

Nitrogen, Phosphorus, Amonia

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Nitrogen, Phosphorus, Amonia
Booklet	Question Paper

Time Allowed: 34 minutes

Score: /28

Percentage: /100

Grade Boundaries:

1. (a) Phosphorus forms a pentachloride, PCl_5 . This exists as a simple molecule in the gas phase.

(i) Draw the structure of PCl_5 in the gas phase, including hashed and wedged bonds where necessary.

On your diagram label the bond angles. Name the shape of the molecule.

name of shape [4]

(ii) PCl_5 reacts with water to form phosphoric acid, H_3PO_4 . What **type** of reaction is taking place between PCl_5 and water?

..... [1]

(iii) Write down the oxidation number of phosphorus in phosphoric acid.

..... [1]

(iv) Suggest **one** advantage that phosphoric acid has over sulfuric acid as a reagent for dehydrating alcohols to form alkenes.

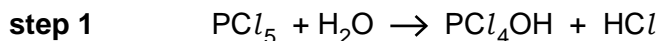
.....
..... [1]

(v) Write out a displayed formula for sulfuric acid, showing all of the chemical bonds.

- (b) (i) Phosphorus oxychloride, POCl_3 , is an intermediate compound formed during the reaction between PCl_5 and water. Write the equation for the reaction of PCl_5 with water to form phosphorus oxychloride.

.....[1]

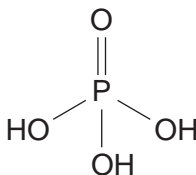
- (ii) Reactions of covalent chlorides with water can be rationalised as step-wise replacement of $-\text{Cl}$ with $-\text{OH}$. Complete the three-step reaction sequence for the formation of phosphorus oxychloride from phosphorus pentachloride.



step 2

step 3[2]

- (c) The structure of phosphoric acid, H_3PO_4 , is shown below.



- (i) Phosphoric acid may dimerise to produce diphosphoric acid, $\text{H}_4\text{P}_2\text{O}_7$, and water. The reaction involves the condensation of an $-\text{OH}$ group from each H_3PO_4 molecule to create an oxygen bridge between the two phosphoric acid units. Draw the structure of diphosphoric acid.

[1]

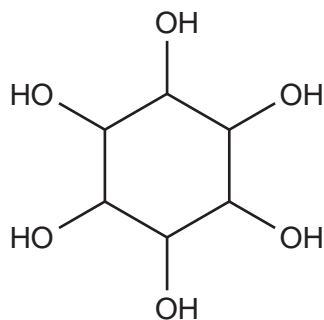
- (ii) This condensation reaction may continue to give triphosphoric acid, $\text{H}_5\text{P}_3\text{O}_{10}$, and tetraphosphoric acid. Give the molecular formula of tetraphosphoric acid.

.....[1]

- (iii) Give a general formula for polyphosphoric acids containing n phosphorus atoms.

.....[1]

- (d) Recent research from a group led by Nobel-prize winning chemist Jean-Marie Lehn (*Proceedings of the National Academy of Science, USA, 2009*) has shown that a compound containing three cyclic diphosphates can improve the body's capacity for exercise. The compound is a derivative of inositol, which is shown below.



inositol

- (i) Give the empirical formula of inositol.

..... [1]

- (ii) In the new compound each pair of adjacent oxygen atoms from the inositol molecule is part of a cyclic diphosphate ester. The overall charge of the inositol-cyclic-phosphate species is 6-. Suggest a structure for the compound.

[2]

[Total: 17]

2. Nitrogen forms a variety of oxides and halides.

- (a) Nitrogen triiodide, NI_3 , is an explosive that detonates with a snap even when only touched lightly. Given that the electronegativity value for nitrogen is 3.07 and for iodine is 2.36, indicate below the dipole in an N–I bond.



[1]

- (b) (i) Nitrogen trifluoride, NF_3 , can be prepared by reacting ammonia with fluorine. In this reaction the fluorine oxidises the nitrogen in ammonia while the oxidation number of hydrogen is unchanged.

Give the equation for this reaction.

.....[1]

- (ii) Nitrogen trifluoride is used to etch silicon in microelectronics. It is decomposed to its elements and the fluorine is used to attack the silicon.

Give the equation for the decomposition of nitrogen trifluoride.

.....[1]

- (iii) Nitrogen trifluoride is a molecule that has attracted controversy recently for its possible potent contribution to the greenhouse effect. Draw the dot-cross diagram of this molecule; only include outer electrons. State the shape and the bond angle.

shape

bond angle [3]

- (iv) Whereas nitrogen trifluoride is reasonably easy to handle, nitrogen trichloride is an extremely dangerous explosive. Suggest why nitrogen trifluoride is more stable than the other nitrogen trihalides.

.....
.....[1]

(c) N_2O_5 is a less well-known oxide of nitrogen.

(i) N_2O_5 is the anhydride of nitric acid, which means that it reacts with water to produce the acid. Write an equation for N_2O_5 reacting with water.

..... [1]

(ii) N_2O_5 can be made by reacting nitric acid with a dehydrating agent such as phosphorus(V) oxide. Bearing in mind that phosphorus(V) oxide is the anhydride of phosphoric acid, H_3PO_4 , write an equation for the reaction between nitric acid and phosphorus(V) oxide.

..... [2]

(iii) In the solid state N_2O_5 is an ionic compound. Given that N_2O_5 is sometimes known as 'nitronium nitrate' write the ionic formula representation of N_2O_5 .

..... [1]

[Total: 11]