Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Thursday 12 May 2016 (morning)

Candidate session number

1 hour 15 minutes

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.
- Write your answers in the 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]**.

2216 – 6105

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

1. Phosphine (IUPAC name phosphane) is a hydride of phosphorus, with the formula PH_3.

(a) (i) Draw a Lewis (electron dot) structure of phosphine. [1]

(ii) Outline whether you expect the bonds in phosphine to be polar or non-polar, giving a brief reason. [1]

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

(iii) Explain why the phosphine molecule is not planar. [2]

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

(iv) Phosphine has a much greater molar mass than ammonia. Explain why phosphine has a significantly lower boiling point than ammonia. [2]

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

(This question continues on the following page)

(Question 1 continued)

(b) Phosphine is usually prepared by heating white phosphorus, one of the allotropes of phosphorus, with concentrated aqueous sodium hydroxide. The equation for the reaction is:

$$P_4(s) + 3OH^-(aq) + 3H_2O(l) \rightarrow PH_3(g) + 3H_2PO_2^-(aq)$$

(i) Identify one other element that has allotropes and list **two** of its allotropes. [2]

Element:

. . . . . .

Allotrope 1:

. . . . . .

Allotrope 2:

. . . . . .

(ii) The first reagent is written as P_4, not 4P. Describe the difference between P_4 and 4P. [1]

. . . . . .

. . . . . .

. . . . . .

(iii) The ion $H_2PO_2^-$ is amphiprotic. Outline what is meant by amphiprotic, giving the formulas of **both** species it is converted to when it behaves in this manner. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(iv) State the oxidation state of phosphorus in P_4 and $H_2PO_2^-$. [2]

P_4:

. . . . . .

$H_2PO_2^-$:

. . . . . .

(v) Oxidation is now defined in terms of change of oxidation number. Explore how earlier definitions of oxidation and reduction may have led to conflicting answers for the conversion of P_4 to $H_2PO_2^-$ and the way in which the use of oxidation numbers has resolved this. [3]

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

(c) 2.478 g of white phosphorus was used to make phosphine according to the equation:

$$P_4(s) + 3OH^-(aq) + 3H_2O(l) \rightarrow PH_3(g) + 3H_2PO_2^-(aq)$$

(i) Calculate the amount, in mol, of white phosphorus used. [1]

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

(This question continues on the following page)

(Question 1 continued)

(ii) This phosphorus was reacted with 100.0 cm^3 of 5.00 $mol\,dm^{-3}$ aqueous sodium hydroxide. Deduce, showing your working, which was the limiting reagent. [1]

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

(iii) Determine the excess amount, in mol, of the other reagent. [1]

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

(iv) Determine the volume of phosphine, measured in cm^3 at standard temperature and pressure, that was produced. [1]

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

2. Impurities cause phosphine to ignite spontaneously in air to form an oxide of phosphorus and water.

(a) (i) 200.0 g of air was heated by the energy from the complete combustion of 1.00 mol phosphine. Calculate the temperature rise using section 1 of the data booklet and the data below. [1]

Standard enthalpy of combustion of phosphine, $\Delta H_c^{\ominus} = -750\,\text{kJ mol}^{-1}$

Specific heat capacity of air $= 1.00\,\text{J g}^{-1}\text{K}^{-1} = 1.00\,\text{kJ kg}^{-1}\text{K}^{-1}$

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) The oxide formed in the reaction with air contains 43.6 % phosphorus by mass. Determine the empirical formula of the oxide, showing your method. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) The molar mass of the oxide is approximately 285 g mol^{-1}. Determine the molecular formula of the oxide. [1]

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(b) (i) State the equation for the reaction of this oxide of phosphorus with water. [1]

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

(ii) Predict how dissolving an oxide of phosphorus would affect the pH and electrical conductivity of water. [1]

pH:

. . . . . .

Electrical conductivity:

. . . . . .

