- Ammonia ($NH_3$) has a boiling point of –33 °C and phosphine ($PH_3$) has a boiling point of –83 °C. Explain the difference in these boiling points in terms of the intermolecular forces present. **2**

**Although $PH_3$ is a larger molecule with greater dispersion forces than ammonia, $NH_3$ has very polar N-H bonds leading to strong hydrogen bonding. This the dominant intermolecular force and results in a greater attraction between $NH_3$ molecules than there is between $PH_3$ molecules.**

3

- Explain, in terms of chemical bonding and intermolecular forces, the following trend in melting points: $CH_4 < I_2 < NaCl <$ silica ($SiO_2$)

**There are only dispersion forces between the molecules in $CH_4$ and $I_2$. The I atom is a large, many-electron atom so its electron cloud is more easily polarised than the C or H in $CH_4$ and therefore $I_2$ has stronger dispersion forces and the higher melting point. NaCl is an ionic compound with strong coulombic attraction between the $Na^+$ ions and the $Cl^-$ ions packed together in the solid. Silica is a covalent network solid. Melting it requires breaking of the very strong covalent Si–O bonds, so it has the highest melting point.**

- Explain briefly, in terms of intermolecular forces, why an analogue of DNA could not be made with phosphorus atoms replacing some nitrogen atoms, while still retaining a double-helical structure. **3**

**The double helical structure is held together by hydrogen bonding between the cytosine and guanine (C≡G) and the adenine and thymine (A=T) base pairs.**

**No H-bonding would occur if the electronegative N atoms in these bases were replaced with P atoms.**

- Explain, in terms of chemical bonding and intermolecular forces, the following trend in melting points: $CH_4$ < $I_2$ < NaCl < silica ($SiO_2$)

2

**The intermolecular forces in $I_2$ and $CH_4$ are weak dispersion forces. Iodine is a much larger atom that H or C and hence has more electrons and these are held further from the nucleus. The electron cloud in $I_2$ is, therefore, much more polarisable leading to stronger dispersion forces in $I_2$. and a higher melting point.**

**NaCl has relatively strong ionic bonds between all of the $Na^+$ and $Cl^-$ ions in the lattice.**

**$SiO_2$ is a covalent network compound with a very high melting point as strong covalent bonds need to be broken.**

- What physical state would water adopt under ambient conditions (1 atm and 25 °C) if it did not possess hydrogen bonding? Explain.

**Marks**
**2**

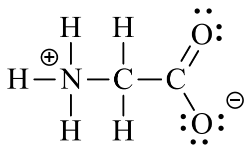
**Water would be a gas.**

**The other hydrides of group 16 elements increase in boiling point as the molar mass increases, due to the increase in dispersion forces. $H_2S$ is a gas. As the dispersion forces in water are weaker, it would be a gas too.**

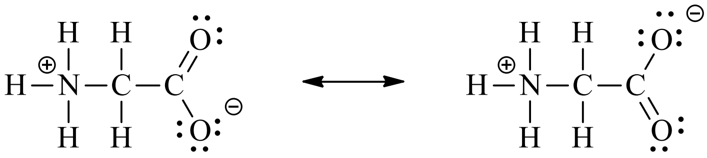
**$H_2O$ has an anomalously high boiling point due to its H-bonds. Without H-bonds it would have a boiling point below that of $H_2S$.**

Marks 7

- Glycine, $NH_2CH_2COOH$, the simplest of all naturally occurring amino acids, has a melting point of 292 °C. The p$K_a$ of the acid group is 2.35 and the p$K_a$ associated with the amino group is 9.78. Draw a Lewis structure that indicates the charges on the molecule at the physiological pH of 7.4.



Use your structure to illustrate the concept of resonance.



Describe the hybridisation of the two carbon atoms and the nitrogen atom in glycine and the molecular geometry of the atoms surrounding these three atoms.

**N: *sp*$^3$ hybridised; tetrahedral geometry**

**$CH_2$: *sp*$^3$ hybridised; tetrahedral geometry**

**$CO_2^-$: *sp*$^2$ hybridised; trigonal planar geometry**

Glycine has an unusually high melting point for a small molecule. Suggest a reason for this.

**In its zwitterionic state, glycine has very strong electrostatic attractions (*i.e.* ionic bonds) between the $NH_3^+$ and $CO_2^-$ groups giving it very high melting point.**

Do you expect glycine to be water soluble? Give a reason for your answer.

**Yes. It is ionic so dissolves in the very polar solvent water.**