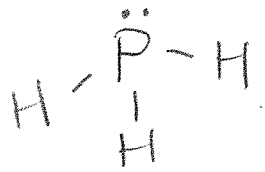
Name: Volbers

Due 11 January

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]

nonpolar → electronegativity values are equal
P = 2.2 2.2 − 2.2 = 0
H = 2.2

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

4 electron domains + lone pair = trigonal pyramidal geometry. For max electron repulsion, molecule cannot be planar

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

PH_3 does not have hydrogen bonding while NH_3 does. hydrogen bonding = strongest intermolecular force = higher boiling point

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(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: carbon	oxygen
Allotrope 1: graphite	O_2
Allotrope 2: diamond	O_3

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

P_4 is a molecule, indicating that 4 phosphorus molecules are bonded together. 4P indicates the mole ratio is used to balance the P, but the substance is only one P atom

(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]

can behave as an acid or a base depending on what solution it is placed in
$H_2PO_2^- + OH \rightarrow HPO_2^{2-} + H_2O$ (behaves as acid)
$H_2PO_2^- + H^+ \rightarrow H_3PO_2$ (behaves as base)

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(Question 1 continued)

SKIP

(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]

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(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]

$(2.478\,g\,P_4)\left(\frac{1\,mol\,P_4}{123.88\,g\,P_4}\right)\left(\frac{1\,mol\,PH_3}{1\,mol\,P_4}\right) = 0.02000\,mol\,PH_3$

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(Question 1 continued)

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

$(5.00\text{ g NaOH})\left(\frac{1\text{ mol NaOH}}{40.00\text{ g NaOH}}\right)\left(\frac{1\text{ mol PH}_3}{3\text{ mol OH}^-}\right) = 0.04167\text{ mol PH}_3$

P_4 limits ★ (used up first)

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

$(2.478\text{ g P}_4)\left(\frac{1\text{ mol P}_4}{123.88\text{ g P}_4}\right)\left(\frac{3\text{ mol OH}^-}{1\text{ mol P}_4}\right)\left(\frac{40.00\text{ g NaOH}}{1\text{ mol NaOH}}\right) = 2.400\text{ g NaOH}$

$5.00 - 2.40 = 2.60\text{ g NaOH}$ leftover

(0.0650 mol NaOH)

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

$(0.02000\text{ mol PH}_3\text{ produced})\left(\frac{22.7\text{ dm}^3}{1\text{ mol}}\right)\left(\frac{1000.\text{ cm}^3}{1\text{ dm}^3}\right) =$

$454.0\text{ cm}^3\text{ PH}_3$

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