(iii) Suggest why oxides of phosphorus are not major contributors to acid deposition. [1]

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

(This question continues on the following page)

(Question 2 continued)

(iv) The levels of sulfur dioxide, a major contributor to acid deposition, can be minimized by either pre-combustion and post-combustion methods. Outline **one** technique of each method. [2]

Pre-combustion:

. . . . . .

. . . . . .

Post-combustion:

. . . . . .

. . . . . .

3. Phosgene, $COCl_2$, is usually produced by the reaction between carbon monoxide and chlorine according to the equation:

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -108\,kJ$$

(a) (i) Deduce the equilibrium constant expression, K_c, for this reaction. [1]

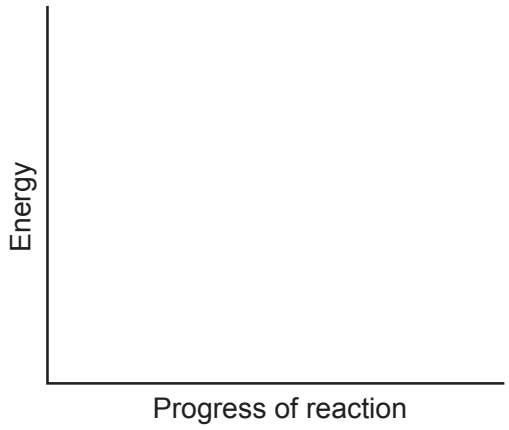
. . . . . .

. . . . . .

(ii) State the effect of an increase in the total pressure on the equilibrium constant, K_c. [1]

. . . . . .

(b) (i) Sketch the potential energy profile for the synthesis of phosgene, using the axes given, indicating both the enthalpy of reaction and activation energy. [2]

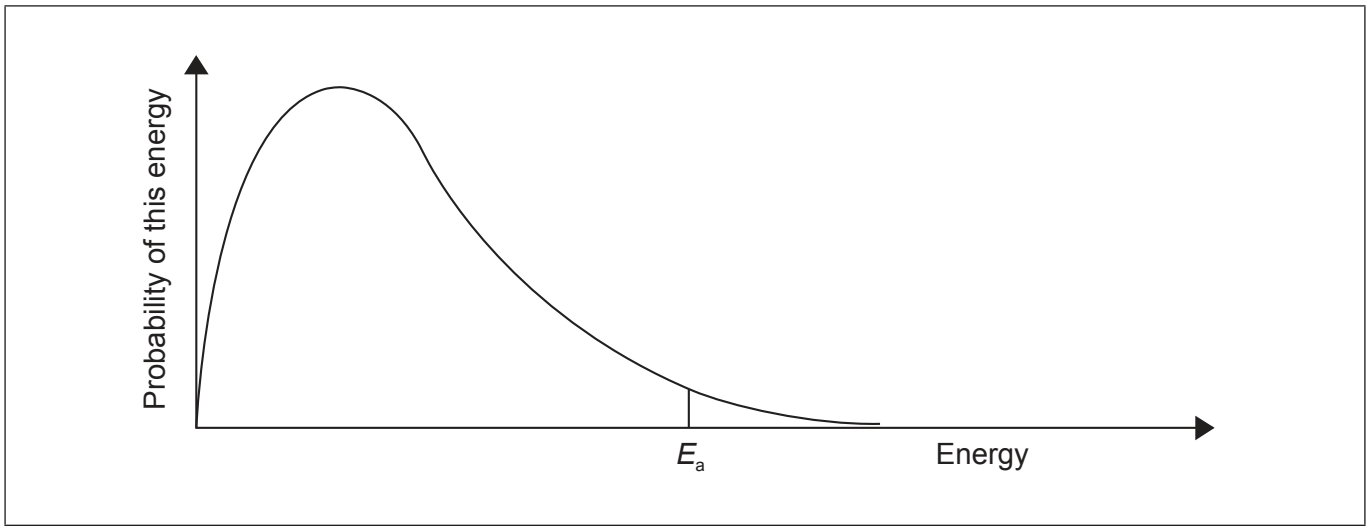


(ii) This reaction is normally carried out using a catalyst. Draw a dotted line labelled "Catalysed" on the diagram above to indicate the effect of the catalyst. [1]

