AP® Chemistry
2001 Sample Student Responses

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8. Account for each of the following observations about pairs of substances. In your answers, use appropriate principles of chemical bonding and/or intermolecular forces. In each part, your answer must include references to both substances.

(a) Even though \( \text{NH}_3 \) and \( \text{CH}_4 \) have similar molecular masses, \( \text{NH}_3 \) has a much higher normal boiling point (\(-33^\circ\text{C}\)) than \( \text{CH}_4 \) (\(-164^\circ\text{C}\)).

(b) At 25\(^\circ\text{C}\) and 1.0 atm, ethane (\( \text{C}_2\text{H}_6 \)) is a gas and hexane (\( \text{C}_6\text{H}_{14} \)) is a liquid.

(c) Si melts at a much higher temperature (1,410\(^\circ\text{C}\)) than \( \text{Cl}_2 \) (\(-101^\circ\text{C}\)).

(d) MgO melts at a much higher temperature (2,852\(^\circ\text{C}\)) than NaF (993\(^\circ\text{C}\)).

(a) \( \text{NH}_3 \) has a much higher boiling pt compared to \( \text{CH}_4 \) because \( \text{CH}_4 \) has only London Dispersion Forces while \( \text{NH}_3 \), which is polar, has dipole-dipole forces & even more specifically hydrogen bonding - which is stronger than regular dipole dipole.

Since \( \text{NH}_3 \)'s intermolecular forces are bigger than those of \( \text{CH}_4 \), the bonds take more KE to break them & thus have a higher boiling pt.

(b) Both have only LDF but since \( \text{C}_6\text{H}_{14} \) is a more complex molecule, it has more \( \sigma \)- & thus more polarization opportunities. Because of this, \( \text{C}_6\text{H}_{14} \) has more chances of inducing dipole forces & thus the intermolecular forces between \( \text{C}_6\text{H}_{14} \) molecules are higher & require more KE to break.

Thus, @ 25\(^\circ\text{C}\), there is enough KE to make \( \text{C}_6\text{H}_{14} \) into a gas while \( \text{C}_6\text{H}_{14} \) is a liquid.

(c) Si has a covalent network bonding structure while \( \text{Cl}_2 \) has only LDF forces. Covalent network is a very rigid bonding structure and is hard to break compared to the easily broken LDF \( \text{Cl}_2 \) bonds. Thus Si melts at higher temp than \( \text{Cl}_2 \).

(d) Coulomb's law states that the higher the atoms change the stronger the bond between the atoms. Mg has a \(+2\) charge & \( \text{O} \) has a \(-2\) charge which are greater than the +1 & -1 charges of \( \text{Na} \) & \( \text{F} \) respectively. Thus, breaking the ion
bond between NaF is easier than the bond between MgO; thus MgO melts at a higher temp than NaF.
8. Account for each of the following observations about pairs of substances:
principles of chemical bonding and/or intermolecular forces. In each part, account for both substances.

(a) Even though NH₃ and CH₄ have similar molecular masses, NH₃ has a much higher normal boiling point (-33°C) than CH₄ (-164°C).

(b) At 25°C and 1.0 atm, ethane (C₂H₆) is a gas and hexane (C₆H₁₄) is a liquid.

(c) Si melts at a much higher temperature (1,410°C) than Cl₂ (-101°C).

(d) MgO melts at a much higher temperature (2,852°C) than NaF (993°C).

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a. NH₃ has a higher boiling point than CH₄ because NH₃ has an unbonded electron pair which allows the NH₃ to form hydrogen bonds, which are much stronger intermolecular forces than the London forces in CH₄. Therefore, the stronger the intermolecular forces, the higher the boiling point.

b. C₆H₁₄ is a much smaller molecule than C₂H₆. Because C₂H₆ is so much larger, its instantaneous dipoles are much stronger than those of C₆H₁₄. Since neither can form hydrogen bonds or dipole-dipole forces (they are non-polar and have no F-O or N) the strongest force is the London forces created by instantaneous dipoles; since the intermolecular forces in C₂H₆ are much stronger, it is far more likely to condense into a liquid.

c. Si melts at a much higher temperature because it forms bonds with other silicon molecules each to complete its octet, while Cl₂ only form in pairs. Since Si have so many more bonds, it takes a much larger temperature to liquify.
d. MgO and NaF are both ionic, however, MgO is formed from Mg$^{2+}$ and O$^{2-}$ ions which have a difference in charge of 1, while Na$^+$ and F$^-$ (the ions that form NaF) have only a 1 difference of 2 charges. Because the strength of the bonds are based on the difference in charge, the MgO takes far more heat to melt.
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- NH₃ has a much higher bp due to H-bonding.
  That is, NH₃ has a much stronger H-bonding than the dispersion forces that CH₄ has.

- They both have the same forces that make them have a much greater molar mass. This increases the melting point.

- Si tends to forms molecular crystals which have a very large melting point. Cl₂ has only weak dispersion forces that can be overcome more easily than Si.

- MgO and NaF are both ionic compounds.
  NaF has a greater difference in electronegativity.