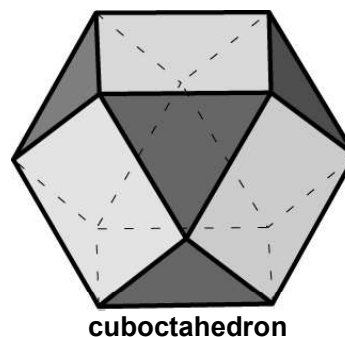


2. This question is about geometric shapes in chemistry

Phosphorus exists as a number of allotropes, the most reactive being white phosphorus. This was first prepared in the 17th century from the reduction of the phosphate present in urine.

Solid white phosphorus contains P_4 molecules, with each P atom at the vertex of a regular tetrahedron.



(a) Draw the structure of a molecule of P_4 , showing all the chemical bonds.

(b) How many edges are there in total in a regular tetrahedron?

White phosphorus spontaneously ignites in air to form a mixture of phosphorus(III) oxide and phosphorus(V) oxide.

(c) Write an equation for the formation of **i)** phosphorus(III) oxide and **ii)** phosphorus(V) oxide from the elements.

The structure of each oxide is also based on a regular tetrahedron. The phosphorus atoms remain at the vertices but are no longer bonded to each other. Instead the P atoms are joined by bridging oxygens.

(d) Draw the structure of phosphorus(III) oxide.

Phosphorus(V) oxide has a further oxygen atom bonded to each phosphorus atom at the vertex of the tetrahedron.

(e) Draw the structure of phosphorus(V) oxide.

Each oxide reacts with water to form an acid – phosphorus(V) oxide forms phosphoric(V) acid, H_3PO_4 .

(f) Draw the molecular structure of phosphoric(V) acid, showing all of the bonds.

(g) Write the equation for the reaction forming phosphoric(V) acid.

A quantitative method for determining phosphate levels in aqueous solution involves adding ammonium molybdate, $(NH_4)_2MoO_4$, to form a precipitate of ammonium molybdophosphate. The structure of this solid is based on a cuboctahedron (**shown above**). A molybdenum atom lies at each vertex of the cuboctahedron and these are joined by oxygen atoms with every edge of the cuboctahedron being bridged by an oxygen atom. A further oxygen atom is joined to every vertex. A single phosphate unit lies at the centre of the structure with each of its four oxygen atoms coordinating to three molybdenum atoms.

(h) Calculate the oxidation state of molybdenum in ammonium molybdate.

(i) How many **i)** vertices and **ii)** edges are there in a cuboctahedron?

(j) Calculate the number of **i)** molybdenum atoms and **ii)** oxygen atoms in the molybdophosphate ion.

(k) Given that no atom changes its oxidation state during the formation of ammonium molybdophosphate, calculate the overall charge of the molybdophosphate ion and hence the formula of ammonium molybdophosphate.