(This question continues on the following page)

(Question 3 continued)

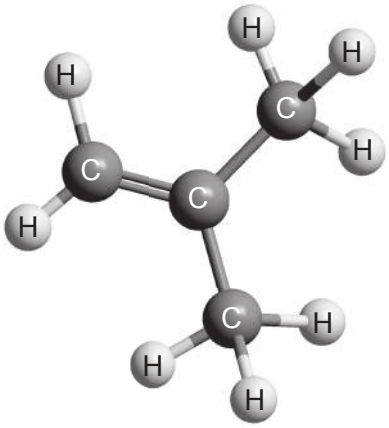
(iii) Sketch and label a second Maxwell–Boltzmann energy distribution curve representing the same system but at a higher temperature, T_{higher}. [1]



(iv) Explain why an increase in temperature increases the rate of this reaction. [2]

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

4. Alkenes are widely used in the production of polymers. The compound **A**, shown below, is used in the manufacture of synthetic rubber.



A

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

. . . . . .

(ii) Draw a section, showing three repeating units, of the polymer that can be formed from compound **A**. [1]

(iii) Compound **A** is flammable. Formulate the equation for its complete combustion. [1]

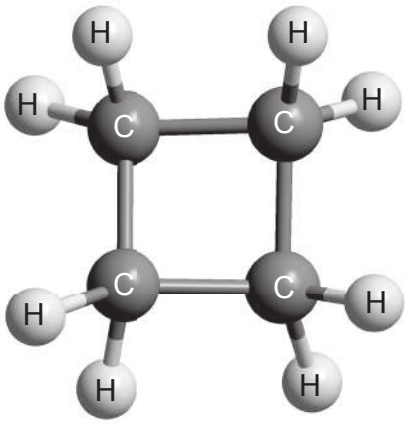
. . . . . .

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(b) Compound **B** is related to compound **A**.



B

(i) State the term that is used to describe molecules that are related to each other in the same way as compound **A** and compound **B**. [1]

. . . . . .

(ii) Suggest a chemical test to distinguish between compound **A** and compound **B**, giving the observation you would expect for each. [2]

Test:

. . . . . .

. . . . . .

Observation with **A**:

. . . . . .

Observation with **B**:

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(iii) Spectroscopic methods could also be used to distinguish between compounds **A** and **B**.

Predict one difference in the IR spectra **and** one difference in the ^{1}H NMR spectra of these compounds, using sections 26 and 27 of the data booklet. [2]

IR spectra:

. . . . . .

. . . . . .

^{1}H NMR spectra:

. . . . . .

. . . . . .

(c) A sample of compound **A** was prepared in which the ^{12}C in the CH_2 group was replaced by ^{13}C.

(i) State the main difference between the mass spectrum of this sample and that of normal compound **A**. [1]

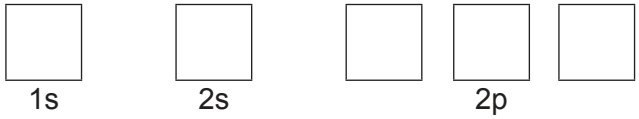
. . . . . .

. . . . . .

(ii) State the structure of the nucleus and the orbital diagram of ^{13}C in its ground state. [2]

No. protons . . . . . No. neutrons . . . . . .

Orbital diagram



(This question continues on the following page)

(Question 4 continued)

(d) Draw a 1s atomic orbital and a 2p atomic orbital. [1]

1s:	2p:

Please **do not** write on this page.

Answers written on this page
will not be marked.

Please **do not** write on this page.

Answers written on this page
will not be marked.