Chapter 4: Chemical bonding

Homework questions

1 The Group 1 metals Li to Cs all react to form ions.

a Give the equation for the formation of a potassium ion from a potassium atom. [1]

b By referring to 1st ionisation energies, atomic radii and electron shielding, explain the change in reactivity as Group 1 is descended. [4]

c Potassium forms an ionic compound, potassium oxide (K_2O), when it reacts with oxygen.

i Give the balanced symbol equation for the formation of K_2O from potassium and oxygen. [1]

ii Draw a dot-and-cross diagram for potassium oxide showing outer electrons only. [3]

Potassium oxide can be prepared by heating potassium nitrate with potassium.

The equation for the reaction is:

$2KNO_3(s) + 10K(s) \rightarrow 6K_2O(s) + N_2(g)$

iii What mass of potassium nitrate is needed to exactly react with 7.82 g of potassium? Give your answer to 3 significant figures. [N = 14.0; O = 16.0; K = 39.1] [5]

iv What is the mass of K_2O formed? [4]

v Explain why potassium oxide does not conduct electricity in the solid state but does in the liquid state. [2]

Total = 20

2 The element nitrogen is the main constituent of air. In the Haber process it is used, along with hydrogen, to make ammonia.

a **i** Draw a dot-and-cross diagram to show the bonding in nitrogen. [2]

ii Draw the sigma bond formed between two nitrogen atoms. [1]

iii Name the other type of bond formed between the atoms in the molecule of nitrogen. [1]

b Ammonia is a very important compound since it is used in the production of fertilisers and nitric acid.

i Draw a dot-and-cross diagram to show the bonding in ammonia. [2]

ii Draw the molecular shape and on your diagram show the bond angles. [2]

iii The boiling point of ammonia is greater than expected. This is because of hydrogen bonding between the molecules. Draw a diagram to show this intermolecular bonding. You must show the hydrogen bonds and any dipoles present. [3]

iv Liquid ammonia undergoes ionisation to form the ammonium ion (NH_4^+) and the amide ion (NH_2^-). Draw both ions showing the bond angles present. [4]

c The metal sodium reacts with liquid ammonia to form the ionic compound, sodium amide ($NaNH_2$) and hydrogen gas.

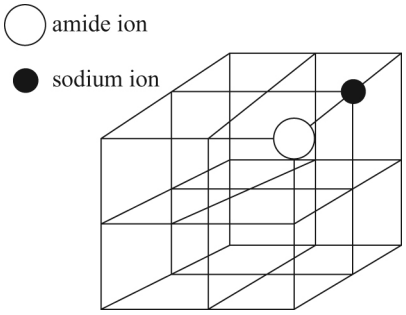
$2NH_3(l) + 2Na(s) \rightarrow 2NaNH_2(s) + H_2(g)$

i Fill in the table below to compare the electrical conductivities of sodium and sodium amide. [4]

Substance	**Electrical conductivity**	
	as solid	**as liquid**
Sodium		
Sodium amide		

ii Explain both sets of properties for both substances. [2]

iii The structure of sodium amide resembles that of sodium chloride. Fill in two faces of the cube using the spheres to represent the two ions. [3]



iv Explain why the sodium ion is smaller than the sodium atom. [3]

Total = 27

3 The element phosphorus (atomic number 15) forms a number of compounds with other elements.

a **i** Using the 'electrons in boxes' notation, give the electron arrangement of a neutral atom of phosphorus. You need to label the subshells present and show how the electrons are arranged. [3]

ii There is only one naturally occurring isotope of phosphorus with a relative isotopic mass of 31. It does, however, form a radioactive isotope known as ^{32}P. Explain the similarities and differences between these two isotopes. [2]

b Phosphorus pentabromide (PBr_5) is a compound formed when phosphorus is heated in the presence of excess bromine. In the solid state phosphorus pentabromide is thought to exist as ions PBr_4^+ and Br^-.

i Draw the likely structure for PBr_4^+ and name its shape and label the bond angle. [3]

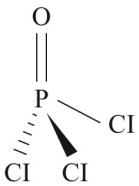
ii In non-polar solvents phosphorus pentabromide exists as simple molecules. Draw the structure of the molecule, showing the bond angles and name the shape taken by the molecule. [3]

c In the same family of compounds phosphorus pentachloride is used in organic chemistry to replace –OH groups with chlorine atoms. The reaction between PCl_5 and ethanol results in the formation of chloroethane (C_2H_5Cl), phosphorus oxychloride ($POCl_3$) and hydrogen chloride.

$PCl_5(s) + C_2H_5OH(l) \rightarrow C_2H_5Cl(g) + POCl_3(l) + HCl(g)$

i Hydrogen chloride is a gas at room temperature. Draw a diagram of hydrogen chloride molecules, showing the dipoles present and the dipole–dipole attractions between the molecules. [2]

ii A diagram of phosphorus oxychloride is shown below. Copy the molecule and write in the bond angles. [1]



iii The electronegativities of oxygen and chlorine are almost equal and both are greater than that of phosphorus. Draw the dipoles present in the molecule. [2]

iv The melting point of $POCl_3$ is 274 K and its boiling point is 378 K. In which state of matter is it in at room temperature (20 °C)? Explain your reasoning. [3]

Total = 19