structural formula of the organic product formed, **S**, when **Q** is heated under reflux with acidified potassium dichromate(VI). *[1]*

(vii) Apply IUPAC rules to state the name of this product, **S**. *[1]*

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(This question continues on the following page)

(Question 7 continued)

(viii) **P** can undergo a polymerization reaction. Draw **two** repeating units of the resulting polymer. *[1]*

(d) Menthol can be used in cough medicines. The compound contains 76.84 % C, 12.92 % H and 10.24 % O by mass.

(i) Determine its empirical formula. *[3]*

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(ii) Determine its molecular formula given that its molar mass is $M = 156.30\,\text{g mol}^{-1}$. *[1]*

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